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THE GEOLOGY OF THE SOUTH SHETLAND ISLANDS

III. THE STRATIGRAPHY OF KING GEORGE ISLAND

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ABSTRACT

THE axial core of King George Island is composed of rocks of probable Upper Jurassic age and plutonic and hypabyssal intrusions of the Andean Intrusive Suite.

Down-faulted blocks of Upper Cretaceous to Miocene lavas flank the central belt of Jurassic rocks; thin sedimentary beds containing plant fossils occur at several horizons within the volcanic sequence. Pliocene–Recent volcanic rocks were extruded from a line of vents along the south coast. A fossiliferous marine conglomerate is interbedded with the Pliocene lavas of Lions Rump.

The island is broken into a series of fault blocks; the main fault system is parallel to the length of the island with complementary faults concurrent with the length of Admiralty Bay.

Upper Cretaceous–Miocene plant fossils occur at Dufayel Island, Ezcurra Inlet, Fildes Peninsula, Point Hennequin and Admiralen Peak. Some of the plants can be closely compared with *Equisetum*, *Araucaria* and *Nothofagus*.

CONTENTS

I. INTRODUCTION

THE stratigraphical account presented in this report is based mainly on field investigations carried out on King George Island between April 1959 and January 1961. Material collected by the author during this period, and by J. S. Bibby (1961) and G. J. Hobbs in the two preceding summer seasons, has been examined in the laboratory and the results are included. The local mapping of Ezcurra Inlet (Bibby, 1961) and the petrological examination of the rocks of King George Island (Hawkes, 1961) have been taken into consideration in the preparation of this report.

1. *Locality*

The South Shetland Islands, of which King George Island is the largest, lie to the north-west of and roughly parallel to the trend of the Antarctic Peninsula. Situated between lat. 61°50′ and 62°15′S., and long. 57°30′ and 59°00′W., King George Island (Fig. 1) varies in width up to 15 miles (24 km.) and extends over 40 miles (64 km.) along the line of this arc of islands. The island possesses several good harbours, is less beset by ice than the Antarctic Peninsula, and lies across the main route from South America and the Falkland Islands to Antarctica. For these reasons it has received considerable scientific (especially geological) attention from previous expeditions. Most of the earlier visits were short and resulted in collections from the easily accessible rocks; latterly, reconnaissance surveys were confined mainly to visual observations.

2. *Previous work*

The first recorded landing on the South Shetland Islands was on the north-east coast of King George Island, by William Smith in October 1819. On the beach where he landed he found numerous "bluish-grey slaty pieces" and cliffs of "chlorite slate or schistose hornblende" (Miers, 1820). These specimens were later examined by Dr. B. Astor, who determined their volcanic origin.

Intense sealing activity which immediately followed, and perhaps even preceded the official discovery, resulted in the haphazard collection of rocks from this region and their transportation to England. A collection obtained in this manner became available to Traill (1822), who described "basaltic rock, beautiful apophyllite crystals, stilbite, quartz-lined druses with zeolites, chalcedony, calcite and iron pyrites".

Between 1911 and 1914 D. Ferguson, who undertook prospecting operations on behalf of Messrs. Chr. Salvesen and Co. of Leith, devoted much of his time to a study of the geology of King George Island (Ferguson, 1921). His account provided the first coherent description and geological map of the island. It described an "older series" of dark mudstones and greywackes with interbedded lavas, separated by an unconformity from a "younger group" of Cainozoic lavas which occupy a broad zone to the south of the older rocks. The contact between the two groups of rocks is marked on his geological map (Ferguson, 1921, fig. 2) from a point west of North Foreland through Martel Inlet and Ezcurra Inlet to Collins Harbour. Intrusions of quartz-mica-diorite, orthoclase-felsite and andesite are described and considerable space is devoted to descriptions of the quartz-pyrite intrusions of Keller Peninsula and Esther Harbour. A geological succession which was established for the older sediments and lavas had a total thickness of 1,060 ft. (323 m.), of which 630 ft. (192 m.) comprised sedimentary rocks. Ferguson's rock collection was examined petrologically by Tyrrell (1921), who recorded quartz-diorite, quartz-augite-hypersthene-diorite and quartz-gabbro from the plutonic intrusions. In this paper he showed that the commonest lava is one of andesitic affinity grouped under bandaite or labradorite-dacite; augite, the most abundant mafic mineral, is frequently accompanied by hypersthene. Among the acid rocks a trachyandesite was reported from Keller Peninsula, an albite-trachyte from Dufayel Island and a felsite from Noel Hill. However, no attempt was made to separate the altered pre-intrusion volcanic rocks from the comparatively fresh Cainozoic lavas. Tyrrell tentatively correlated Ferguson's "older series" with the Jurassic volcanic rocks of Graham Land, and in a later paper (Tyrrell, 1945) he recognized a third group of olivine-rich volcanic rocks which belong to the Penguin Island Group (Hawkes, 1961).

This area was visited in the summer of 1927–28 by Holtedahl (1929), who contrasted the plane of abrasion on the north-west side of the South Shetland Islands with the relatively steep fall of the submarine surface beneath Bransfield Strait to the south-east. He considered that this difference in relative relief was a result of greater marine erosion on the more open north-west side, coupled with a subsidence of Bransfield Strait and the South Shetland Islands landmass.

In 1943 British interest in this sector of Antarctica was revived with the organization of Operation Tabarin, later called the Falkland Islands Dependencies Survey and more recently the British Antarctic Survey. The sphere of operations of the Falkland Islands Dependencies Survey extended to King George Island in January 1947 and by March of that year the first hut was built at Admiralty Bay. The first rock collection was made by A. Reece in the vicinity of the station. It remained unoccupied throughout the winter of 1947 but in January 1948 it was established permanently. From August to November 1948, E. Platt collected further rock specimens from the Admiralty Bay area but it was not until July 1949 that a reconnaissance survey was initiated by Jardine (1950), who was able to sledge extensively over the island. He completed a reconnaissance of the most important accessible rock exposures and, together with G. Hattersley-Smith, he made the most comprehensive rock collection up to that date. Jardine's geological survey report was the main reference to field observations in the petrological study by Hawkes and to some extent it governed the course and intensity of Hawkes's (1961) detailed work which followed. Jardine found that sedimentary rocks are very subordinate to lavas, a conclusion which has been supported by all workers since 1949 and one which is in marked contrast to Ferguson's (1921) views. Jardine noted that sedimentary rocks containing plant fossils were found in a moraine near Point Hennequin by G. Hattersley-Smith in December 1948. He thought that the small exposures of plutonic rocks were all derivatives of the same magma, which was intruded in Oligocene times, and that these exposures were parts of larger masses concealed beneath the central ice cap. A map appended to his report shows the distribution of the andesitic lavas, tuffs and agglomerates, the plutonic intrusions and the sites of main volcanic centres.

Argentine geologists visited King George Island in 1953 and their work was reported by Diaz and Teruggi (1956), who briefly described their observations on the south-east of the island; in particular they discussed Dufayel Island, where an unconformity between the earlier and later volcanic groups was observed.

The discovery of plant fossils at Ezcurra Inlet and Dufayel Island led to the detailed surveys by Bibby in the summer months of 1957–58 and 1959–60 (Bibby, 1961) and Hobbs in 1958–59. Bibby recognized several similar stratigraphical units within the rocks south of Ezcurra Inlet. Each of these sub-divisions is separated by a slight unconformity. At the eastern limit of the exposures, near Point Thomas, the lavas were found to have been invaded by an andesite intrusion. Dufayel Island was also shown to be highly faulted and composed of lavas and sedimentary rocks very different from those of the adjacent south coast of Ezcurra Inlet. When he had completed mapping at Ezcurra Inlet, Hobbs extended his observations to Lions Rump, where he discovered an important marine horizon containing a rich and varied fauna in a conglomerate band between Lions Rump and Low Head.

In 1959, while the author's field work was in progress, Hawkes (1961) completed a petrological examination of rocks collected by geologists of the Falkland Islands Dependencies Survey in the years 1947–50. This comprehensive report revealed that pyroxene-andesites were the most important of the Jurassic volcanic rocks. The Tertiary rocks were subdivided into basaltic andesite and hypersthene-augite-andesite groups, and separated from the Quaternary olivine-rich basalts. It was shown that the Jurassic volcanic rocks belong to a calc-alkaline suite with an andesite–rhyolite association and that this group had been subjected to three distinct phases of metasomatic replacement. Modal analyses of eight rocks from the Andean Intrusive Suite were presented and attention was drawn to their petrographic similarity to the Andean intrusions of Graham Land. Hawkes suggested that petrographically the Tertiary lavas form a calc-alkaline suite with an alkaline trend expressed in the trachyandesite acid derivatives. He also demonstrated the linear pattern of Tertiary and Quaternary vulcanicity, and described the petrogenesis of these volcanic rocks. The geological map in his report shows the distribution of the various petrological groups of the volcanic rocks and their relationship to the intrusive masses.

A comparison between the successions established by earlier workers and the present interpretation is shown in Table I.

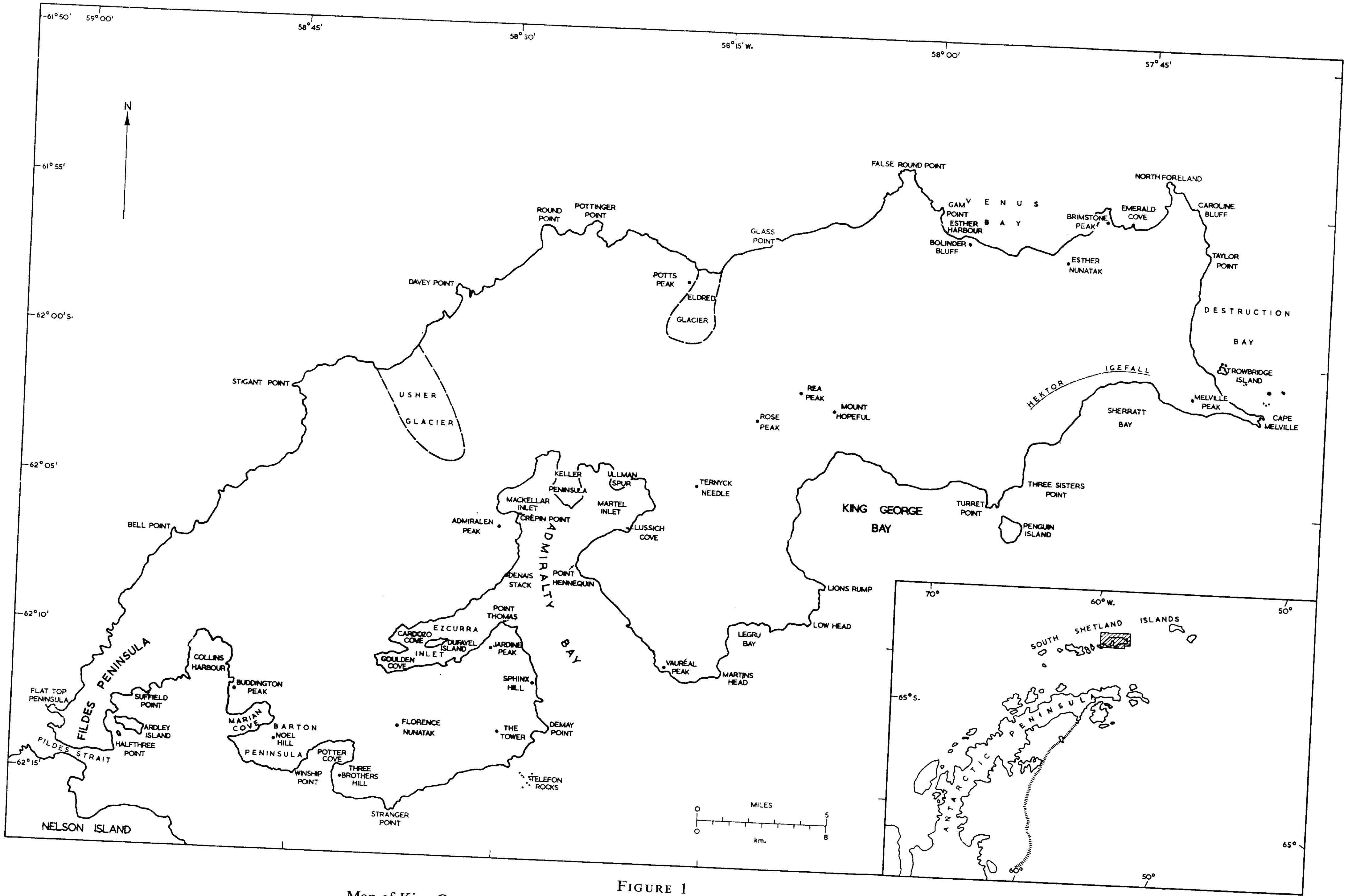

FIGURE 1
Map of King George Island. The inset shows the position of King George Island in relation to the South Shetland Islands and the Antarctic Peninsula.

TABLE I
STRATIGRAPHICAL SUCCESSIONS OF PREVIOUS AUTHORS COMPARED WITH THE PRESENT INTERPRETATION

Age	*Ferguson (1921)*	*Hawkes (1961)*	*Present Interpretation*
Pleistocene–Recent		Penguin Island Group	Penguin Island Group
Pliocene			Lions Rump Group
Middle Miocene		Point Hennequin Group	
Lower Miocene	Cainozoic lavas	Fildes Peninsula Group	
Miocene			Point Hennequin Group
———			Fildes Peninsula Group
Upper Cretaceous			Ezcurra Inlet Group
			Dufayel Island Group
Late Cretaceous to early Tertiary	Intrusions	Andean Intrusive Suite	Andean Intrusive Suite
Upper Jurassic	Dark mudstones and greywackes	Jurassic volcanics	Jurassic volcanic rocks

II. PHYSIOGRAPHY

THE large ice cap (Fig. 2), which covers the central part of the island, takes the form of a long round-topped ice ridge of almost uniform height extending roughly parallel to the trend of the northern coastline. It rises gradually to the highest point of the island at a height of over 2,000 ft. (610 m.). On its north,

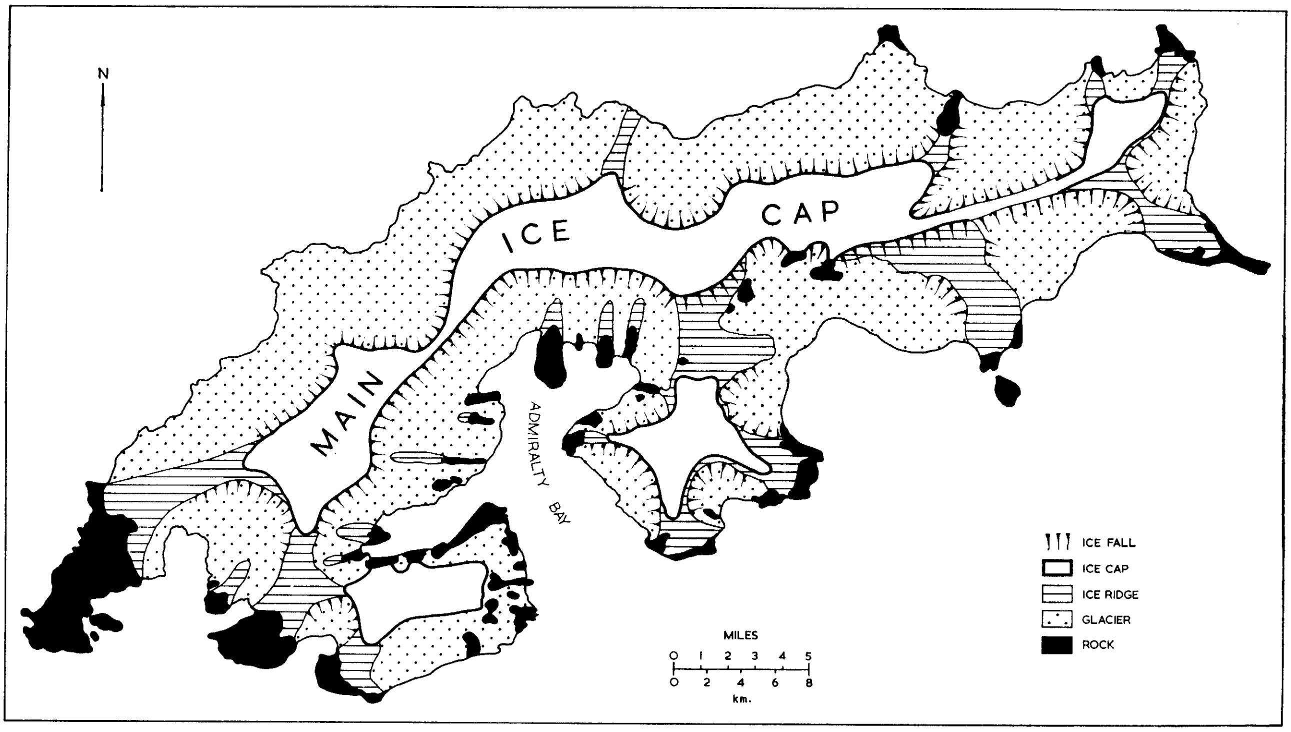

FIGURE 2
General physiographical map of King George Island.

south and west sides it is ringed by almost continuous cliffs over which the ice falls, either directly to the sea or on to a coastal ice piedmont. Ice domes over 1,000 ft. (305 m.) high extend southwards from the ice cap along the east and west sides of Admiralty Bay.

Ice-free coastal areas and peninsulas are often connected to the ice cap by gently rising glacierized ridges which act as divides between the more active glaciers. A few small nunataks pierce the inland ice but most ice-free areas occur along the coast. The northern coastline is fringed by numerous offshore reefs and islands. In contrast, the south coast is cut by deep embayments of which the largest, Admiralty Bay, nearly bisects the island.

The dominant trend of the island is governed by lines of structural weakness parallel to the line of the South Shetland Islands (Fig. 3). Extrusion of volcanic rocks and differential movement along these lines has resulted in linear separation of rocks which vary in their resistance to erosion. Mesozoic rocks show through and ring the high area of the main ice cap. Within this belt the topography is exceedingly rugged and in marked contrast to the more gentle topography of the south coast areas.

The low ice domes on the east and west sides of Admiralty Bay are separated from the main ice cap by low cols. These cols are joined by a valley which is continued through Ezcurra Inlet and the north-eastern arm of Admiralty Bay. The valley separates the Jurassic from the younger rocks to the south and is no doubt the result of erosion along a fault zone. Parallel alignment of the bays of the south-west coast and the scarp along the mountains at the head of King George Bay further demonstrates the presence of weaker rocks along similar or complementary lines of structural weakness. Field evidence supports the view that fault and shatter zones pass along the deep inlets of Admiralty Bay.

It is clear that glacial erosion is dominant now and was on a far greater scale than at present to explain the deep U-shaped valleys and truncated spurs of Admiralty Bay. Ice erosion is also evident on many of the higher inland rock exposures. Ridges of rock which are commonly found between glaciers and the former extensions of glaciers are invariably arête-shaped. Such is the case on most of the exposures around the head of Admiralty Bay and King George Bay. Where rocks are exposed on the side walls of a glacier, the initial U-shape of the valley is very obvious. Glacial erosion of the bedrock on the sheltered coasts of the island can often be correlated with the moraines marking the retreat of the nearby main, side or cirque glaciers. It is significant that none of these moraines show any relationship to the former large glaciers which appear to have excavated Admiralty Bay. Perhaps a slight but temporary glacial re-advance has destroyed the earlier moraines.

The Jurassic rocks have been extensively shattered, mineralized and intruded. Consequently, the variation in hardness between the individual beds is far less marked than the variation in the relatively unaltered Upper Cretaceous–Tertiary rocks. These differences were undoubtedly accentuated by the subaerial weathering which followed glacial retreat. Repeated freezing and thawing of the Jurassic rocks generally dislodges small irregularly shaped fragments which are quite distinct from the larger, often hexagonal, fragments which are dislodged from the Upper Cretaceous–Tertiary rocks. Abrasion by wind-borne fragments is also expressed in a different manner. On the Jurassic rocks this form of weathering acts mainly along joint surfaces, while on the younger rocks the weaker zones of bedding are more susceptible to wind abrasion. Mainly as a result of these processes, the Jurassic rocks have weathered into uneven shapes, while the younger rocks are generally smoother in outline with more marked differences between the individual beds.

Extensive flat-lying areas occur at heights of approximately 170–200 ft. (52–61 m.) on west Fildes Peninsula and at 90–110 ft. (27·5–33·5 m.) on North Foreland, False Round Point and Low Head. At Fildes Peninsula the platform only occurs on the open sea coast. Along the sheltered coast of the peninsula, as indeed along most exposures on the south side of the island, only raised beaches are present. There is one notable exception on the south coast exposure of Low Head where the 100 ft. (30·5 m.) platform coincides with the top of a lava flow. Its sole occurrence on the south coast of the island is therefore the result of fortuitous circumstances. It can only be concluded that, with the exception of the easily eroded Low Head, the sheltered waters of the south coast lack the erosive ability to cut a wide marine platform in hard rocks.

Raised beaches, which rise to 250 ft. (76 m.) above sea-level on the south coast, are not found above 100 ft. (30·5 m.) on the north coast. This is not surprising since the few rocks which do rise above 100 ft. (30·5 m.) are steep and severely glaciated.

Soundings taken from *Meteor* in 1925–27 (Holtedahl, 1929) revealed that a 60 m. submarine platform

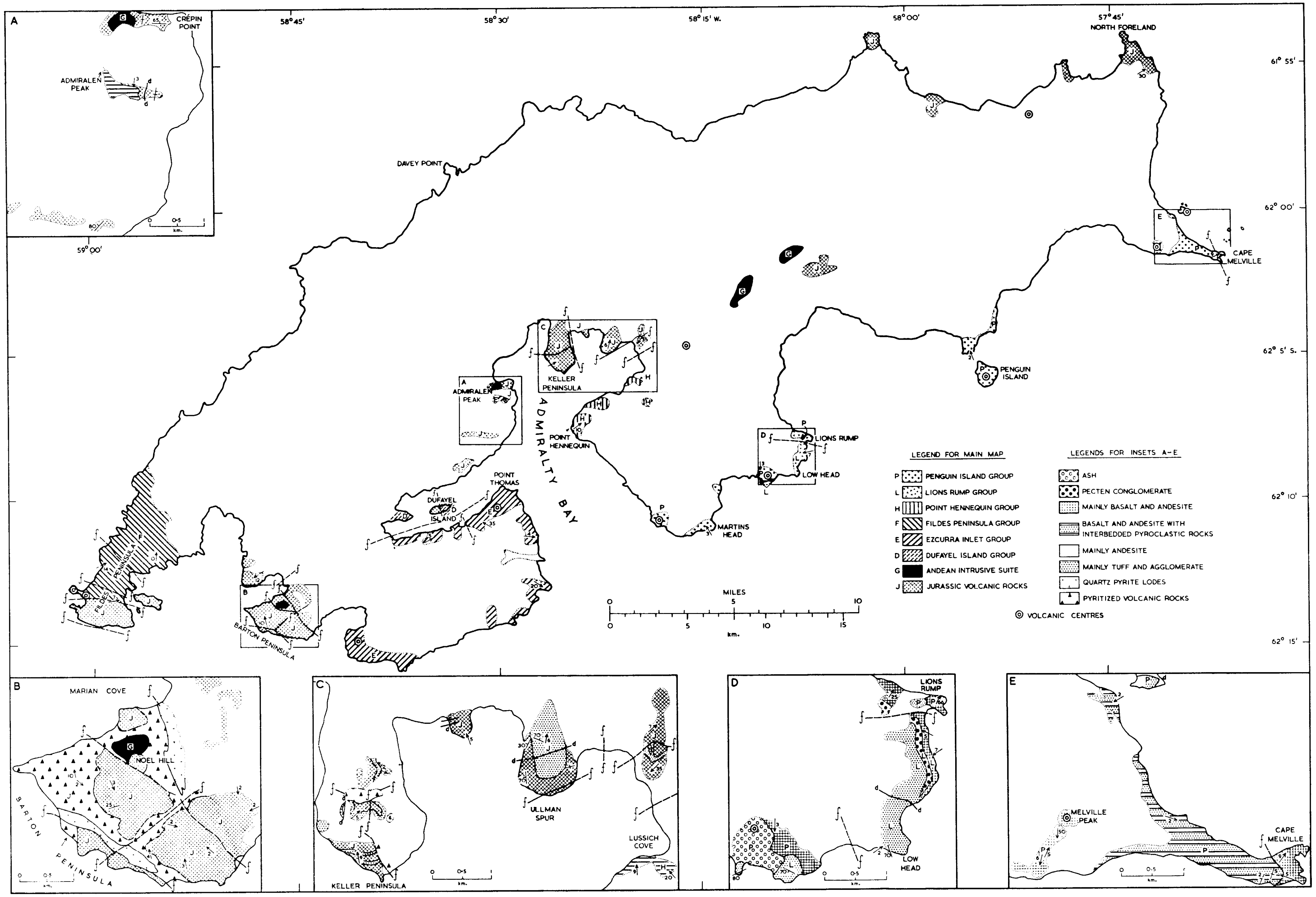

FIGURE 3

Geological map of King George Island. The insets show the detail of areas indicated on the central map.

A. Geological map of the Admiralen Peaks–Crépin Point area.
B. Geological map of the Potter Cove–Marian Cove area.
C. Geological map of northern Admiralty Bay.
D. Geological map of the Lions Rump–Low Head area.
E. Geological map of the Cape Melville area.

[*face page 6*

borders the north coast of the island. This was found to be in sharp contrast to the submarine topography off the south coast where such a platform is completely absent. Indeed, the inlet of Admiralty Bay is a deeply excavated U-shaped valley in which there are depths of 200 fathoms (183 m.) very close to the land. Holtedahl has suggested that the cutting of the marine platform and the glacial excavation of Admiralty Bay occurred when the land was approximately 50 m. above the present level and when glacial action was correspondingly more intense. He thought that the subsidence following this episode was greater on the south than on the north coastal areas and that this gave rise to the very great depths of Admiralty Bay. The north coast submarine platform continues along the north-east edge of Fildes Peninsula; less than 1 mile (1·6 km.) to the south-east on the south-east side of the peninsula there are typical south coast fjord-like inlets. If the difference between the two types of coastline was a result of tilting and subsidence, then it is difficult to imagine that this tilting should not only follow exactly the course of the island but that its axis should pass along the narrow Fildes Peninsula. Axial tilting can be largely disregarded if the distribution of post-Jurassic volcanic rocks and the structural pattern are studied. The north coast is parallel to the lines of structural weakness known to be present on the south-west coast and in Admiralty Bay. Furthermore, Upper Cretaceous–Tertiary volcanic rocks, which greatly increase the ice catchment area around Admiralty Bay, are absent in the north coastal areas. A great volume of ice was therefore channelled through Admiralty Bay and other south coast inlets, while the northward-moving ice had no opportunity of excavating deep valleys.

III. GENERAL STRATIGRAPHY

FRAGMENTS of gneiss and schist in the volcanic rocks of the south-east coast of King George Island have been used by previous workers to postulate the presence of a Basement Complex. These fragments are identical with those on the present beaches and their inclusion within Recent volcanic rocks near sea-level invalidates their use as evidence for the *in situ* occurrence of a Basement Complex on King George Island.

The oldest rocks found *in situ* are of probable Upper Jurassic age. They are composed mainly of pyroxene-andesites which have been metasomatized and intruded by the plutonic intrusions of the Andean Intrusive Suite. Outcrops extend across the length of the island from the south-west coast to the north coast east of False Round Point. This central belt of Jurassic rocks is flanked to the north and south by down-faulted Upper Cretaceous–Tertiary lavas and sedimentary rocks. The southern rock unit gives way to Pliocene–Recent rocks which are exposed along the south-east coast (Table II; Fig. 3). At Admiralen Peak and southern Fildes Peninsula, Upper Cretaceous–Tertiary outliers rest unconformably on Jurassic lavas.

TABLE II

STRATIGRAPHICAL SUCCESSION

Age	*Stratigraphical Sub-divisions*	*Characteristic Rock Type*
Pleistocene–Recent	Penguin Island Group	Olivine-basalt
Pliocene	Lions Rump Group	Olivine-basalt
Miocene	Point Hennequin Group	Hypersthene-augite-andesite
Miocene	Fildes Peninsula Group	Basaltic andesite
Upper Cretaceous	Ezcurra Inlet Group	Hypersthene-augite-andesite
Upper Cretaceous	Dufayel Island Group	Tuff and agglomerate
Late Cretaceous to early Tertiary	Andean Intrusive Suite	Quartz-diorite
Upper Jurassic	Jurassic volcanic rocks	Pyroxene-andesite

Fossiliferous sedimentary rocks, tuffs and agglomerates of the Dufayel Island Group are exposed in the central areas of the island immediately to the south of the Jurassic volcanic rocks. The outcrop of this group is small and it only occurs on Dufayel Island and at the western end of Ezcurra Inlet.

The Ezcurra Inlet Group, which was extruded from vents near Ezcurra Inlet and Potter Cove, post-dates the Dufayel Island Group. In addition to hypersthene-augite-andesites it comprises thin interbedded sedimentary rocks which contain fossil plants.

At the extreme south-west of the island basaltic andesites of the Fildes Peninsula Group are down-faulted to the north against the Jurassic rocks. The higher parts of the succession overlap on to the Jurassic volcanic rocks near Fildes Strait. A sedimentary bed near the base of the succession attains a thickness of over 50 ft. (15 m.), while thin mudstone layers higher in the succession contain fossil plants. This group probably post-dates the Ezcurra Inlet Group.

Hypersthene-augite-andesites and trachyandesites characterize the succeeding pre-Pliocene Point Hennequin Group. The plant fossils, which occur in moraines north of Point Hennequin, were almost certainly derived from the sedimentary beds of the Point Hennequin Group.

A small outlier of Upper Cretaceous–Tertiary age, which rests on the Jurassic volcanic rocks of Admiralen Peak, also contains plant fossils.

The Pliocene to Recent rocks, which are characterized by olivine-basalts, crop out along a line of vents on the south coast of the island west of Point Hennequin. They are subdivided by an unconformity into the Pliocene Lions Rump Group and the Quaternary–Recent Penguin Island Group. Recent field work has revealed that a Pecten Conglomerate is interbedded with lavas of the Lions Rump Group.

Moraines, raised beaches and marine platforms are also present on the island and they provide evidence of a last stage of glacial retreat roughly contemporaneous with a relative drop in sea-level.

IV. JURASSIC VOLCANIC ROCKS

A. Field Relationships

The Jurassic volcanic rocks extend diagonally across the length of King George Island from the south-west coast to the north coast east of Round Point. East of Collins Harbour they are flanked on the south by the down-faulted Upper Cretaceous–Tertiary rocks. West of Collins Harbour the Jurassic lavas are up-faulted between the later rocks of north Fildes Peninsula and Nelson Island. The base of the Jurassic volcanic rocks is not exposed but their upper limit is marked by a major unconformity visible at Admiralen Peak and Fildes Peninsula.

B. Age

Carbonized, silicified and calcified woods occur in the agglomerates of Keller Peninsula and Precious Peaks. Much of their original structure has been obscured by secondary mineralization. No associated leaves have been found but it is possible that they are comparable to woods from the Upper Jurassic rhyolites of Cape Disappointment (Adie, 1952). These rocks pre-date the Andean Intrusive Suite (late Cretaceous–early Tertiary) and exhibit strong petrological affinities with the Upper Jurassic volcanic rocks of the nearby Antarctic Peninsula.

C. Petrology

Pyroxene-andesite, which is the dominant lava, contains phenocrysts of plagioclase and varying amounts of ferromagnesian minerals. Plagioclase phenocrysts are commonly of labradorite which is frequently replaced by albite and saussurite. The groundmass is often obscured by alteration but it is usually holocrystalline and composed of andesine microlites and small grains of pyroxene and magnetite. Interstitial devitrified glass is occasionally present, especially in the acid varieties. The original ferromagnesian minerals have been altered or completely destroyed but, from the shape of the phenocrysts, Hawkes (1961) concluded that the original rocks included olivine-basalts, hypersthene-augite-andesites and augite-andesites.

A porphyritic andesite (G.463.1) from Fildes Peninsula consists of altered andesine-labradorite phenocrysts set in a matrix of feldspar microlites, and augite and magnetite granules. Augite is also present as altered microphenocrysts. Secondary chlorite, calcite and epidote replace the feldspars and augite, and are disseminated through the groundmass. Quartz and chlorite occur within amygdales. An oligoclase-andesite crops out near Fildes Strait. This rock contains highly altered oligoclase-andesine phenocrysts set in a groundmass composed mainly of oligoclase and also possible albite microlites together with indeterminate felsitic material. Calcite, chlorite and iron ore are dispersed throughout the rock. Epidote granules are abundant within the groundmass and are frequently enclosed within the feldspar phenocrysts.

Basalts are comparatively rare and generally follow or precede a more acid flow. An intergranular quartz-basalt, described by Hawkes (1961, p. 7) from Keller Peninsula, is composed of labradorite laths, intergranular augite and magnetite together with a little interstitial quartz. Acid lavas are also relatively uncommon and make up a very small part of the total. Of these lavas, trachyandesites and dacites are the commonest with rhyolites and albite-trachytes less abundant. A devitrified rhyolite from Noel Hill and an albite-trachyte from Dufayel Island were described by Tyrrell (1921).

Metasomatism associated with the plutonic intrusions has widely altered the lavas. Silicification is a usual feature and chlorite and serpentine nearly always replace the ferromagnesian minerals. Pyritization and epidotization are common in these rocks. The intensity of this metasomatism can usually be related to the proximity of pyrite lodes and plutonic intrusions.

Hawkes has suggested that the Jurassic lavas form a calc-alkaline suite with andesite–rhyolite associations. The anomalous albite-trachytes have been thought to be an expression of secondary albitization.

D. Stratigraphy

Jardine (1950) believed that the Jurassic volcanic rocks could be subdivided stratigraphically into a lower group of lavas and an upper group of tuff beds containing fossil woods. This partition can be applied to the rocks of Ullmann Spur but further field observations show that there is insufficient evidence for the sub-division of the whole group of Jurassic volcanic rocks on this basis.

Variation in the intensity of metasomatism, primary lateral change and the absence of reliable marker horizons prevents accurate stratigraphical correlation of individual rock exposures. Consequently, the total thickness has been estimated at a minimum of 3,000 ft. (915 m.), but it is almost certainly more.

The difficulties of precise correlation have necessitated the sub-division of exposures on a geographical basis.

E. Stratigraphy and Nature of Separate Exposures

1. *Fildes Peninsula*

The Jurassic volcanic rocks of Fildes Peninsula crop out south of rocks of the Fildes Peninsula Group. Two stratigraphical sub-divisions have been recognized: a lower series of folded andesites separated by an unconformity from an upper series of gently folded pyritized, calcitized and silicified fragmental rocks (Figs. 4 and 7).

The series beneath the unconformity is at least 750 ft. (228 m.) thick and is composed of folded andesites with interbedded contact volcanic breccias and agglomerates. An altered porphyritic andesite and an oligoclase-andesite from this series are described above. There is considerable variation in the intensity of folding across the exposure of the Jurassic andesites. The dip in the south-west of the area is constant at approximately 15° to the east, but adjacent to Fildes Strait and in all other outcrop areas the andesites are more closely folded. It is possible that the intensity of earth movements increases towards the main fault zone which occupies a position approximately concurrent with the contact between the Jurassic and post-Jurassic rocks. Consequently, this folding cannot be correlated with regional folding of known age elsewhere in north-west Antarctica.

The rocks of the upper series are highly altered and under the microscope they appear to be of a pyroclastic origin. However, certain of the larger fragments are rounded and may possibly have been subjected to water erosion.

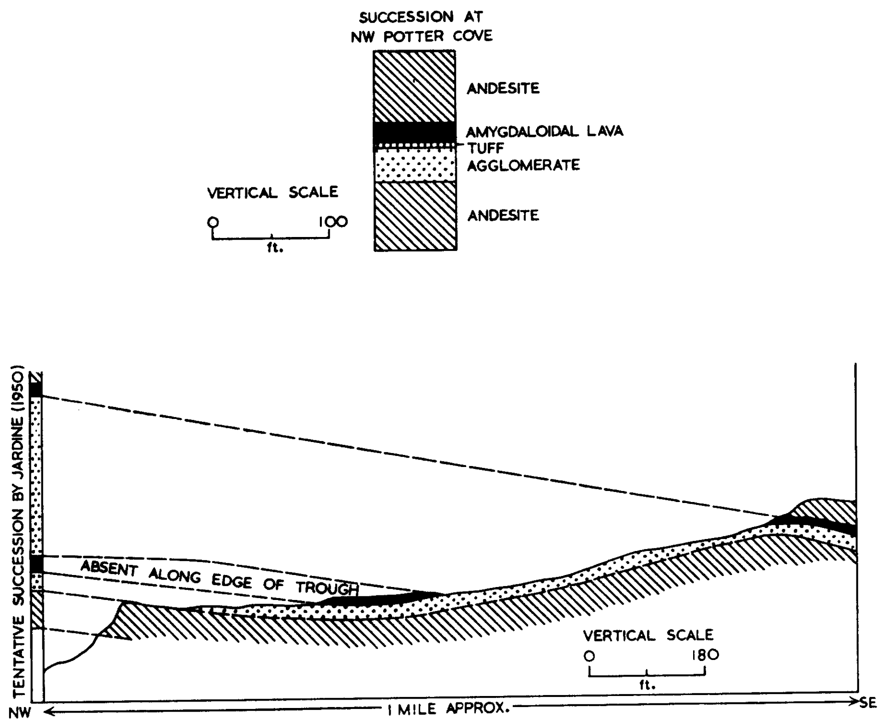

FIGURE 4

The succession for north-west Potter Cove and a north-west to south-east section through the same area.

2. *Barton Peninsula*

This exposure, which is the most extensive single outcrop of Jurassic rocks on the island, is composed of 900–1,000 ft. (275–305 m.) of andesites, agglomerates and thin tuffs, all of which are metasomatized and intruded at Noel Hill by granodiorite (Fig. 3).

Adjacent to the Noel Hill intrusion the pyroxene-andesites have been feldspathized. One rock (G.526.1) from this locality shows zoned feldspar phenocrysts with inner cores of labradorite and outer rims of albite. Secondary epidote granules and interlocking anhedral quartz penetrate the groundmass which is mainly composed of small andesine laths. This quartz replacement imparts a granoblastic texture to parts of the groundmass.

In common with all other exposures of Jurassic rocks, true acid lavas are rare. However, Tyrrell (1921, p. 72) has described a devitrified rhyolite from Noel Hill. Exactly where this rhyolite was collected must remain obscure, since no trace of such a rock was discovered during the course of the field work.

Pyrite is commonly disseminated along shatter zones within the lavas, while feldspathization and silicification are closely associated with the outcrop of the granodiorite. The features of mineralization are discussed on p. 14.

The succession given by Jardine (1950) for the north Potter Cove area has been related to the gentle anticline and syncline located along the original line of section (Fig. 4). The succession consists of two andesitic lava flows separated by agglomerates and thin tuffs.

3. *Admiralty Bay*

From Precious Peaks, north-east of Admiralty Bay, through Keller Peninsula to the north shore of Ezcurra Inlet, the andesites are mainly older than the intrusions. The southern boundary of this succession is faulted against Upper Cretaceous–Tertiary volcanic rocks, but an isolated exposure of the unconformable volcanic cover remains high on the ridge south of Crépin Point.

Although the granodiorite is limited to a small exposure at Crépin Point, the associated mineralization is widespread and reaches its maximum intensity on Keller Peninsula, where extensive quartz-iron ore deposits vein and replace the volcanic rocks (Fig. 3).

A detailed examination of Keller Peninsula (Figs. 3 and 5) has revealed a minor unconformity near the base of the succession; this is preceded by andesitic lavas and followed by 1,720 ft. (524 m.) of lavas exhibiting rhythmic stratigraphical phases. It is clear that in Keller Peninsula there are four phases which are repeated three times throughout the exposed succession; they are characterized, in turn, by predominant pyroclastic rocks with wood remains, highly porphyritic andesite, andesite and an upper porphyritic andesite.

A few thin trachyandesite and dacite flow lavas are interbedded with the pyroxene-andesites. The fairly common remnant trachytic structures may indicate that acid lavas were somewhat more abundant than usual. In his petrological study, Hawkes (1961) noted that a quartz-gabbro intrusion had been reported

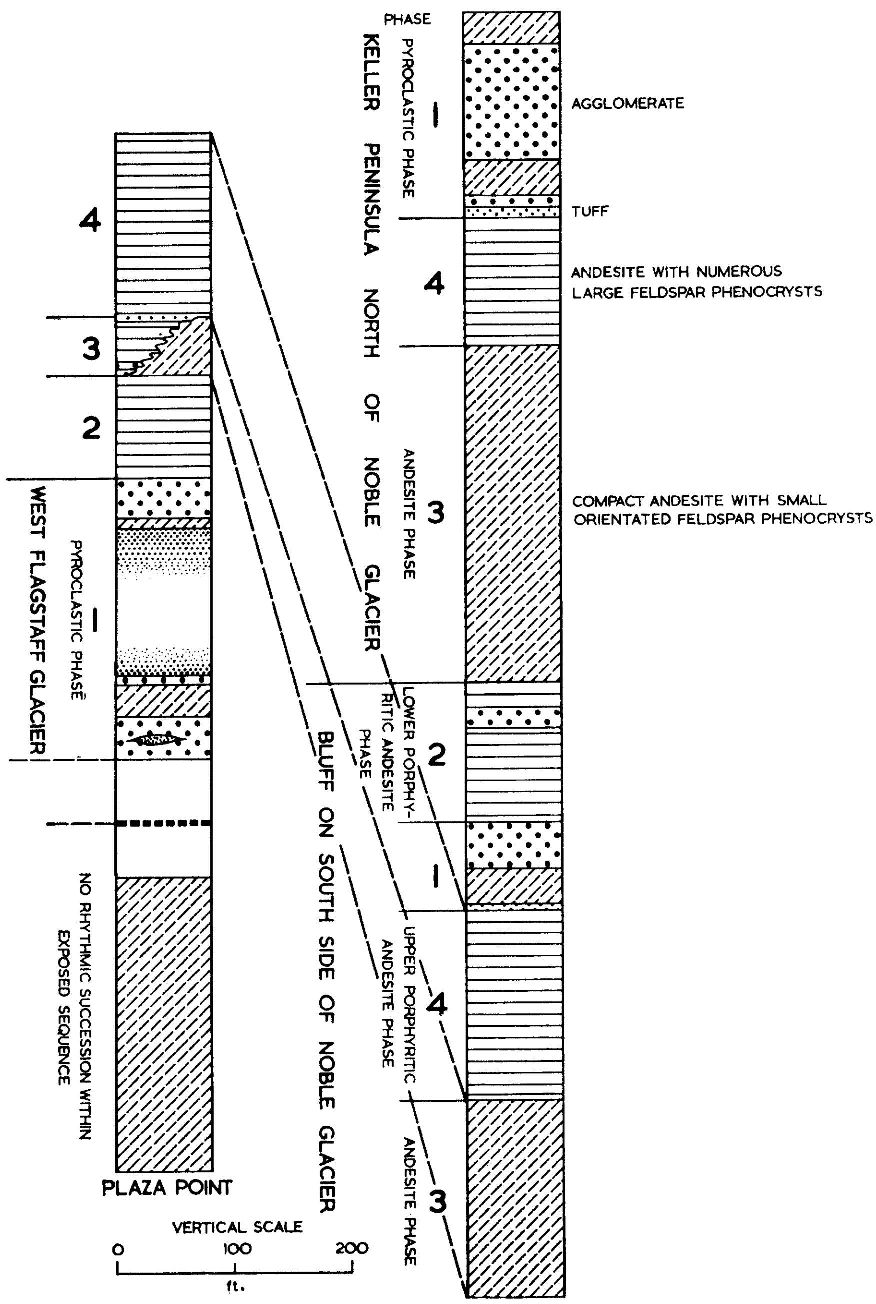

FIGURE 5
The stratigraphical succession at Keller Peninsula.

from the north of the peninsula. When this same locality was visited, no trace of any intrusion could be seen. Although it may have been covered by snow, this is unlikely since the visit coincided with the period of maximum ablation and near minimum snow cover.

The rocks of Keller Peninsula are more altered than those of Ullmann Spur or Precious Peaks. The feldspars are frequently albitized and calcitized, while the pyroxenes are often completely pseudomorphed. Silicification and pyritization is intense and calcitization is especially well developed at the south end of the exposure. Hawkes (1961) showed that the outline of calcite and chlorite pseudomorphs is reminiscent of hypersthene, concluding that many of the primary lavas were hypersthene-andesites.

The volcanic rocks of Stenhouse Bluff, the small promontory east of Keller Peninsula, are petrologically similar to those of Ullmann Spur and they exhibit the same two-fold sub-division into basal lavas with overlying pyroclastic rocks. At least two dykes of dioritic composition intrude the gently northward-dipping andesite flows forming the southern section of the exposure (Fig. 3).

The stratigraphical succession established by Jardine (1950) for Ullmann Spur is shown in Table III. It was possible to re-visit the area but no significant additional interpretation could be made to the succession.

TABLE III

SUCCESSION AT ULLMANN SPUR
(after Jardine, 1950)

		ft.	m.
Tuffs and agglomerates	Coarse agglomerates and tuffs	500	152
Lavas	Fine-grained andesite Microporphyritic basic andesite Acid andesite Porphyritic basic andesite Andesite	300	91

The succession can be subdivided into two main series: the lower series is 600 ft. (183 m.) thick and consists of six andesitic lava flows, whereas the upper series is 500 ft. (152 m.) thick and consists of pyroclastic rocks containing wood remains. The agglomerates at the base of the pyroclastic rocks are coarse, but they grade laterally southward into fine tuffaceous agglomerates and upwards into bedded tuffs. Wood beds occur near the base of the agglomerates and also within the tuff beds high in the exposed succession.

Precious Peaks, at the extreme north-east of Admiralty Bay, is composed of silicified and chloritized andesites and agglomerates cut by a west–east trending fault. South of the fault a minor unconformity separates two essentially similar lava series. Wood is preserved in agglomerates at approximately 100 ft. (30·5 m.) above sea-level on the south side of the exposure.

Exposures on the east coast of Admiralty Bay are mainly of Jurassic pyroxene-andesites and interbedded pyroclastic rocks. At Crépin Point the volcanic rocks are intruded by quartz-diorite and unconformably overlain by later lavas and sedimentary rocks on the ridge south of Crépin Point. This area differs from northern Admiralty Bay both in the absence of large quartz-pyrite veins and in the aplite and diorite dykes which are frequently intruded along the well-developed joints (Fig. 3). Lavas within the narrow contact-metamorphosed zone of the Crépin Point intrusion are veined with calcite and quartz. Biotite and amphibole replace pyroxene, and grains of magnetite and hypersthene are abundant. Immediately adjacent to the intrusion the andesites possess recrystallized feldspars and a granoblastic texture (Hawkes, 1961).

The lavas of Dufayel Island lie within a major fault zone which marks the southern boundary of the Jurassic rocks. Pyroxene-andesites separated by thin tuffs and agglomerates comprise the bulk of the volcanic rocks. This sequence is faulted on the west against several hundred feet of probably Jurassic albite-trachytes, and on the east against the Upper Cretaceous–Tertiary Dufayel Island Group (Bibby, 1961; Hawkes, 1961). At the eastern end of the island small areas of the Jurassic rocks may be overthrust southwards on to the tuffs, sedimentary rocks and agglomerates of the Dufayel Island Group (p. 18). Alteration products typical of the Upper Jurassic volcanic rocks occur throughout the succession. Plagioclase has been extensively sericitized and epidote replacement has in certain cases spread through the whole rock. Hawkes (1961, p. 9) has described this rock as an aggregate of epidote, chlorite and leucoxene. Quartz and iron pyrites veins and stockworks increase in number and size westwards. The dip of the lavas on the north coast of the island averages 60° to the north (Bibby, 1961, p. 7).

4. *Mountains at the head of King George Bay*

Approximately 1,000 ft. (305 m.) of lavas, which are exposed at Mount Hopeful, are intruded to the west by the Rose Peak granodiorite. Specimens collected from all accessible outcrops are pyroxene-andesites with large feldspar phenocrysts. Alteration, attributed to metasomatism associated with the intrusion, is characterized by abundant disseminated pyrite and epidote, and the intrusion of thin aplite veins. In effect, these lavas show metasomatic alteration on a similar scale to that affecting the pyroxene-andesites of Dufayel Island.

Joints in the volcanic rocks can be subdivided into several patterns (p. 29) and are continuous through the nearby granodiorite.

5. *North Foreland and Brimstone Peak*

Both of these exposures are composed of altered flow lavas. Metasomatic products similar to those adjacent to the Noel Hill granodiorite are abundant. The least-altered rocks are pyroxene-andesites with scattered pyroxene and feldspar phenocrysts. Towards the north-east these rocks become progressively feldspathized and silicified. No exposures of true plutonic rocks were found on the North Foreland peninsula.

Field observations show that pyrite accompanies epidote either as a dissemination or as thin veins emplaced within or parallel to the numerous well-developed joints. In general, metasomatic replacement is closely similar to that of Dufayel Island and the mountains at the head of King George Bay. The dip at the south end of North Foreland is 30° to the north-east, but at nearby Brimstone Peak it is 9° to approximately 322° mag.

6. *Coastal exposures west of Brimstone Peak*

The Jurassic pyroxene-andesites of False Round Point and Bolinder Bluff have been irregularly metasomatized; at Bolinder Bluff they are intruded by veins of quartz, aplite and microdiorite, which trend 030° and 100° mag. and become more numerous towards the east of the exposure where secondary pyrite is abundant. A short distance offshore from Bolinder Bluff there are several small islands composed mainly of quartz and pyrite.

V. ANDEAN INTRUSIVE SUITE

A. Intrusions

The plutonic and hypabyssal intrusions are arranged along the length of King George Island. A parallel line of petrographically similar intrusions extends along the length of the nearby Antarctic Peninsula. Both the Antarctic Peninsula and the South Shetland Islands are part of the orogenic belt which extends from Antarctica, through the Scotia arc, to the Andes of South America. Within this sector of the orogenic belt the intrusion was initiated subsequent to Jurassic times and terminated, at the latest, in the early Tertiary.

Granodiorite, quartz-diorite and quartz-gabbro have been described (Hawkes, 1961) but, in contrast to the intrusions of the Antarctic Peninsula, neither true granites nor ultra-basic derivatives are represented.

1. *Field relationships*

The plutonic intrusions invade the central zone of Jurassic volcanic rocks and they are exposed at Rose Peak, Crépin Point and Noel Hill.

a. *Crépin Point.* Quartz-diorite and quartz-gabbro intrude Jurassic andesites which crop out at the eastern and western ends of the exposure near Crépin Point (Fig. 3). Along the eastern side of the intrusive mass the contact with the andesite is clearly visible. Within 3 yd. (2·7 m.) of the contact the quartz-diorite decreases slightly in grain-size. Finer parts of the heterogeneous intrusive rock contain small flecks of pyrite. Throughout the whole of the Crépin Point area the country rocks are intruded by thin veins of quartz, calcite, aplite and fine-grained quartz-diorite. Xenoliths and inclusions of andesite are abundant within the plutonic rocks. Quartz-gabbro and quartz-diorite intermingle patchily and field observations show that they clearly belong to the same phase of intrusion.

b. *Noel Hill.* Granodiorite and quartz-diorite intrude the volcanic rocks of Noel Hill (Fig. 3; Plate Ia). Near the summit of Noel Hill an altered andesite crops out; the contacts between the andesite and the intrusion are obscured by scree and snow slopes but the general field relationships suggest that the lava forms a cap to the intrusion. The contact to the west dips steeply towards Marian Cove at about 70° in a direction 230° true. Small exposures of pyritized and shattered andesite appear in a narrow fault zone along the southern boundary of the intrusive mass. On King George Island pyritization is apparently a feature of metasomatism associated with the closing phases of intrusion.

This intrusion is cut by thin aplite veins and several sets of widely spaced joints. Quartz-diorite and granodiorite are intermingled but there is no evidence for more than one stage of intrusion.

c. *Other areas.* A wide quartz-diorite dyke cuts the volcanic rocks of Stenhouse Bluff. Perhaps this quartz-diorite and the pyrite of nearby Keller Peninsula were both emplaced in close proximity to a large acid intrusion.

The relationship between the coarse Rose Peak granodiorite and the surrounding Jurassic lavas is obscured by glaciers which divide the mountains into several isolated nunataks.

No plutonic intrusion was observed on North Foreland peninsula.

2. *Petrology*

The Noel Hill and Rose Peak intrusions are in part granodiorite. This has a typical hypidiomorphic texture and contains up to 10 per cent of free quartz, kaolinized orthoclase, andesine, hornblende and biotite. Actinolite often replaces pyroxene and quartz occurs as allotriomorphic crystals and intergrowths with albite (Hawkes, 1961).

The quartz-diorite from Noel Hill, Crépin Point and Stenhouse Bluff has less than 10 per cent of free quartz, but under 5 per cent of orthoclase (Hawkes, 1961, p. 11, table III). It is usually characterized by a hypidiomorphic texture and it contains feldspar with an average composition between andesine and acid labradorite.

Quartz-gabbro has only been found at Crépin Point. Apart from the more basic feldspars and the presence of hypersthene, the rock is similar to the quartz-diorite of the same intrusion.

B. Alteration Associated with Major Intrusions

1. *Metasomatism*

Most of the Jurassic volcanic rocks have been altered by the introduction of metasomatic products associated with the plutonic and hypabyssal intrusions.

Intense epidotization and pyritization is confined to Jurassic lavas and attains its maximum development in areas peripheral to the quartz-diorite and granodiorite intrusions. Pyrite occurs as a dissemination throughout the andesites at Barton Peninsula and North Foreland, but at Fildes and Keller Peninsulas selective low-grade pyrite mineralization has taken place mainly along pyroclastic beds and at the contacts between the lavas. Albite generally replaces more calcic feldspars and many of the original ferromagnesian minerals have been replaced by chlorite and chalcedony, quartz, jasper and hematite.

2. *Quartz-pyrite lodes*

Quartz-pyrite lodes invade the Jurassic lavas of Keller and Barton Peninsulas and several of the islands off the north coast.

a. *Keller Peninsula.* On the central ridge of Keller Peninsula the main lode is up to 170 yd. (155 m.) wide and dips steeply to the north. Emplacement has occurred along an approximately east–west trending pre-Tertiary fault (Fig. 3). Most of this lode is composed of a grey to milky white silica-rich rock containing thin veins and disseminated crystals of pyrite. Where silicification is less intense, flow structures and blasto-porphyritic feldspars are occasionally visible in the hand specimen. At the top of the main ridge pure quartz-pyrite occurs as lenses adjacent to the foot and hanging walls. Approximately 0·5 miles (0·8 km.) north from the main lode there is a subsidiary quartz-pyrite intrusion exposed through the terminal moraines of Noble Glacier. This is a mineralized breccia which occurs discontinuously along a shatter zone. Quartz-pyrite injection to the south-west of Flagstaff Hill has taken place along an agglomerate bed.

b. *Barton Peninsula.* North and south of Noel Hill pyritized andesites are cut by two large quartz-pyrite lodes. The quartz-pyrite occurs in a breccia which extends along near-vertical pre-Tertiary shatter zones trending 350° and 305° true. Almost pure quartz-pyrite occupies the centre of the lode south of Noel Hill. Towards the margins the rock becomes slightly richer in iron ore and grades sharply into silicified and pyritized andesites containing inclusions of quartz (Plate Ib).

A small vein at Potter Cove is surrounded by several zones of quartz-injected andesite (Fig. 6). The

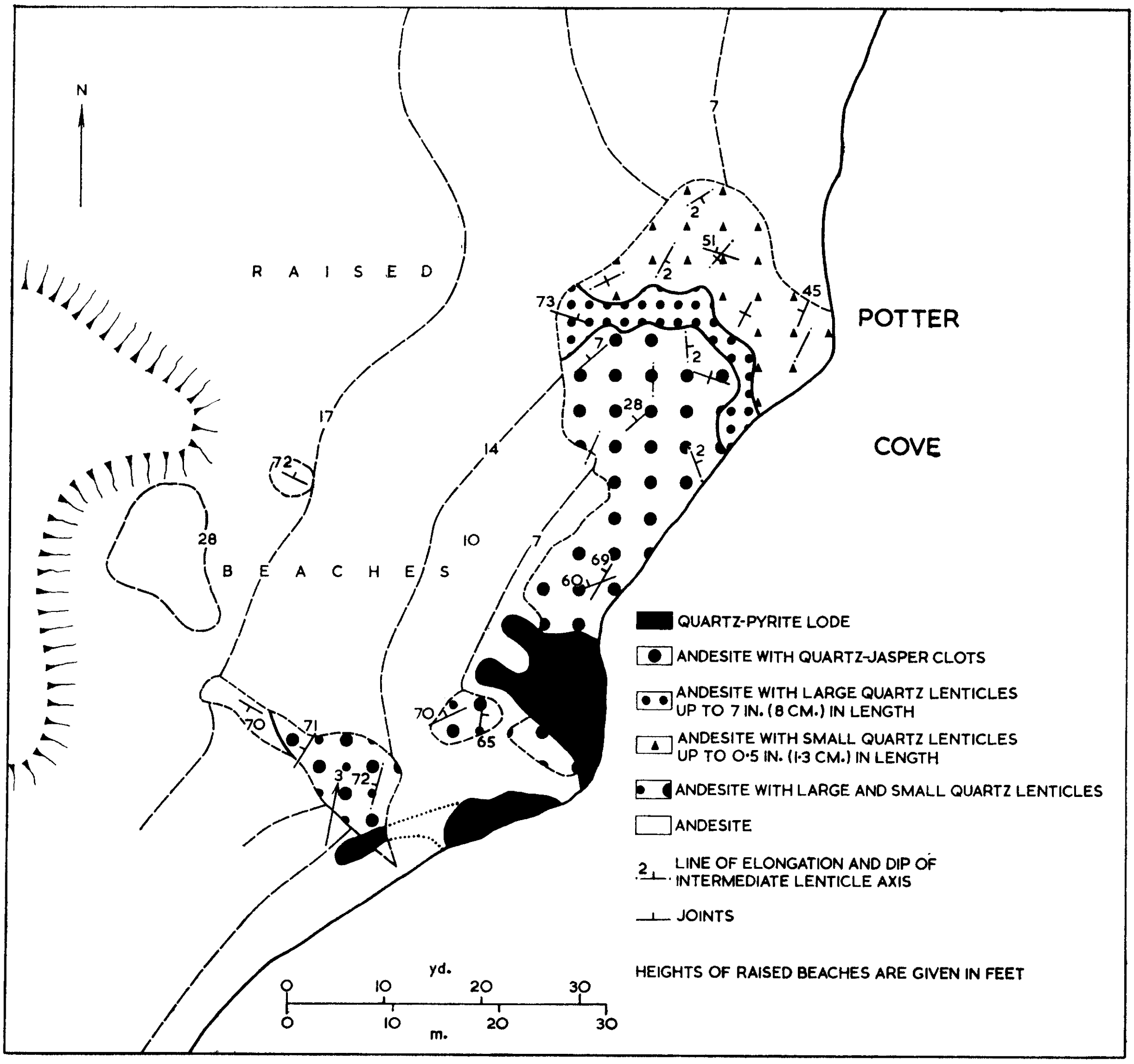

FIGURE 6

Geological map of mineralized zones adjacent to a quartz-pyrite lode at north-west Potter Cove.

dip of the andesite is parallel to the line of elongation of the quartz lenticles. The size of the quartz inclusions increases towards the quartz-pyrite lode but it bears no apparent relationship to original flow structures in the andesite.

VI. UPPER CRETACEOUS–MIOCENE ROCKS

THE Upper Cretaceous–Miocene rocks are subdivided into four volcanic groups, each of which contains thin interbedded plant-bearing sedimentary rocks. These groups are named after the type areas and are, from oldest to youngest: the Dufayel Island, Ezcurra Inlet, Fildes Peninsula and Point Hennequin Groups. The rocks of the Dufayel Island Group pre-date mineralization which appears to have accompanied the final stages of plutonic intrusion, but the other groups post-date this mineralization. The respective ages of the Upper Cretaceous–Miocene rock groups are discussed in greater detail below.

The Dufayel Island Group is exposed within the major fault system on the southern margin of the main area of Jurassic volcanic rocks. Both the Ezcurra Inlet and Point Hennequin Groups were extruded to the south of this fault. In contrast, the Fildes Peninsula Group originated from volcanic centres to the north of the up-faulted Jurassic rocks.

The lavas on the southern flanks of the Jurassic volcanic rocks are predominantly hypersthene-augite-andesites, whereas those to the north are mainly basaltic andesites (Hawkes, 1961).

A. STRATIGRAPHICAL RELATIONSHIPS AND AGES OF INDIVIDUAL ROCK GROUPS

Both the Upper Jurassic volcanic rocks and the plant-bearing sedimentary rocks of Dufayel Island are silicified and pyritized. This mineralization is attributed to late-stage alteration which accompanied the closing phases of the plutonic intrusions of the Andean Intrusive Suite. This view is supported by Hawkes (1961). Secondary quartz-pyrite emplacement is notably absent from the Pliocene and Quaternary rocks and also from the volcanic rocks and interbedded plant-bearing beds of the Ezcurra Inlet, Fildes Peninsula and Point Hennequin Groups; rocks from these three areas appear to have post-dated this phase of mineralization. On this basis, the oldest of the plant beds are those of Dufayel Island. The presence of pebbles of granite and quartz-pyrite in the lavas of Fildes Peninsula and Point Hennequin adds further support and is conclusive evidence that these rocks post-date the plutonic intrusions. Evidence from included pebbles of plutonic rocks is lacking in rocks of the Ezcurra Inlet Group.

The upper stratigraphic boundary of the Upper Cretaceous–Miocene rocks is fixed by the superposition of the distinctive rocks of the Lions Rump Group.

Work on Foraminifera from Lions Rump is still in progress but it indicates that this group is of Pliocene age (personal communication from R. J. Adie). During the Pliocene–Recent period, olivine-basalts were extruded along the south-facing side of the South Shetland Islands between King George and Deception Islands. Both the Point Hennequin Group and the Pliocene–Recent lavas of Deception Island contain thick trachyandesite lavas. Hawkes (1961) believed that these trachyandesites are representative of an alkaline trend which reaches its full development in the Recent lavas of Deception Island; since they have not been found in the Fildes Peninsula and Ezcurra Inlet Groups, he concluded that the rocks of Point Hennequin comprise the youngest of the Tertiary petrological groups of King George Island. The trachyandesites stand out in marked colour contrast from the darker-coloured andesites and agglomerates. A similar light-coloured bed of agglomerate, over 100 ft. (30·5 m.) thick, occurs within the Lions Rump Group near Low Head. Petrologically, the Point Hennequin Group is closely allied to the Pliocene–Recent lavas of the Scotia arc, and in consequence it seems likely that it occupies a stratigraphical position above the volcanic rocks and interbedded sediments of the Ezcurra Inlet and Fildes Peninsula Groups.

The Jurassic trachyandesites occur in irregular zones, marginal to mineralization belts and associated with the major intrusions. They are secondary products of the silicification and albitization of more calcic lavas and have a different mode of origin from the later trachyandesites.

The Dufayel Island Group is the oldest of the rock groups containing fossil plants and the Point Hennequin Group is, in all probability, the youngest. It is now relevant to discuss the evidence for the relative ages of the plant-bearing sedimentary and volcanic rocks of the Fildes Peninsula and Ezcurra Inlet Groups. Petrologically, the Ezcurra Inlet Group, in common with the overlying Point Hennequin Group, is dominated by hypersthene-augite-andesites. However, the shape of the pseudomorphs in the Upper Jurassic andesites shows that primary hypersthene-augite-andesites were also common in the Mesozoic. Hypersthene-augite-andesites also occur as subordinate rock types in the Fildes Peninsula, Lions Rump and Penguin Island Groups. Therefore, this extremely common and persistent eruptive rock cannot be used as a reliable stratigraphical marker. Only direct field observation can provide the key to this problem. For example, both the Ezcurra Inlet and Fildes Peninsula Groups crop out along the boundary of the major fault separating the Jurassic from the post-Jurassic rocks. In the central areas of the south coast of Ezcurra Inlet, near this major fault, the rocks of the Ezcurra Inlet Group are severely disturbed. Dips over an area of nearly 1 sq. mile (1·6 km.^{2}) are random; angles up to 55° have been recorded and in one area the exposed rocks are folded into a dome and syncline with limbs dipping at 35–40° (Bibby, 1961). The angles of dip are clearly not related to the plug intrusions. Folding on this same scale cannot be demonstrated in the post-intrusion rocks of any other area on King George Island. Anomalous dips also occur in the Jurassic rocks near the main fault at Precious Peaks, Dufayel Island and Fildes Peninsula. At other localities the intimate relationship is obscured by wide glacial channels along the fault system and by the great ice masses which flow down to the coast from the high inland areas of Jurassic rocks.

Lavas and plant-bearing sedimentary rocks of the Fildes Peninsula Group are also adjacent to the major fault of Mesozoic to post-intrusion age; here, in sharp contrast to the structure in southern Ezcurra Inlet, no change can be detected in the gentle primary angles of dip. The southward overlap of the Fildes Peninsula Group on to the low-lying Jurassic rocks near Fildes Strait and the presence of Jurassic inliers north of the fault show that since the formation of the Fildes Peninsula Group movements along the main fault zone have been relatively slight. On the other hand, considerable tectonic movement has taken place along the same fault zone since the formation of the Ezcurra Inlet Group. The Ezcurra Inlet Group therefore pre-dates a tectonic phase which does not appear to have affected the rocks of the Fildes Peninsula, Point Hennequin, Lions Rump or Penguin Island Groups.

From the petrological and structural evidence outlined above, it can be inferred that the probable order of succession, from the base upwards, is: the Dufayel Island, Ezcurra Inlet, Fildes Peninsula and Point Hennequin Groups.

The relatively numerous modern-looking net-veined (dicotyledonous type) leaves which occur in the plant beds indicate that they are certainly younger than Middle Cretaceous (Barton, 1964; Orlando, 1964; Schauer and Fourcade, 1964); they are post-dated by the Pliocene rocks and their age range is therefore Upper Cretaceous–Upper Miocene. All previous workers have unanimously declared that the younger lavas and their interbedded plant-bearing sedimentary rocks and tuffs are of Tertiary age. Schauer, Fourcade and Dalinger (1961) placed the Fildes Peninsula plant beds in the Middle Oligocene. Adie (1962) has suggested that the post-Jurassic plant-bearing lavas and tuffs could be Miocene in age. Finer divisions were erected by Hawkes (1961) who recognized a Middle Miocene Point Hennequin Group and a probable Lower Miocene Fildes Peninsula Group.

An hiatus in marine sedimentation occurred in the Graham Land area between the Upper Cretaceous and Oligocene–Miocene. Adie (1962) has attributed this early Tertiary sedimentary break to uplift which may have accompanied the batholithic intrusions of the Andean Intrusive Suite. Early Tertiary uplift along the Antarctic–Andean cordilleran chain was accompanied in Patagonia by the extrusion of huge thicknesses of andesites (Jenks, 1956, p. 163). Similarly, a great thickness of andesites was also extruded at King George Island during the Upper Cretaceous–Tertiary period. This tectonic phase also occurred in early Tertiary times along the Antarctic–Andean chain to the south of Graham Land and to the north in South America. Consequently, there is reason to believe that the volcanic rocks associated with the earlier plant beds of King George Island were also extruded in early Tertiary (Eocene–Oligocene) times.

The three youngest rock groups on King George Island post-date the plutonic intrusions. In the Antarctic Peninsula intrusion of plutonic rocks of the Andean Intrusive Suite ranged from the late Cretaceous to early Tertiary. If, as seems quite likely, the intrusions of the Andean Intrusive Suite of the Antarctic Peninsula are contemporaneous with those of nearby King George Island, then these plant-bearing rock groups are of mid-Tertiary (Oligocene–Miocene) age. The petrological affinity between the Point Hennequin Group and the succeeding Pliocene–Recent rocks adds some support to this opinion.

B. Dufayel Island Group

1. *Field relationships*

Unfavourable sea-ice conditions prevented a close field examination of the rocks of Ezcurra Inlet. As a result, most of the field observations recorded here are those of Bibby (1961), who mapped the area.

The Ezcurra Inlet Group crops out along the southern shores of Ezcurra Inlet, while the Jurassic volcanic rocks crop out along the northern shore. This, together with the intense shattering and mineralization of Dufayel Island, indicates that the Dufayel Island Group occurs within a major west–east trending fault zone. A complementary north-west to south-east trending fault, which crosses Dufayel Island, brings the Dufayel Island Group in the east against the Jurassic volcanic rocks in the west (Hawkes, 1961).

At Dufayel Island the group is overlain by highly altered horizontal andesitic lavas 50–75 ft. (15–22·5 m.) in thickness. These lavas are rich in silica and contain chlorite, epidote, calcite and pyrite in appreciable amounts. They are therefore similar to the Jurassic lavas exposed elsewhere on King George Island. Despite this, the underlying tuffs and sedimentary rocks of the Dufayel Island Group contain Upper Cretaceous–Tertiary plant fossils. Although secondary quartz and pyrite occur in both rock types, marked epidotization is confined to the lavas.

Therefore, there are two alternative explanations of the relationship between the andesites and the underlying fossiliferous beds. Perhaps mineralization continued after extrusion of the lavas. If this were so, then the paucity of epidote in the tuffs could be a result of their different response to the same mineralization media. Alternatively, the lavas could have been thrust southwards over the tuffs. The fact that the rocks of Dufayel Island are intensely faulted, contorted and sheared supports the feasibility of this mechanism. Further support is furnished by the abundance of epidote in the andesites, which according to Hawkes (1961, p. 9), is indicative of Upper Jurassic rocks.

2. *Age*

Mineralization associated with the plutonic intrusions post-dates the Dufayel Island Group but predates all other plant-bearing rock groups. The plant fossils are post-Middle Cretaceous in age and in the nearby Antarctic Peninsula plutonic intrusion ceased before the Middle Tertiary. There is some support for an Eocene–Oligocene age for these beds (p. 17).

3. *Stratigraphy and lithology*

On Dufayel Island, agglomerates, tuffs and thin sedimentary beds occur throughout the 300 ft. (91 m.) of exposed succession. The lowest beds, on the north-east coast, are coarse purple agglomerates, tuffs and tuffaceous flagstones. These are overlain by a series of green beds which are similar in lithology but contain a higher proportion of tuffs and tuffaceous flagstones (Bibby, 1961). The contact between the two sub-divisions is gradational and there is some overlap of green and purple beds throughout the succession. Some of the fragments in the agglomerates are typical of the altered Jurassic pyroxene-andesites. Angular, fine-grained lava fragments comprise the bulk of the tuffaceous flagstones; these fragments are relatively fresh and contain numerous orientated feldspar microlites. Secondary quartz, chlorite and sericite irregularly replace the indistinct matrix. Pyrite and leucoxene grains are scattered throughout the rock.

The tuffs and agglomerates exposed on the eastern side of the headland between Goulden and Cardozo Coves are closely similar in lithology and colouring. Plant remains have not been found in this area. The most prolific plant-bearing horizons are in the green tuffaceous flagstones exposed along the north side of Dufayel Island.

Numerous quartz veins intrude the rocks of this group. They are of varying size and are irregularly orientated. In places they form a close stockwork which is occasionally fused into a solid mass of quartz. On Dufayel Island quartz veining increases to the west of the exposure where the rocks are highly contorted. Dips in the tuffs and agglomerates of Dufayel Island are random and can mainly be attributed to earth movements accompanying faulting. A dip of 15° to the south-east has been recorded on the rocks of the headland between Goulden and Cardozo Coves.

C. Ezcurra Inlet Group

1. *Field relationships*

The Ezcurra Inlet Group crops out in the area west of Admiralty Bay, between Point Thomas and Potter Cove (Fig. 3). Its northern boundary is followed by a major fault zone which brings the Ezcurra Inlet Group in the south against the Dufayel Island Group and the central belt of Mesozoic rocks in the north. The Ezcurra Inlet Group is separated from the Point Hennequin Group by the intervening fault channel of Admiralty Bay.

Approximately 4 miles (6·4 km.) north of Ezcurra Inlet, at Admiralen Peak, a small post-intrusion outlier rests unconformably on the Upper Jurassic rocks (Plate Ic). Its age is uncertain but it may belong to this group.

Lavas were extruded from vents in the vicinity of the plugs at Point Thomas and Three Brothers Hill (Plate Id). These centres occur near the northern boundary fault and extend in a line along the length of King George Island. An eastward continuation of this line joins the probable later centre of Ternyck Needle.

2. *Age*

The plant fossils from the interbedded tuffs of this group are younger than Middle Cretaceous. Structural evidence indicates that this group pre-dates the Fildes Peninsula Group, and there is some support for a Middle Tertiary (Oligocene–Miocene) age for these beds (p. 17).

3. *Petrology*

The commonest lavas are hypersthene-augite-andesites, although basaltic andesites and augite-andesites are included. In general, the hypersthene-augite-andesites contain labradorite, augite and hypersthene phenocrysts set in a matrix of andesine microlites, octahedra of magnetite and variable amounts of interstitial glass. The plug of Three Brothers Hill is mainly composed of hypersthene-augite-andesite. Amygdales and veins of chalcedony, quartz, jasper and zeolite are common in all the rocks of this group.

4. *Stratigraphy*

a. *South Ezcurra Inlet.* Lavas, tuffs and agglomerates are well exposed along the southern shore of Ezcurra Inlet. The oldest rocks occur in the vicinity of Point Thomas. Near the centre of the south coast these are overlain unconformably by younger beds. The south Ezcurra Inlet succession is given in Table IV.

The sequence above the unconformity can be traced along the west coastal areas, while the sequence below the unconformity was measured at a rock bluff 3·5 miles (5·6 km.) south-west of Point Thomas. At the centre of the south coast of Ezcurra Inlet the massive lavas and tuffs (at the top of the succession) overstep eastwards on to the older rocks. Bibby (1961, p. 6) noted that the old surface has been water-worn and that the rounded hollows have been infilled by conglomerate and tuffaceous sand.

Primary structures have been affected by faulting but it appears that the volcanic rocks below the unconformity were extruded from centres at Jardine Peak and Point Thomas. Volcanic centres west of Ezcurra Inlet gave rise to the lavas forming the upper part of the succession. Plant remains have been found in thin sedimentary bands in the bedded lavas and tuffs at the western end of Ezcurra Inlet.

The dip of the upper part of the sequence varies from 5° to 10° to the east. Dips of the rocks beneath the unconformity are complicated by north-west to south-east trending faults. Adjacent to each of the three faults, dips are irregular and up to 54°. Westwards, away from the faulted area, the dip is outwards from the Jardine Peak plug. Plugs occur at Point Thomas, Jardine Peak and the offshore stack south from Point Thomas.

b. *Area south of Ezcurra Inlet.* Because rock exposures in this area are in general small and are often widely separated by glaciers, a detailed stratigraphical succession cannot be determined.

The stack immediately south of Point Thomas is composed of a lava flow with a slaggy top and base. To the south the flow is broken by a small plug of hypersthene-augite-andesite which exhibits fan-shaped columnar jointing in its upper part. Massive lavas and thin interbedded agglomerates crop out near the shoreline between the hyalo-andesite plug and Demay Point. These lavas are overlain, apparently unconformably, by horizontal lavas with interbedded pyroclastic rocks. Field evidence suggests that these beds belong to the same series of lavas and tuffs which contain plant fossils at Ezcurra Inlet.

TABLE IV

SUCCESSION AT SOUTH EZCURRA INLET
(after Bibby, 1961)

	ft.	m.
Massive lavas and tuffs	200	61
Brown-grey lava and tuff	50	15
Massive lavas and thin tuffs	150	46
Pink tuffs with lavas	400	122
Bedded lavas and tuffs	600	183
	∿∿∿∿	∿∿∿∿
Conglomerate	20	6
Red agglomerate	60	18
Andesite	8	2·4
Red and yellow tuffs	75	23
Lavas and tuffs	190	58
Tuff	70	21
Lavas and tuffs	125	38
Total thickness	1,948	593·4

Three Brothers Hill is a large volcanic plug situated west of Demay Point. An agglomerate adjacent to the hill attains a thickness greater than 40 ft. (12 m.). It appears to break through the andesite lavas exposed in the sea cliffs. A brown pseudobrecciated lava occurs at the base of the main flow and an amygdaloidal lava at the top of the underlying flow. The dips of these lavas suggest that they were extruded from a volcanic centre at or near the position of Three Brothers Hill.

D. Fildes Peninsula Group

1. *Field relationships*

This group is exposed at the south-west of the island on Fildes Peninsula (Fig. 7) and nearby Nelson Island. At the southern tip of the peninsula a fault brings the Jurassic lavas and pyroclastic rocks in the south against the Fildes Peninsula Group in the north. A parallel fault, just over 1 mile (1·6 km.) to the south, extends along the line of Fildes Strait and brings the Fildes Peninsula Group of Nelson Island against the up-faulted block of Jurassic rocks (Plate IIa).

An outlier of the Fildes Peninsula Group rests unconformably on Jurassic volcanic rocks near Fildes Strait, and small inliers of Jurassic rocks are exposed through the agglomerates west of Ardley Island.

2. *Age*

Plant fossils from the thin interbedded sedimentary rocks of this group are almost certainly younger than Middle Cretaceous. The group probably post-dates the Ezcurra Inlet Group and pre-dates the pre-Pliocene Point Hennequin Group. There is some evidence for the Middle Tertiary age of these beds (p. 17).

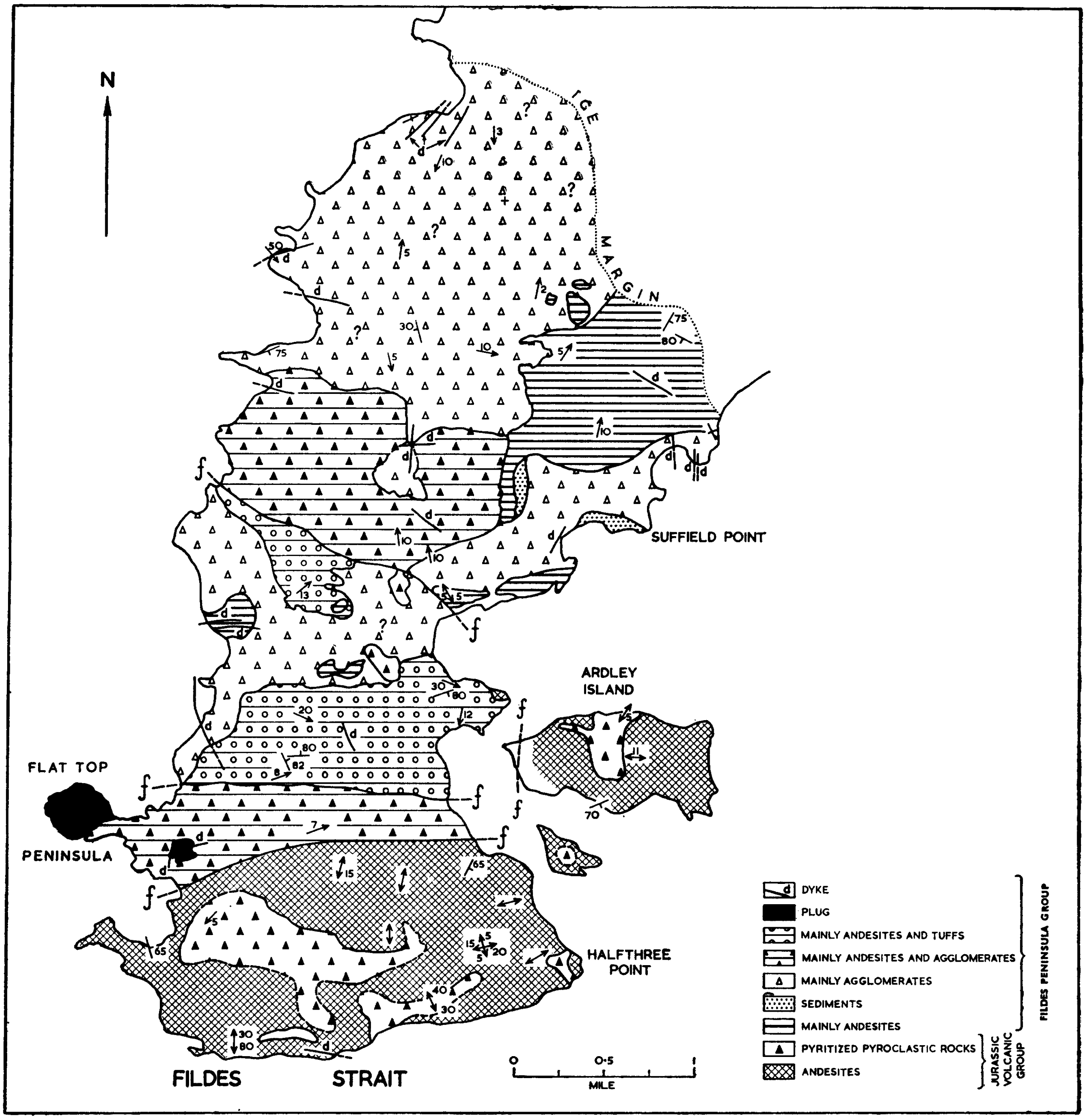

FIGURE 7
Geological map of Fildes Peninsula.

3. *Petrology*

Basaltic andesites are the commonest lavas but occasional flows of hypersthene-augite-andesite and augite-andesite are also present. Lavas were extruded from vents north of the Jurassic rocks. Therefore, they are separated both in geographical positioning and petrology from the hypersthene-augite-andesites which were extruded south of the central Mesozoic belt.

Two textural varieties of basaltic andesite have been recognized by Hawkes (1961): the porphyritic and intergranular types. The latter occurs mainly in volcanic necks and dykes and is composed of a groundmass of labradorite microlites, pyroxene and iron ore, in which are set occasional microphenocrysts of labradorite and augite. The commoner porphyritic types contain large phenocrysts of zoned labradorite and an intergranular matrix of labradorite microlites, pyroxene granules and iron ore. A typical intergranular basaltic andesite (G.435.1) occurs within the andesites at the base of the succession. Intergranular varieties have also been reported by Hawkes (1961, p. 15) from the plug of Flat Top Peninsula and the lavas high in the succession north-east of Horatio Stump.

At the summit of the cliffs adjacent to Suffield Point there is an outcrop of a porphyritic variety of basaltic andesite (G.449.1), in which pyroxene phenocrysts are more abundant than in the porphyritic rock from Horatio Stump. Scattered serpentinized olivine crystals are present in the matrix.

4. *Stratigraphy*

Rocks of the Fildes Peninsula Group are subdivided by unconformities into at least four stratigraphical sub-divisions: predominant andesites, sedimentary rocks, agglomerates, and andesites with interbedded tuffs (Table V). Correlation of the sub-divisions across faults is complicated by the paucity of distinctive marker horizons and by the attendant possibility of the occurrence of similar rock sequences in different parts of the succession. Many local unconformities are present and important contacts are often obscured by rock debris.

TABLE V

GENERALIZED SUCCESSION FOR THE FILDES PENINSULA GROUP

Andesites and interbedded tuffs	Basaltic andesites with interbedded tuffs, contact agglomerates and thin sedimentary beds containing plant remains
Agglomerates with subordinate lavas and tuffs	Agglomerates with occasional basaltic andesites Agglomerates alternating with basaltic andesites Agglomerates with occasional basaltic andesites
Sedimentary rocks	Sedimentary rocks including tuffaceous sandstone, mudstone and thin carbonaceous laminae
Andesitic lavas	Basaltic andesites with thin interbedded pyroclastic rocks

a. *Andesitic lavas.* Predominant andesitic lavas with interbedded pyroclastic rocks, which attain a thickness of at least 600 ft. (183 m.), crop out to the north and inland from Suffield Point. The base of the andesites is not exposed. The top appears to be unconformable against succeeding agglomerates and alternating agglomerates and lavas. Three small inliers of andesite occur north-west of the main andesite outcrops. The rock forming the inliers is flow-banded, has a rough fracture and exhibits labradorite microphenocrysts arranged sub-parallel to the bedding planes; it is overlain by 120 ft. (37 m.) of fine-grained porphyritic basaltic andesite.

b. *Sedimentary rocks.* The actual basal contact of the sedimentary rocks is not clearly exposed but their field distribution indicates that they rest unconformably on the predominant andesites. They are covered unconformably by agglomerates and interbedded lavas. Small areas of sedimentary rocks crop out approximately 0·75 miles (1·2 km.) north of Suffield Point and at Suffield Point itself, where a good cliff section is exposed. The succession comprises sandstone, mudstone, shale and thin coals. At Suffield Point the beds are over 50 ft. (15 m.) thick but within a short distance to the west they are overstepped by agglomerates interbedded with lavas. Unrecognizable carbonaceous fragments are commonly dispersed throughout these beds. The sedimentary rocks are intruded by a thin discontinuous sill of andesite.

c. *Agglomerates with subordinate lavas and tuffs.* Agglomerates, volcanic breccias and volcanic debris, much of which appears to have been derived from coarse pyroclastic rocks, extend from Suffield Point westwards to Gemel Peaks and northwards to the boundary glacier. The total thickness cannot be estimated because exposures are poor, numerous minor unconformities are present and the area is cut by several faults. Basaltic andesites occur throughout the succession but they are subordinate to the agglomerates.

The pyroclastic rocks vary from fine tuffs to volcanic breccias and coarse explosive agglomerates with bombs up to several yards in diameter. The fragments are almost exclusively volcanic and are mainly of andesitic lavas. Near Suffield Point agglomerates unconformably overlie the sedimentary series but farther west the predominant agglomerates appear to rest unconformably on andesites. At Gemel Peaks agglomerates with interbedded lavas rest on possible representatives of the underlying andesite sub-division; these overstep westwards on to pyritized rocks which are very similar to the Jurassic pyroclastic beds. In this part of Fildes Peninsula the agglomerates seem to be overlain, again unconformably, by andesites with thin tuffs and agglomerates. West of Ardley Island a similar series of andesites and tuffs contains thin plant-bearing sedimentary bands. Alternating andesites and agglomerates crop out east of Flat Top Peninsula along a fault block separating the agglomerates and andesite-tuffs in the north from the Jurassic lavas in the south; they grade laterally westwards into agglomerates.

The dips of these beds indicate that they were erupted from volcanic centres near Flat Top Peninsula and Horatio Stump. A small lens of sinter crops out between the two plugs.

d. *Andesites and interbedded tuffs*. North-east of Gemel Peaks, andesites with interbedded tuffs and contact agglomerates appear to rest unconformably on the predominant agglomerates. A similar sequence rests unconformably on agglomerates which crop out west of Ardley Island. The southern boundary is faulted against alternating andesites and agglomerates. Adjacent to Fildes Strait an outlier of andesites and interbedded tuffs lies unconformably on the Jurassic volcanic rocks. This sub-division post-dates, at least in part, the predominant agglomerate sub-division. The lavas dip away from the Flat Top Peninsula extrusive centre. North-east of Flat Top Peninsula thin sedimentary beds (Plate IIb) occur between lavas, and two of these have yielded a flora which is mainly composed of leaves.

E. Point Hennequin Group

1. *Field relationships*

The Point Hennequin Group crops out on the eastern side of Admiralty Bay between Point Hennequin and Lussich Cove. The rocks shelve beneath the ice dome to the east and are limited to the south and west by the waters of Admiralty Bay (Fig. 3). Contacts with rocks of other age groups are not exposed. Admiralty Bay separates the Point Hennequin Group from the Ezcurra Inlet Group. Structural observations at the head of the bay support the conclusion that the western boundary is down-faulted against the Ezcurra Inlet Group. A fault zone passes along Lussich Cove and brings the Point Hennequin Group in the south against the Jurassic volcanic rocks in the north. Westwards from Point Hennequin the adjacent outcrops are of Pliocene–Recent age, but the field relationships between the two groups are obscured by the extensive intervening ice cover.

2. *Age*

Trachyandesites are characteristic both of this group and Pliocene–Recent volcanic rocks elsewhere in the South Shetland Islands. Plant fossils from the associated tuffaceous rocks are almost certainly later than the Middle Cretaceous and the group is superseded by the Pliocene Lions Rump Group. There is some evidence for a Middle Tertiary age for these beds (p. 17).

3. *Petrology*

The petrology of the Point Hennequin Group has been intensively studied by Hawkes (1961), who noted that the lavas are predominantly hypersthene-augite-andesites similar to those from the Ezcurra Inlet Group. In common with the Pliocene–Recent lavas of Deception Island, this group is characterized by thick trachyandesite lava flows. Augite-andesites and augite-hyalo-andesites also occur at Point Hennequin. The latter rock is dark grey-black in colour with a vitreous lustre on the fracture surfaces. The glomeroporphyritic clusters of augite and hypersthene are frequently so large that they are easily visible in the hand specimen. Other rocks are augite-andesites, trachyandesites and agglomerates. Many amygdaloidal cavities within the lavas have been infilled by quartz, chalcedony, jasper and zeolite. Thin veins of all these minerals, except chalcedony, are numerous at the base of the south-facing scarp near Point Hennequin.

4. *Stratigraphy*

The succession near Point Hennequin (Table VI) is 1,260 ft. (384 m.) thick, of which 240 ft. (73 m.) are not exposed. It comprises at least eleven different lavas and one agglomerate.

The trachyandesite at Point Hennequin thins laterally to the east and south, and cannot be traced

TABLE VI

SUCCESSION NEAR POINT HENNEQUIN

	ft.	m.
Augite-andesite	100	30·5
Augite-andesite	85	25·9
Hypersthene-augite-andesite	80	24·4
Chloritized tuffaceous andesite	15	4·5
Andesite	100	30·5
Hypersthene-augite-hyalo-andesite	70	21·3
Banded agglomerate	170	51·8
Trachyandesite	120	36·6
Unexposed	90	27·4
Augite-andesite	100	30·5
Friable andesite	20	6·1
Unexposed	150	45·7
Hypersthene-augite-hyalo-andesite	70	21·3

for more than 300 yd. (274 m.). Another lens-shaped trachyandesite flow occurs at the same horizon on the exposure north of Point Hennequin. Numerous large bombs are embedded in the brown tuffaceous matrix of the agglomerate. Fragments are of andesite, trachyandesite, red tuff and what appears to be altered granodiorite. Small elliptical infilled vesicles of carbonaceous material are dispersed throughout the matrix. The chloritized tuffaceous andesite and the friable andesite are contact features of the succeeding lava flow. 300 ft. (91 m.) of porphyritic grey-green andesite are exposed on the south side of Lussich Cove; this is underlain by a conglomerate containing large water-worn pebbles and overlain by the hypersthene-augite-andesite of the nearby nunatak.

Plant-bearing sedimentary rocks are present in moraines along the entire length of the outcrop of the Point Hennequin beds. The extent and direction of flow of the glacier north of Lussich Cove indicates that the plant beds occur immediately beneath the lavas of the nearby nunatak. No unconformity can be detected between the andesites above and below the inferred position of the plant beds.

Primary dip directions of the lavas adjacent to Lussich Cove show that they were extruded from a volcanic centre in the vicinity of Ternyck Needle. The general dip is 6–15° to the north-east. An open westward-pitching anticline is located between the Point Hennequin exposure and the one to the south, while an open syncline occurs north of Point Hennequin.

VII. PLIOCENE–RECENT ROCKS

THE Pliocene–Recent rocks are in part olivine-basalts and are subdivided into the Pliocene Lions Rump Group and the Pleistocene–Recent Penguin Island Group. Lavas were extruded from vents along the south coast of King George Island between Cape Melville and the mouth of Admiralty Bay. The line of extrusion is roughly parallel to the trend of earlier fault and shatter zones and is apparently related to a post-Miocene crustal rupture. The olivine-basalts are expressions of a distinct phase of volcanic activity which was initiated in the Pliocene and continued until Recent times. Hypersthene-augite-andesites and augite-andesites are also present but these are generally subordinate to the olivine-basalts.

A marine conglomerate in the Pliocene Lions Rump Group contains fossils similar to those from the Pliocene-Pleistocene Pecten Conglomerate of Cockburn Island.

A. Lions Rump Group

1. *Field relationships*

Outcrops of the Lions Rump Group extend over a small area, west of King George Bay, between Lions Rump and Low Head (Fig. 3).

To the north-west and west these rocks are separated from the exposure of the Point Hennequin Group by over 7 miles (11 km.) of glacier-covered terrain. The contacts between the two groups lie under the surface of the ice dome on the east side of Admiralty Bay. This group is delimited in the south by Bransfield Strait and in the west by King George Bay. Westward from King George Bay the volcanic rocks are of Pleistocene–Recent age.

East of Low Head olivine-basalts of the Penguin Island Group overlie the Lions Rump Group unconformably.

2. *Age*

Macro-fossils from the marine conglomerate are very similar to those from the Pliocene–Pleistocene Pecten Conglomerate of Cockburn Island. Recent work on the Foraminifera is near completion and preliminary results indicate that they are Pliocene in age; some of the fossils appear to have been re-worked and of Cretaceous age (personal communication from R. J. Adie).

At Lions Rump the lavas are overlain by a Pleistocene–Recent tuff and feldspar-conglomerate; near Low Head Pleistocene–Recent lavas rest unconformably on the Lions Rump Group.

3. *Petrology*

The lowest lava (G.520.1) is an augite-andesite which is exposed at Lions Rump. It is overlain by hypersthene-augite-andesite (G.524.1) and olivine-basalt flow lavas. The olivine-basalt is 150 ft. (46 m.) thick and extends from Lions Rump southward to Low Head. A highly altered light-coloured agglomerate occurs at the top of the exposed succession.

4. *Stratigraphy*

At the base of the exposed succession (Table VII) there is a vesicular andesite (Fig. 8), which is overlain at Lions Rump by an augite-andesite that crops out in the sea cliffs. An agglomerate rests unconformably

Table VII
SUCCESSION AT LIONS RUMP

	ft.	m.
Acid agglomerate with thin tuffs	150	45·7
Andesitic agglomerate	120	36·6
Pecten Conglomerate	30	9·1
Olivine-basalt	150	45·7
Hypersthene-augite-andesite	50	15·2
Agglomerate with thin tuff and carbonaceous sediment	20	6·1
Augite-andesite	20	6·1
Vesicular andesite	12	3·6
Total thickness	552	168·1

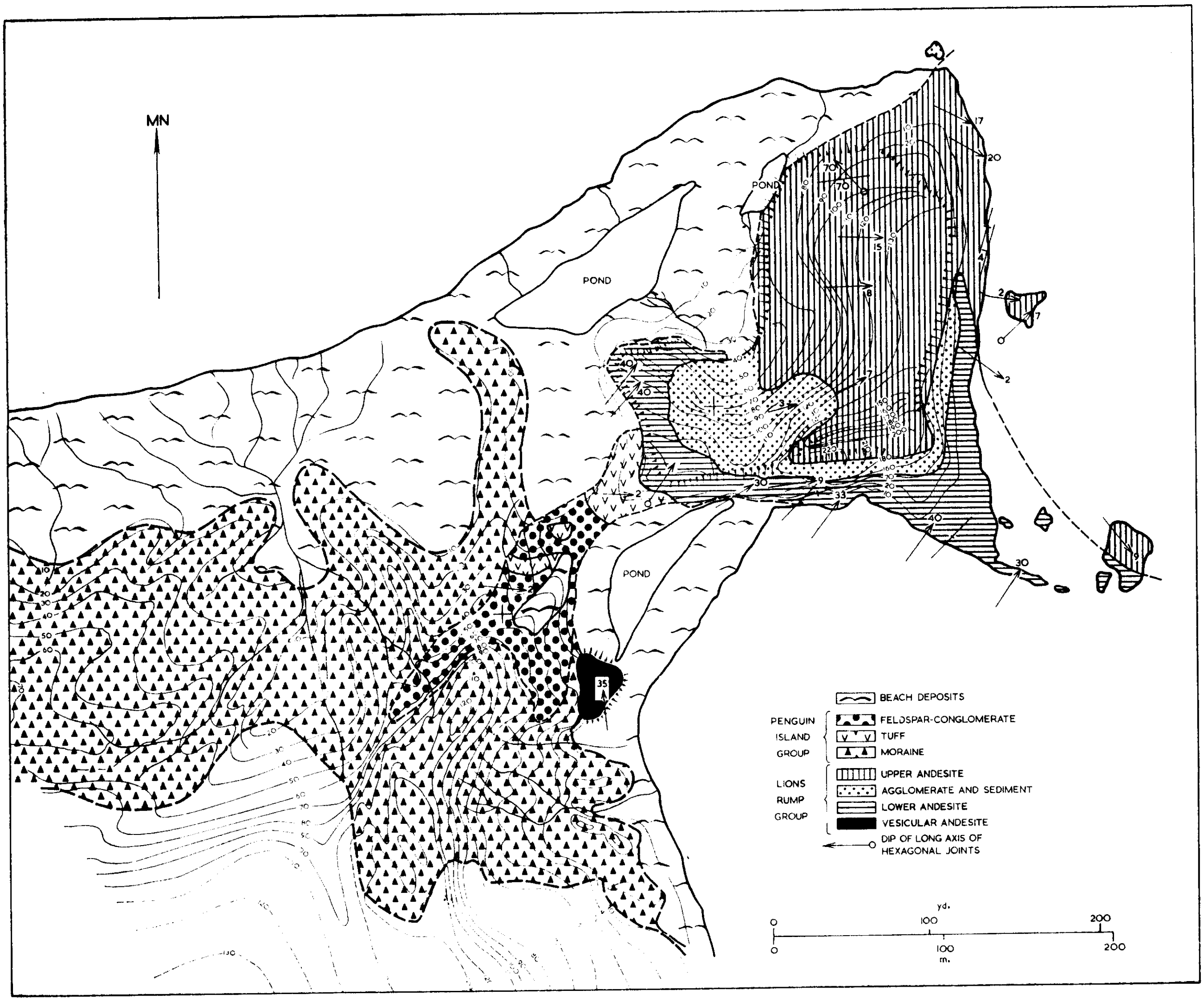

FIGURE 8
Geological map of Lions Rump.

on the lower augite-andesite; it contains interbedded, almost horizontal, water-lain tuffaceous sedimentary bands with thin carbonaceous laminae. The succeeding hypersthene-augite-andesite is covered, in turn, by olivine-basalt. Immediately south of Lions Rump, the olivine-basalt exhibits excellent columnar jointing (Plate IIc).

A marine conglomerate containing *Pecten* rests with slight unconformity on the olivine-basalt and grades upwards and laterally southwards into andesitic agglomerate. Water-worn boulders, cobbles and pebbles accompanied by a varied fauna occur within the matrix of the conglomerate.

Near Low Head, 10 ft. (3 m.) of tuffaceous sandstone rest on andesitic agglomerate. Immediately above this bed, at the top of the cliffs, is a light-coloured agglomerate with thin interbedded tuffs near the base. Enclosed fragments are nearly all composed of agglomerate or breccia and they are difficult to distinguish from the remainder of the rock. Occasional fragments and particles of red tuff, chloritized tuff and olivine crystals are dispersed throughout the cryptocrystalline matrix of this rock.

B. PENGUIN ISLAND GROUP

1. *Field relationships*

The volcanic rocks of the Penguin Island Group are exposed in the south coastal areas between Cape Melville and Vauréal Peak. Melville Peak and Penguin Island are the sites of vents which occupy a position south of the Jurassic volcanic rocks. The lavas at Cape Melville and Three Sisters Point were extruded from these centres (Fig. 3). East of Low Head, lavas of the Penguin Island Group rest unconformably on the Lions Rump Group and are broken by a Recent ash cone. Farther to the south-west this series of lavas infills the volcanic vent of Vauréal Peak. A small Pleistocene–Recent outlier of red tuff and unconsolidated feldspar-rich conglomerate rests unconformably on the moraines of Lions Rump (Fig. 8).

2. *Age*

The Penguin Island volcanic cone is composed of unconsolidated ash, scoria and occasional bombs; it is almost completely unmodified by weathering and marine erosion, and is probably not much more than 100 years old. A small volcanic plug occurs within the crater. Lavas of the Penguin Island Group rest unconformably on the Pliocene rocks. At Cinder Spur they are broken by an ash- and scoria-filled vent which is more weathered and is therefore probably older than the Penguin Island ash cone.

3. *Petrology*

Olivine-basalts from Penguin Island, Three Sisters Point, Cape Melville and Melville Peak have been described by Hawkes (1961). He has noted that "they are usually porphyritic with subhedral crystals of olivine and diopsidic augite". Olivine crystals are less abundant in the coarser-grained rocks which usually possess a groundmass of plagioclase microlites, pyroxene granules and iron ore. A hemicrystalline variety from Cape Melville (G.31.1) contains large olivine phenocrysts and clusters of diopsidic augite crystals set in a groundmass of feldspar microlites, augite and interstitial glass.

A dyke at Penguin Island contains augite and occasional phenocrysts of olivine and hypersthene. This rock is very similar in mineral content to the lowest lava flow (G.492.1) exposed on the mainland opposite Penguin Island.

4. *Stratigraphy*

Correlation of rock exposures is difficult in this area since they are often 5–10 miles (8–16 km.) apart and are composed of unfossiliferous volcanic rocks erupted from different vents.

The ash cone of Penguin Island shows little signs of weathering and the associated lavas probably occupy a higher position in the sequence than the lavas at either Cape Melville or Low Head. At Melville Peak and Trowbridge Island (Fig. 3) volcanic plugs mark the former centres of eruption for a lower series of olivine-basalts and interbedded agglomerates. The dip of this series is outwards from the Melville Peak centre; over 600 ft. (183 m.) of nearly horizontal basalts with interbedded contact pyroclastic rocks are unconformable in the north-west and faulted in the south-east against the lower series. To the east of Cape Melville the rocks are associated with ash cones which pre-date only the lower raised beaches. This is also the case at Penguin Island where two lavas, respectively of andesite and olivine-basalt, were extruded from a centre in the vicinity of the present Penguin Island ash cone.

Between Low Head and Vauréal Peak the sequence is composed of olivine-basalts and andesite lava flows with thin contact volcanic breccias and agglomerates. Fifteen lavas, subdivided by minor unconformities, are exposed in the cliff section at Martins Head. West of Low Head the base of this succession of volcanic rocks rests unconformably on Pliocene agglomerates. Here the lavas are broken by an ash- and scoria-covered vent but farther west, at Vauréal Peak, they pre-date and flow into a small ash cone (Fig. 3). At Lions Rump water-lain red and green tuffs are banked against the cliffs of Pliocene andesites and rest unconformably on moraine. Within a distance of 30 yd. (27·5 m.) to the west these tuffs grade laterally into brown-weathering unconsolidated feldspar-conglomerate (Fig. 8).

VIII. MORAINES AND RAISED BEACHES

MORAINES and raised beaches are common over the whole of King George Island and provide evidence of a last stage of glacial retreat roughly contemporaneous with a drop in the relative sea-level.

On the steeper rock exposures, such as those of the Admiralty Bay and Potter Cove areas, the moraines extend for several miles away from the present ice margin. Recessional moraines, representing three main stages of glacial retreat, cover almost the entire area of Buddington Peak and the Three Brothers Hill peninsula. Glacial debris also occurs over almost the whole of Keller Peninsula (Fig. 3) and the Point Hennequin area, where *eight* distinct stages of recession are apparent. There is similar evidence for the former extent of the ice cap at numerous other localities, but in those areas which have been affected by the 170–200 ft. (52–61 m.) and 90–110 ft. (27·5–33·5 m.) marine platforms only the late recessional moraines are preserved.

The highest of the flat-lying topographical platforms occurs at approximately 500 ft. (152 m.) on Flat Top Peninsula and Cape Melville. In the latter area, the moraine-covered platform is cut in flat-lying bedrock, and therefore it cannot definitely be ascribed to marine erosion. Flat Top Peninsula, on the other hand, is a volcanic plug and its flat upper surface appears to have been caused by marine erosion. No regional platform has been reported at this level. Perhaps local plug elevation took place after the formation of the platform. Nick marks occur at a height of approximately 200 ft. (61 m.) on the encircling cliffs and they can be correlated with the 170–200 ft. (52–61 m.) marine platform which extends from Flat Top Peninsula northwards to within 400 yd. (366 m.) of the present ice margin where it passes beneath end moraines. The indicated glacial re-advance may well have been caused by the re-establishment of relative fall in sea-level and the attendant cessation of marine erosion at the glacier snout. Loose debris, composed mainly of angular volcanic rocks, covers the platform (Plate IId). Periglacial erosion processes are operative, and mud flows and creep are probably effective in moving fragmental material across the platform towards the sea.

Although the 170–200 ft. (52–61 m.) marine platform does not occur on the sheltered coasts, Ferrar (1962) has noted that the 170–190 ft. (52–58 m.) beaches of Barton Peninsula apparently rest on a flat-lying plane. At South Spit on Barton Peninsula, beaches occur 1·5 miles (2·4 km.) from the ice margin and up to 250 ft. (66 m.) above sea-level, but around Admiralty Bay and Three Brothers Hill these higher-level beaches are not represented. In these areas the ice cover may have extended down to the sea during the formation of the higher raised beaches. Alternatively, the older beaches could have been destroyed by normal weathering processes.

There are traces of a marine platform at approximately 100 ft. (30·5 m.) on North Foreland, False Round Point and Low Head (p. 6). A raised beach occurs at the same height along most of the ice-free areas on the sheltered south coast. This beach slopes down in several successive stages to a 50 ft. (15 m.) beach which, on Keller Peninsula, terminates abruptly at a distance of 0·4 miles (0·6 km.) from the present ice margin. Below this level, fourteen minor stages have been recognized at Ardley Island, but only the 30, 17 and 7 ft. (9·1, 5·2 and 2·1 m.) beaches are preserved at Potter Cove.

IX. BASIC DYKE INTRUSION

BASIC dykes are associated both with the major intrusions and with the extrusion of volcanic rocks throughout the succession. Andesitic dykes of Jurassic age are generally altered by metasomatism. A dyke intruding the agglomerates on Barton Peninsula is altered by pyritization along the narrow chilled margin. This dyke is up to 3·5 ft. (1·1 m.) across and is vertical with a trend gently concave to the west at about 350° mag. The basic dykes at Crépin Point are connected with the intrusion of the quartz-gabbros and are described on p. 12.

Other dykes which cut Jurassic volcanic rocks exhibit few signs of metasomatism and probably post-date the plutonic intrusions. Such is the case at Ullmann Spur, where a main west–east trending microdiorite dyke has minor dyke and sill offshoots, and is offset by a series of small transverse faults (Fig. 3). A narrow andesite dyke which is intruded along the foot wall of the main pyrite lode of Keller Peninsula contains large hornblende crystals. At Fildes Peninsula the andesites with interbedded tuffs post-date earlier dykes and are intruded by a later dyke set. The younger dykes are roughly contemporaneous with the intrusion of the Horatio Stump plug and are cross-cut and displaced by joints trending 140° mag.

Post-Pliocene dykes of olivine-basalt trend approximately west–east and cut the Pliocene volcanic rocks of Low Head and the Recent ash cone of Penguin Island (Fig. 3).

X. STRUCTURE AND TECTONICS

1. *Folding*

A series of cross-cutting folds arranged about north–south and west–east axes affects the Jurassic andesites of Fildes Peninsula, but the overlying pyroclastic rocks are not so intensely folded. Away from south Fildes Peninsula the folding is generally very open and a dip of 20° is rarely exceeded. However, in the vicinity of volcanic centres or faults high dips are occasionally present. Examples of the former are at Melville Peak and Flat Top Peninsula, and of the latter at south Ezcurra Inlet, Dufayel Island and the southern part of Precious Peaks.

On Barton Peninsula a zone of low-grade mineralization occurs above a gently folded open trough, while higher grades with increased pyrite emplacement are present above the site of a dome. Consequently, such structures may be closely connected with updoming by the Noel Hill plutonic intrusion (Fig. 3).

2. *Jointing*

The high intensity of shattering and jointing in the Jurassic volcanic rocks is in sharp contrast to the relatively undisturbed post-Jurassic volcanic rocks (Fig. 9). Steeply dipping joints striking 015°, 132° and 099° mag. are only represented in rocks older than the main intrusions, but those which strike 055° to 060° mag. can be traced throughout all the stratigraphical units. In northern Admiralty Bay the latter set is parallel to the main fault zone and is accompanied by joints which strike 172° mag., parallel to faults inferred along the length of the bay. This linear correlation of joints with the main fault zone is more marked in the Jurassic volcanic rocks. Flat-lying joints striking 130° mag. and dipping at 3–10° to the north are characteristic of the Jurassic rocks.

The four main joint directions recognized in Cretaceous–Recent rocks strike in directions 123°, 073°, 150° and 055° mag. with dips varying from 80 to 90°. The directions 123° and 073° mag. are closely connected with the line of Quaternary volcanic centres.

Joints sub-parallel to bedding surfaces, such as those affecting the trachyandesites of Point Hennequin, appear to have been initiated during primary cooling and do not exhibit regional trends.

3. *Epeirogenic movements*

The Pliocene rocks of King George Island and the northern Graham Land area contain marine horizons. During this period there was a relative submergence of the land in north-west Antarctica.

The present height of the Lions Rump marine conglomerate is lower than the late Pleistocene–Recent platform. Between Pliocene and Pleistocene–Recent times relative sea-level rose in the King George Island area, but in Pleistocene–Recent times relative sea-level fell both in the Graham Land area and in the South Shetland Islands.

4. *Faulting*

A major fault zone, with an upthrow to the north, brings Jurassic rocks against younger ones; it extends the length of King George Island from the east coast through Lussich Cove and along Ezcurra Inlet. The relative disposition of pre- and post-Andean Intrusive Suite volcanic rocks west of Ezcurra Inlet suggests that this fault swings southwards through Potter Cove and then again westwards through Maxwell Bay and Fildes Strait. Alternatively, it is just possible that this fault zone extends between Ezcurra Inlet, Marian Cove and Fildes Strait. In this case Barton Peninsula would be up-faulted on the west of a complementary fault along Potter Cove. Pyritization in the shatter zones of associated faults, coupled with post-mineralization displacement across the main fault zone, indicates that at least two phases of movement occurred along these lines. Parallel faults which occur at Precious Peaks trend 062° mag. and dip at 70° south, and also along the main pyrite lode of Keller Peninsula.

Just over 1 mile (1·6 km.) north of Fildes Strait, rocks of the Fildes Peninsula Group are down-faulted to the north of the Jurassic andesites. This fault line marks the northern margin of the central up-faulted block of Jurassic volcanic rocks; it passes in a west–east direction across Fildes Peninsula and, to the east, it either swings north or is intersected by a fault which separates Ardley Island from the mainland.

A series of post-Middle Cretaceous faults crosses Fildes Peninsula north of the up-faulted Jurassic rocks. In the south they are roughly parallel to the main west–east fault but farther north they swing to trend north-west to south-east.

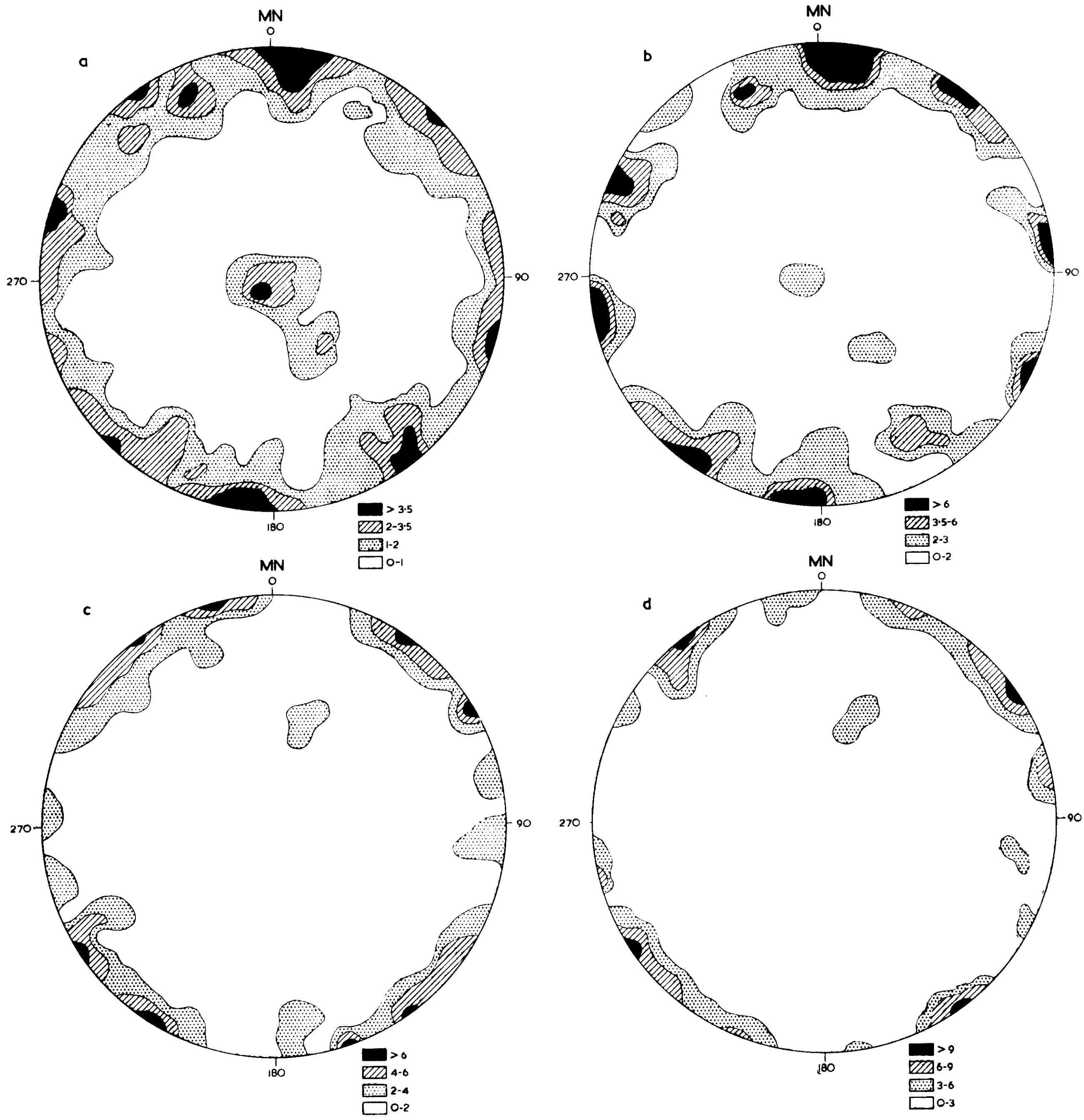

FIGURE 9

Stereographic plots of the poles of joints.

a. Joints in the Jurassic rocks.

b. Joints in the Jurassic rocks of northern Admiralty Bay.

c. Joints in the Pliocene–Recent rocks.

d. Joints in the Cretaceous–Miocene rocks.

On Barton Peninsula post-Jurassic shatter zones are both parallel to and across the north-east to south-west elongation line of Marian Cove.

Faults, which are complementary to the major west–east fault zone, extend along Admiralty Bay and intersect both Dufayel Island and south Ezcurra Inlet. A north-west to south-east trending fault crosses Dufayel Island and brings the Dufayel Island Group in the east against the Jurassic rocks in the west. Movement along many of these faults has occurred since Upper Jurassic times.

A Quaternary fault at Lions Rump trends 280° mag. and has an upthrow of 300 ft. (91 m.) to the north. A fault of the same age at Cape Melville trends 340° mag., dips at 60° to the north-east and has an upthrow to the south-west (Fig. 3).

In general, two main fault patterns may be recognized at King George Island: one trends parallel to the length of the island and the other is across it. Nevertheless, many of the faults are hidden by the snow cover and it seems quite likely that the detailed structure is far more complicated than the sparse evidence would suggest.

XI. PATTERN OF UPPER CRETACEOUS–RECENT VOLCANIC CENTRES

UPPER Cretaceous–Recent volcanic centres are situated on lines parallel to the trend of the arc of islands. The southernmost series of vents belongs to the Pliocene–Recent phase of activity (Fig. 10).

Eruptive centres of the Ezcurra Inlet Group occur adjacent to the fault system along the southern boundary of the Jurassic rocks. Farther east, along the same fault system, the volcanic centres are associated with lavas of the Point Hennequin Group. In the intervening period volcanic centres were formed near the boundary fault north of the Jurassic rocks.

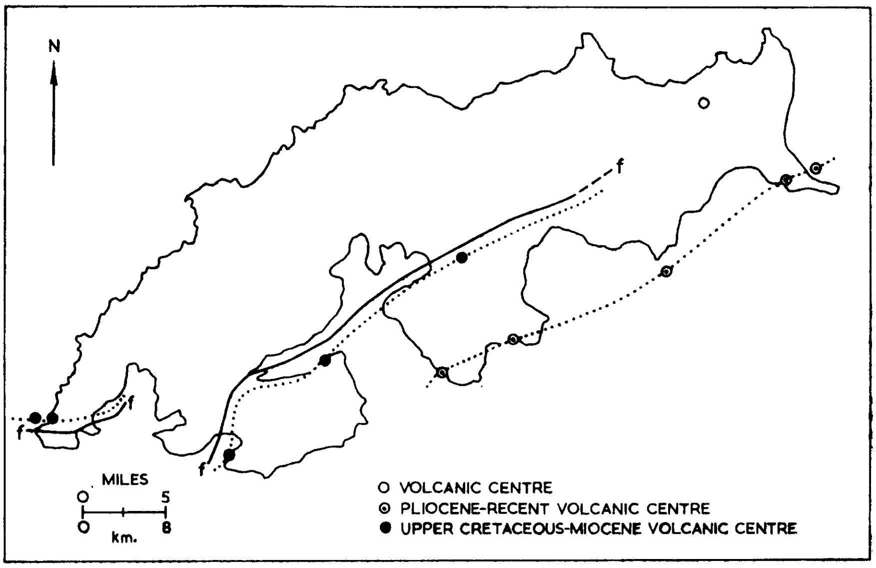

FIGURE 10

Map of King George Island showing the positions of post-Jurassic volcanic centres.

During Upper Cretaceous–Miocene times the centres of volcanic eruption appear to have migrated initially to the north and later towards the south-east. The Upper Cretaceous–Miocene centres that have been mapped are situated along the fault systems which bound the central area of older rocks, and it seems that volcanic eruptions have occurred along lines of crustal weakness associated with these faults.

In Pliocene times a linear eruptive belt became established to the south of the earlier centres of volcanic activity. The vents of Pliocene to Recent age are distributed along this belt. If, as seems likely, the mode of occurrence of the earlier centres is comparable to that of the Pliocene–Recent centres, then the entire pattern of vulcanicity may be governed by underlying fault systems. A line drawn through the Pliocene–

Recent vents follows the trend of the islands and joins laterally with the Recent volcano of Deception Island. The Quaternary eruptive centres of the South Shetland Islands are therefore restricted to a narrow zone fringing the northern margin of Bransfield strait. It is suggested that the vents extend along a fault complex and zone of crustal weakness associated with the subsidence of Bransfield Strait, an hypothesis first proposed by Nordenskjöld (1913).

XII. GEOLOGICAL HISTORY

THE oldest volcanic episode represented on King George Island is of Upper Jurassic age. At this time, a great thickness of basalts, andesites and pyroclastic material was extruded. Woods were buried by agglomerates in the Keller Peninsula area.

After the Jurassic vulcanicity had terminated these rocks were invaded by plutonic and hypabyssal intrusions of the Andean Intrusive Suite. Faults and shatter zones developed in the crustal rocks by displacement accompanying intrusion. Attendant pneumatolytic and hydrothermal processes altered the Jurassic lavas and caused mineral emplacement along the weaker zones. This was followed by uplift and weathering, processes which removed part of the Jurassic lava covering and exposed some of the earlier plutonic rocks at the surface.

Volcanic activity re-commenced in Upper Cretaceous–Miocene times. Leaves and plant fragments, derived from the vegetation growing in this area, were incorporated in the sediments of the Dufayel Island Group. Veins of quartz which intruded these rocks soon after their deposition were apparently contemporaneous with the final stages of plutonic and hypabyssal intrusion.

Subaerial weathering and earth movements, which may have caused a small area of Jurassic rocks to be thrust over the younger rocks of Dufayel Island, occurred before the commencement of the next phase of Upper Cretaceous–Miocene volcanic activity. This took place when a line of volcanic centres was initiated south of the present outcrop of Jurassic rocks and gave rise to the hypersthene-augite-andesites of the Ezcurra Inlet Group. Leaves and plant fragments from the local vegetation of this area were preserved in fresh-water sediments and covered by later lavas.

The Fildes Peninsula Group basaltic andesites and pyroclastic rocks were subsequently erupted from volcanic centres north of the present outcrop of Jurassic volcanic rocks. Water-lain sediments enveloped remnants of plants that grew in this area.

Volcanic activity was then transferred to the present south coastal areas when at least 1,500 ft. (457 m.) of predominantly hypersthene-augite-andesites were extruded. Parts of plants, including leaves of the southern beech (*Nothofagus*) were enclosed in fresh-water sediments and buried by later deposits.

Movement along earlier fault lines continued intermittently during the Cretaceous to the Pliocene, and resulted in the down-faulting of Upper Cretaceous–Miocene rocks against the Jurassic volcanic rocks and Andean plutonic intrusions. Subsequent erosion stripped off nearly all the later rocks from the central areas of the island.

By Pliocene or Pleistocene times the climate had become sufficiently frigid for the establishment of permanent ice caps; these have persisted until Recent times. The predominant olivine-basalts of Pliocene–Recent times were erupted from a line of vents situated along the south-east coast of the island. At least once during this time the sea covered part of the land and deposited a littoral conglomerate in which the remains of *Pecten* and other organisms were preserved.

Throughout the Pleistocene, vulcanicity continued spasmodically, terminating in Recent times after the formation of small ash and scoria cones. Also, in comparatively Recent times the ice cover has been slightly reduced and the sea-level has dropped.

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PLATE I

a. Noel Hill, Barton Peninsula, showing the steep south-facing rock scarp of granodiorite.

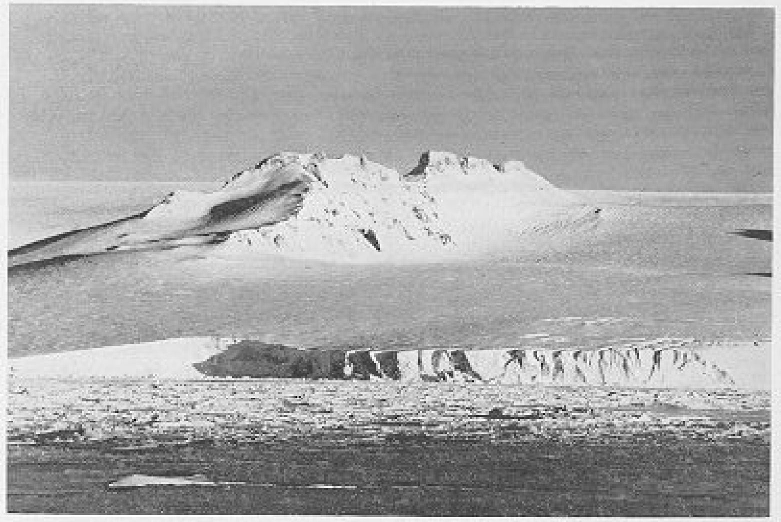
b. Quartz inclusions in silicified andesite adjacent to a quartz-pyrite lode at Barton Peninsula.

c. Post-Jurassic lavas resting unconformably on Jurassic volcanic rocks at Admiralen Peak.

d. The volcanic plug of Three Brothers Hill.

a

b



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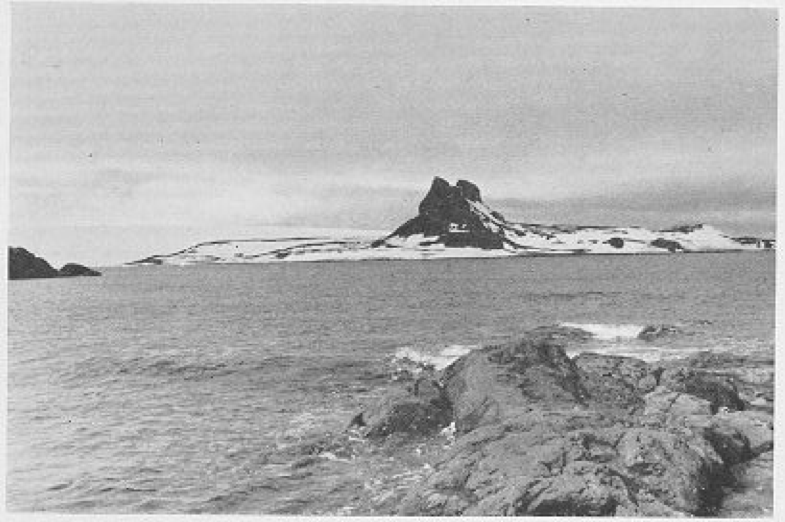

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PLATE I

PLATE II

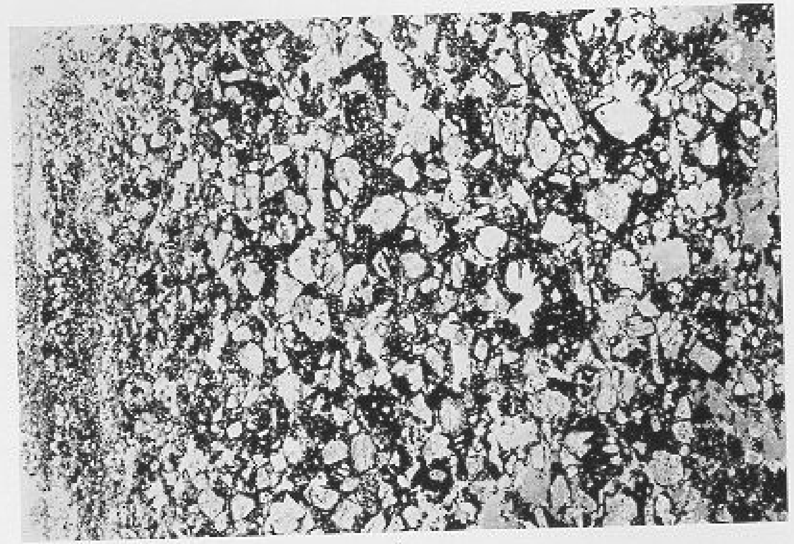
a. South Fildes Peninsula, showing the Fildes Peninsula Group in the middle distance and folded Jurassic andesites in the background.

b. Photomicrograph of a graded sedimentary rock from the plant-bearing beds of Fildes Peninsula (ordinary light; × 4).

c. Columnar jointing in olivine-basalt at Lions Rump.

d. The raised marine platform of Fildes Peninsula, showing the old cliff line.

a



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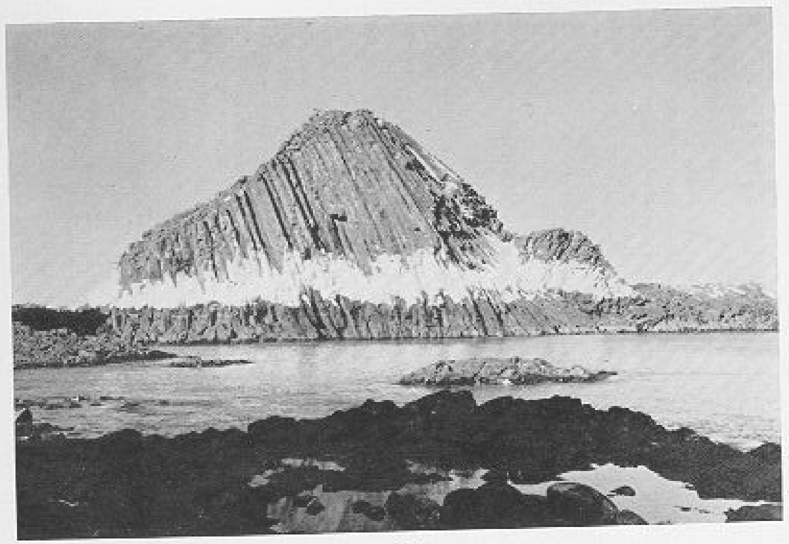

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PLATE II