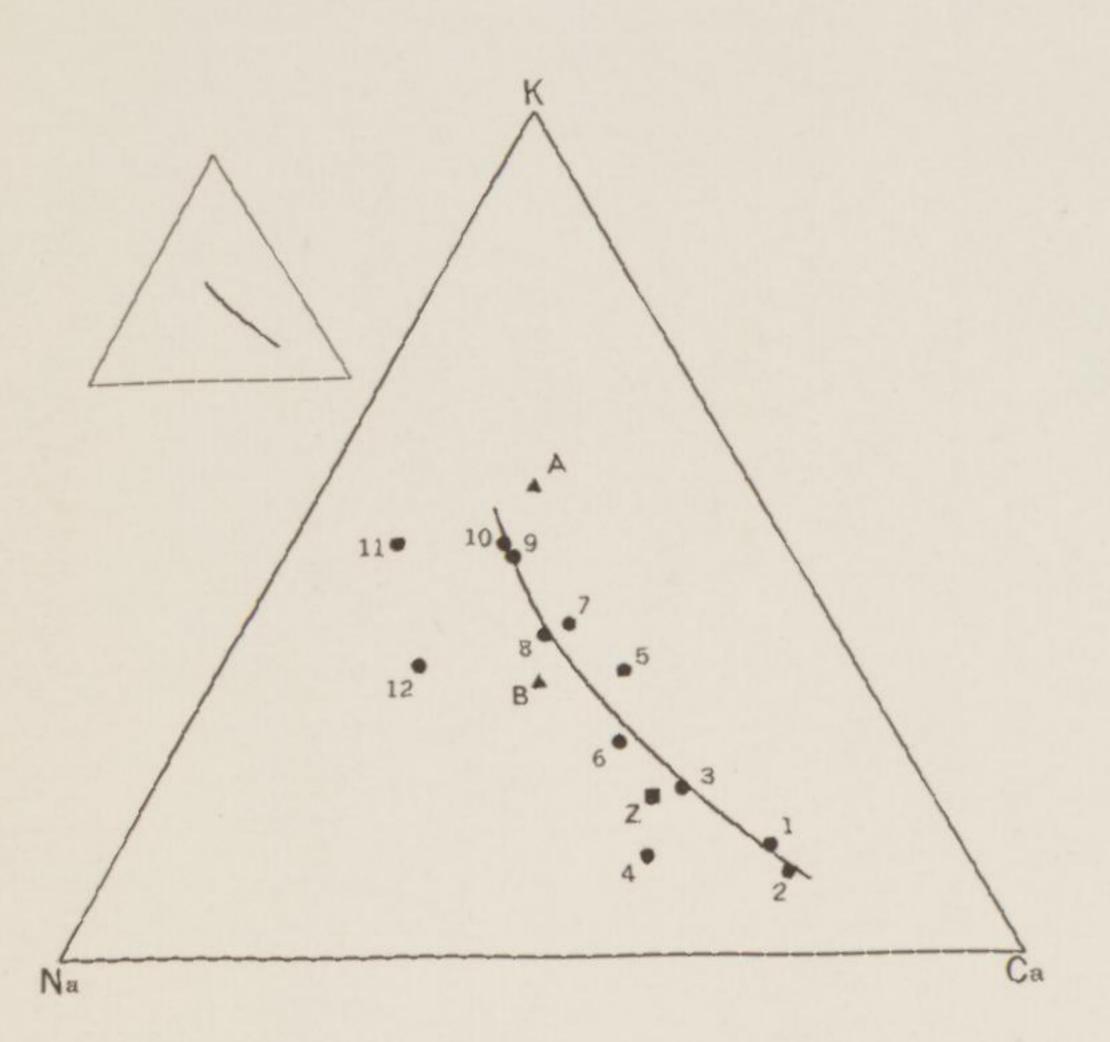


Fig. 1. Variation of Na<sub>2</sub>O + K<sub>2</sub>O versus SiO<sub>2</sub>, and CaO versus SiO<sub>2</sub>.<sup>1</sup>



similar variation diagram for the Andean Intrusive Suite in the Antarctic Peninsula (small diagram, upper left, after Adie, 1955)

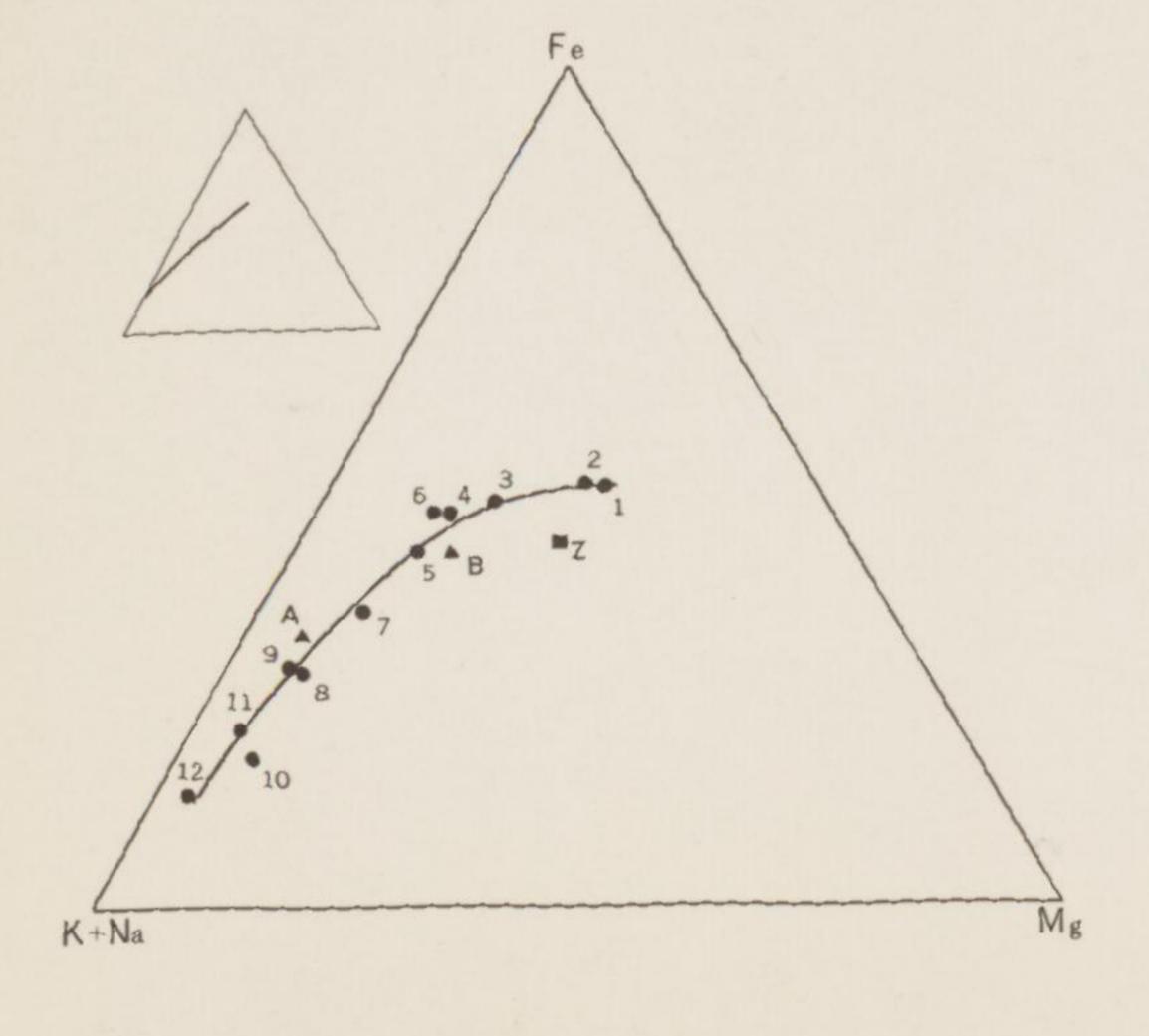


Fig. 3. Variation diagram K - Na - Ca compared to similar variation diagram for the Andean Intrusive Suite in the Antarctic Peninsula

Analyses were made by Japan Analytical Chemistry Research Institute. Explanations of the numbers and symbols in the diagrams are given in Table 2.

TABLE 1. RADIOMETRIC AGE DETERMINATIONS

Location	Lithology	Method and Material	Age (m.y.)	Ref.
Mt. Berger	Diorite	Rb-Sr Whole rock isochron	109±10	1
Mt. Brice	Quartz monzonite	Rb-Sr Whole rock isochron	103±6	1
Luck Nunatak	Granodiorite	Rb-Sr Whole rock isochron	103±5	1
Mt. Caywood	Granodiorite	Rb-Sr Whole rock isochron	102±2	1
Mt. Glowa	Quartz diorite	Rb-Sr Whole rock	102±6	1

## 1. Halpern (1967)

Pre-Jurassic

Bedrock exposure

Sources of base map:

University of Wisconsin

Scientific station

Sky-Hi-Mt. Hassage Region, Eastern Ellsworth Land, sketch map, 1:100,000,

University of Wisconsin; Area East of Eights Station, sketch map, 1:505,244,

Ice-flow lines

Amygdaloidal andesite flows with interbedded shale

Predominantly felsic volcanic rocks (dacite, in part

Eights Station

TABLE

. INDEX FOR FIGURES 1, 2, AND 3
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No. an	d sy	mboli	Sample No.	Lithology	Location
1	•	0	APT 44	Andesite dike	Cheeks Nunatak
2	•	0	66-157	Diorite	Merrick Mountains
3		0	66-154	Quartz diorite	Mt. Berger
4	•	0	EE 931	Granodiorite	Mt. Hassage
5		0	66-175	Quartz monzonite	Thomas Mountains
6		0	66-217	Granodiorite	Quilty Nunataks
7		0	EE 780	Quartz monzonite	Thomas Mountains
8	•	0	66-1	Granodiorite	Weather Guesser Nunataks
9		0	66-19	Quartz monzonite	Mt. Trimpi
10	•	0	APT 51	Quartz monzonite	Merrick Mountains
11		0	66-34	Aplite dike	Mt. Trimpi
12		0	EE 603	Rhyolite porphyry	Mt. Boyer
A	A	۵	APT 10	Dacite	Mt. Rex
В	4	Δ	APT 41	Dacite	Cheeks Nunatak
Z		0	EE 604	Olivine basalt	Merrick Mountains

A a = felsic volcanics; = = olivine basalt flow.

TABLE 3. GEOLOGIC HISTORY OF EASTERN ELLSWORTH LAND

Age	Rock Units	Events
Recent		Partial deglaciation
Pleistocene		Continental glaciation; alpine glaciation
Late Tertiary	Olivine basalt flows	Arching and block faulting of post-Andean peneplair
Tertiary		Development of post-Andean peneplain
Middle Cretaceous	Andean Intrusives	
Early Cretaceous	Mafic dikes	
		Orogeny, folding of strat- ified rocks
Jurassic	Clastic sedimentary rocks; felsic vol- canics, andesite	Geosynclinal deposition; volcanism

# Geology of Eastern Ellsworth Land

### T.S. Laudon<sup>1</sup>, L.L. Lackey<sup>2</sup>, P.G. Quilty<sup>3</sup>, and P.M. Otway<sup>4</sup>

## Introduction

The geology of eastern Ellsworth Land is closely related to that of the Mesozoic to Cenozoic mobile belt of the Antarctic Peninsula and Tierra del Fuego. Similarities in the volcanic and plutonic rocks, stratigrap paleontology, sedimentary petrology, and structural geology have been recorded.

The mountains of eastern Ellsworth Land were dis-Merrick Mountains from a distance of 190 to 225 km equally with a Jurassic or a Cretaceous age. He further on November 23, 1935 (Ellsworth, 1936, p. 9). The entire area covered by this map was photographed by the Ronne Antarctic Research Expedition on flights November 21, 1947, and December 23, 1947 (Ronne, 1949). The Ellsworth Land Traverse of 1961-1962 passed through this region, making brief stops to ex-Rex, Lyon Nunataks, Cheeks Nunatak, the Merrick and the Sweeney Mountains (Behrendt and Parks, 1962; Behrendt, 1964).

done by the authors during the 1965-1966 field season. The base map was done by Otway based on his survey, on aerial photographs obtained in 1965 and 1966, and on a survey done by C. G. Merrick during the Ellsworth Land Traverse in 1962. The many outcrops for accompanied the field party, has discussed the radiometrically determined ages of the plutonic intrusive bodies (Halpern, 1967). These ages are given in

## Geomorphology and Glacial Geology

glaciation in the Pleistocene. This landscape was com- ously noted occurrence of probable Kimmeridgian rocks. These dikes are locally pegmatitic. been partially uncovered by deglaciation.

plain is found in the accordance of summit elevations genera Astarte and Myophorella. The richest faunas similarity (SiO2=44.64%) to low-silica basalts of late structural trends, stratigraphic position, and radioand in beveled summits on some peaks, notably on occur at the first and third localities where there ap- Tertiary age from the Jones Mountains (Craddock metrically determined middle Cretaceous age (Hal-Mount Hassage and in the Quilty Nunataks. Summit pear to be two or three species of Astarte, one of which et al., 1964) suggest that their age is late Cenozoic. pern, 1967) of the plutonic intrusives are further elevations progressively increase from south to north, is somewhat similar to A. morgani (Trechmann) but Geochemistry of igneous rocks. Figures 1, 2, and 3 evidence in favor of their close relationships with the from 1122 m at Mount Hassage to 1768 m in the differs in the character of the external concentric ribs. are chemical variation diagrams based on whole rock Andean Intrusives of the Antarctic Peninsula. A fur-Sky-Hi Nunataks.

eastern Ellsworth Land obtained by the United States pelecypods Entolium, Nuculana, and Inoceramus, and ing samples from each of the groups mentioned above. Halpern's radiometric age results and the 104 m.y. age Navy during 1965 and 1966 show a number of re- the tube worms Rotularia and Ditrupa are common These indicate that the plutonic intrusives and as- reported by Craddock et al. (1964) for a felsite dike markably straight, parallel-sided depressions in the while the gastropod Aporrhais antarctica Cox is pres- sociated felsic dikes constitute a normal calc-alkalic in the basement complex of the Jones Mountains. vicinity of 75°S, 63°W (for example, TMA 1645, F33, ent but rare. In the Weather Guesser Nunataks, series. The relations of the felsic volcanics and the 207). These depressions appear to be graben and are Astarte and Myophorella are associated with a de- mafic dikes to this series are not clear. On the tri- Merrick Mountains is thought to be related to postinterpreted as being extensional features in keeping pauperate pelecypod fauna including Grammatodon, angular diagrams (Fe-(K+Na)-Mg, Figure 2; K- orogenic arching and block faulting of the Antarctic with the late Tertiary arching of the Antarctic Penin- Pinna, Pleuromya, Inoceramus sp. aff. brownei Mar- Na-Ca, Figure 3), the specimens of dacite (A and B) Peninsula in the late Cenozoic. Their presence is in sula which was proposed by King (1964). It seems wick, the belemnite Belemnopsis, and the gastropod and the seems wick, the belemnite Belemnopsis, and the gastropod and gastr likely that their formation was associated with the ex- Aporrhais sp. trusion of olivine basalt lavas in the Merrick Moun- A fauna dominated by the brachiopod genus Tau- and Na<sub>2</sub>O + K<sub>2</sub>O variation diagrams (Figure 1) both Islands, Peter I Island, the Jones Mountains, the Hud-

southwest at about 30 m/km from elevations greater to recognized Liassic species or genera.

the summit of every range visited, indicating that the A wide band of richly concretionary black shale probably situated near buried plutonic bodies. ranges were completely ice-covered in the Pleistocene. crops out 3.3 km northeast of Mount Hirman. Most Most of the cirques are presently ice filled to within a of the concretions contain some organic traces, usually Structural Geology few tens or hundreds of meters of their tops, indicating unidentifiable wood fragments. Many contain frag-

## Sedimentary Rocks

stones, and conglomerates of Jurassic age is present. Eryon, and also a teleost backbone and a teleost skull. tectonic complexity of the region, the lack of con-A stratigraphic section, thought to be continuous, was Many concretions contain brachial ossicles of Penta- tinuity of existing outcrops, their restricted area, and measured in the southern Behrendt Mountains along crinites. Several pieces of pyritized wood were col- the absence of stratigraphic and structural markers. the ridge including Mount Hirman; however, the lected including one belonging to the Araucariaceae. Complex overturned folds and isoclinal folds were obtion are repeated by either thrust faulting or isoclinal fragments, most of which apparently belong to a small Mount Abrams; they are also postulated on Mount folding or both. Similar structural complications were perisphinctid species. One fragment seems to belong to Hirman on the basis of the stratigraphic paleontology encountered at all localities visited. These, together the Macrocephalitidae, suggesting a Middle Jurassic and the primary sedimentary structures. now appears to be on the ridge trending southwest the Merrick Mountains. from Mount Neuner where an apparently continuous In addition to previously noted occurrences, speci- color bands in dacite, suggesting that the color bands section is calculated to be 1200 m thick. This thickness mens of Inoceramus were found at several places on are parallel to original bedding. Elsewhere the strucis probably a minimum for the Jurassic sedimentary Mount Hirman, Mount Neuner, the Thomas Mount veral attitudes of the sedimentary rocks are charrocks in the region.

graywacke. They are characterized by abundant feld- eastern Ellsworth Land are of Jurassic age. Early, bedding strike with very steep to vertical dips, is Goldring, D. C. (1962) The geology of the Loubet Coast, spars and lithic clasts. Devitrified glassy clasts are Middle, and Late Jurassic assemblages are present in strongly developed in sedimentary and dacitic rocks. Graham Land, Sci. Rept., No. 36, Brit. Antarctic Surv., 50 commonly present, and devitrified shards occur in a different localities. Thus it is concluded that the sedifew specimens. Volcanic quartz is most abundant with mentary rocks examined in this region are probably this cleavage, which tends to mask or obliterate the common and metamorphic types present in smaller all of Jurassic age.

Intraformational shale-pebble conglomerates are abundant throughout the sequence; terriginous conglomerates are less abundant. Several hundred terrig inous conglomerate pebbles have been identified; more than half of these are composed of felsic and intermediate volcanic rocks including tuffs and flows. Sandstones, metamorphic rocks (quartzite and schists) and plutonic rocks (granodiorite) are also present. The source of the sediments in these strata was prob-

ably a nearby volcanic island arc with a crystalli basement complex. Dacites which crop out in the northern part of the region are believed to be part of this arc. They are in part older than and in part contemporaneous with the sedimentary rocks.

<sup>1</sup>Wisconsin State University, Oshkosh <sup>2</sup>Bear Creek Mining Company, Spokane <sup>3</sup>University of Tasmania, Hobart 'New Zealand Geological Survey

Fossils were discovered by the 1961-1962 Ellsworth Land Traverse at Lyon Nunataks. The following forms have been identified by Stevens (1967): Conodiocoel ites spp., Rotularia sp. indet., indet, petinacean:

includes the ammonites Sphaeroceras sp., Teloceras that their age is Early Cretaceous.

cus Clark, is present as columnals.

northwest of the summit of Mount Hirman. These gonian Cordillera (Adie, 1955). sphinctid cf. Lithacoceras.

ronemia (?) associated with Entolium cf. fossatum dacites are significantly less alkalic than the intrusive son Mountains, probably Mount Murphy, Mount The present mountain ranges consist of a series of Marwick, Rotularia cf. callosa (Stoliczka), and scat- series while the andesite is considerably more alkalic Takahe, Mount Crary, the Executive Committee arête ridges projecting above the gently undulating tered broken belemnites occurs 200 m northeast of the and less calcic than the intrusives. surface of the ice sheet which slopes to the south- summit of Mount Hirman. All the fossils are similar Metamorphic rocks. Contact aureoles of chiastolite- tains).

stratigraphic markers, seriously hindered both struc- Rotularia and Ditrupa occur in association with taks occupies the axis of a closed anticline. The axis tural and stratigraphic interpretation. Thus no satis- broken belemnites in many places including Mount of a closed syncline follows the crest of the ridge 2.3 factory measured stratigraphic section was obtained. Glowa, Mount Hirman, Mount Brice, km southeast of the summit of Mount Brice. At Mount The best possibility for securing a measured section Mount Abrams, the Weather Guesser Nunataks, and Wasilewski fracture cleavage is strongly developed

tains, and Mount Hassage.

## Igneous and Metamorphic Rocks

shales and siltstones crops out 3.3 km southwest of the tween these formations are snow-covered; therefore their structural position is not known and their age cannot be determined more precisely than pre-middle

of masses of dacite which have been intensely folded, eastern Ellsworth Land--andesite flows, felsic volcansheared, saussuritized and locally mylonitized. Pyro- ics, Jurassic sedimentary rocks, mafic dikes, Andean clastic textures in some specimens and flow structures intrusives and olivine basalt—can be readily correlated

in others indicate an extrusive origin for the dacites. with units that have been previously described in the The Jurassic sedimentary rocks are predominantly Antarctic Peninsula and Alexander Island. of felsic volcanic provenance. Volcanic components The andesite flows and dacite volcanics of Ellsworth include abundant sand-sized quartz, feldspar and lithic Land are believed to be equivalent to rhyolites, dacites, clasts, and abundant conglomerate pebbles of felsic and andesites, which have a widespread occurrence in and intermediate composition. Some of the conglom- the Antarctic Peninsula where they are called the erate pebbles possess extrusive textures and structures Upper Jurassic Volcanic Group on the basis of their

seems most probable that the dacites are representa- Jurassic strata at Hope Bay (Adie, 1964b). However, tives of a felsic volcanic terrane which was the source in most places there is no direct evidence regarding the of the terriginous volcanic components of the Jurassic age of this group (Goldring, 1962; Hooper, 1962; sedimentary rocks. Devitrified shards are present, but Elliot, 1964; Curtis, 1966). In Ellsworth Land the rare, in a few of the Jurassic sandstones, indicating dacites and andesite flows are believed to be in part Entolium, and Variamusium lyonensis Stevens. The that at times pyroclastic activity coincided with sand- older than Lower Jurassic sedimentary rocks for age of the assemblage was first given as Cretaceous stone deposition. With the possible exception of the which they served as a source of clastic material. Howandesite flows, the dacites are the oldest igneous rocks ever, a precise upper age limit for these volcanic rocks tion of Rotularia callosa; however, Stevens (1967) has encountered. They appear to be in part older than and cannot be determined. A few of the Jurassic sedimen-

dated fauna, of Middle Bajocian age, occurs 6.3 km rocks in some places and in others are truncated by Island (Adie, 1964b; Halpern, 1964). northeast of the summit of Mount Hirman. This fauna middle Cretaceous plutonic intrusives, it is most likely Following the deposition of Upper Jurassic sedi-

Plutonic intrusives. Plutonic bodies of middle Cre- sedimentary strata were severely deformed in latest temmatoceras; the pelecypods, Camptonectes, Ento- taceous age-102 m.y. to 109 m.y. (Halpern, 1967) - Jurassic or early Cretaceous times. The folded strata lium cf. clammoseum Marwick, Pholadomya, and which intrude the Jurassic sedimentary rocks make up were intruded by mafic dikes, probably in the early Thracia; the gastropod, Exelissa sp.; and the belem- the cores of the Merrick Mountains, the Behrendt Cretaceous. The mafic dikes of eastern Ellsworth Land Mountains, the Weather Guesser Nunataks, the are probably equivalent to similar dikes occurring in Thomas Mountains, the Quilty Nunataks, and Mount the Antarctic Peninsula where they are variously rea site 1.3 km northwest of the one mentioned above. Hassage. South of 75°15'S latitude the plutons are ferred to as Upper Jurassic hypabyssal rocks on the rocks with a similar fauna and probably a very similar small stocks or cupolas of quartz-monzonite and Loubet Coast (Goldring, 1962), pre-Andean hypaage crop out. Ammonites present are Sphaeroceras sp. granodiorite; north of 75°15'S the plutons are gen- byssal rocks in the Argentine Islands (Elliot, 1964), and gen. aff. Stephanoceras; the pelecypod fauna in- erally smaller bodies of gabbro and diorite. In exposed Upper Jurassic dikes on Anvers Island (Hooper, cludes Camptonectes cf. grandis Hector and contacts the walls of the plutons are nearly vertical. 1962) and upper Jurassic volcanics on King George Pseudolimea; and a crinoid, Pentacrinus cf. californi- Contacts between plutonic rocks and metasedimentary Island (Hooper, 1962), the Graham Coast (Curtis, rocks are rarely sharp, more commonly showing evi- 1966) and elsewhere in the Peninsula (Adie, 1964a).

trends for the intrusive series. However, on the CaO lar rocks in West Antarctica (in the South Shetland

cordierite hornfels and slates and quartzites are dethan 1700 m north of Sky-Hi Nunataks to less than A small, poorly preserved, fragmented flora occurs veloped adjacent to plutonic bodies. The metamorphic Acknowledgments. Field work was carried out as part of 500 m south of the Behrendt Mountains. Smaller in the saddle 600 m northeast of the summit of Mount in the States Antarctic Research Program. U.S. Navy Air nunataks occur throughout the region. Most are as- Neuner. The following forms have been tentatively 100 m of exposed plutons; beyond 100 m the alteration Development Squadron Six (VX-6) provided logistic support sociated with the major ranges, but many are isolated identified: Todites williamsoni (Brongniart), Clado- is not conspicuous, but the rocks are flinty and exhibit tional Science Foundation to the University of Wisconsin. from any neighbors. Except on the largest peaks, out- phlebis oblonga Halle, Coniopteris lobata (Oldham), strong slaty cleavage. The outer limit of alteration is crops are limited to narrow bands along the crests of Taeniopteris sp. and a species referable either to about 300 m. Similar metamorphic rocks which are Phlebopteris or Matonidium. An Early to Middle not associated with exposed igneous rocks occur in References Glacial striations and erratics are found at or near Jurassic age is suggested by the named forms. many places in the Behrendt Mountains; these are Adie, R. J. (1955) The petrology of Graham Land, Pt. 2, The

only partial deglaciation of the outcrop area. mentary belemnites and pelecypods. While most of sedimentary strata were complexly folded about west- land, Amsterdam. the fossils are of little stratigraphic value, many are northwest trending axes prior to the emplacement of Adie, R. J. (1964b) Stratigraphic correlation in West Antarcinteresting in themselves. Among these are four frag- the mafic dikes and the Andean intrusives. Detailed ments of a reptant decapod crustacean similar to structural interpretation is seriously hampered by the paleontologic evidence indicates that parts of this sec- One stratum contains great numbers of ammonite served on the ridge running south from the summit of Behrendt, J. C., and Laudon, T. S. (1964) Cretaceous fossils

parallel to the axial planes of complexly contorted bedding in thick shale and dacite sequences.

No direct evidence of thrust faulting was observed in the field. However, three lines of indirect evidence suggest that significant faulting has occurred, espeare: (1) the intensity and complexity of the folding, (2) the paleontologic sequence, and (3) the common

### Geologic History and Regional Relationships

nearly identical with those found in the dacites. It conformable relationship with underlying Middle

subsequently concluded that the characteristics shown in part contemporaneous with the Jurassic sedimentary rocks give evidence of contemporaneous pyrotary rocks and therefore may be the oldest rocks in the clastic activity, but their exact age is unknown. The thick graywacke-shale sequence represents Mafic dikes. Both the folded dacites and the Jurassic probably continuous deposition under geosynclinal sedimentary rocks are penetrated by two types of conditions throughout the Jurassic period. The Lower mafic dikes. The smaller dikes range in width from a Jurassic sedimentary rocks of the Behrendt Mountains few centimeters to 2 m and vary in composition from are the first of this age to be reported from West Antandesite to diabase. The larger dikes are as much as arctica. However, similar clastic sequences of Middle 10 m wide and are composed of gabbro. Because these and Late Jurassic and Cretaceous ages are known from

PLATE III

FOLIO 12 - GEOLOGY

ANTARCTIC MAP FOLIO SERIES

dikes penetrate folded Upper Jurassic sedimentary many areas of the Antarctic Peninsula and Alexander mentary rocks, the andesite flows, felsic volcanics and

Three poorly preserved ammonite specimens of dence of assimilation. These are related to the Andean The plutonic intrusives in Ellsworth Land bear a probable Kimmeridgian age were found 1.8 km north- intrusives of the Antarctic Peninsula and the Pata- close genetic relationship to the Andean Intrusive Suite which is widespread in the Antarctic Peninsula, have been identified as Torquadisphinctes sp. indet., Felsic dikes. In the Merrick Mountains rhyolite por- Alexander Island, the Palmer Archipelago and the indet. perisphinctid cf. Prorasenia, and indet. peri- phyry dikes ranging in width from 1 cm to 10 m cut South Shetland Islands. On the basis of geochemical gabbro and diorite plutonic bodies and Jurassic sedi- variation trends, Adie (1955, 1964b) has concluded The present morphology of eastern Ellsworth Land One distinctive assemblage was recognized in four mentary rocks. In the Behrendt Mountains, the Thomas that the Andean Intrusives constitute a normal calcis the result of the arching of a post-Andean (Tertiary) localities: (1) 1.7 km southwest of the summit of Mountains, and Mount Hassage aplite dikes reaching alkalic magmatic series having been derived by crystalpeneplain and its subsequent disruption by block fault- Mount Hirman; (2) 1.8 km north-northwest of the thicknesses of as much as 10 m cut granodiorite and lization differentiation from a common parental ing in the late Tertiary and later dissection by alpine summit of Mount Hirman, within 100 m of the previ- quartz-monzonite plutons and Jurassic sedimentary magma. Chemical analyses of the plutonic intrusives and associated felsic dikes from Ellsworth Land show pletely buried by glacial ice in the Pleistocene and has ammonites; (3) 2.0 km southwest of the summit of Olivine basalt. Extrusive vesicular olivine basalt that they form a similar calc-alkalic series (Figure 1) Mount Brice; and (4) in the Weather Guesser Nuna- forms one small outcrop 2.1 km south-southwest of whose geochemical trends are very close to those of Evidence for the existence of a post-Andean pene- taks. The assemblage is characterized by the pelecypod Mount Matheson. Lack of alteration and chemical the Andean Intrusive suite (Figures 2 and 3). The The species of Myophorella is very similar to an unanalyses of fifteen igneous rock specimens, ther westward continuation of the Andean Intrusives Aerial photographs of the Weddell Sea coast in named form from New Zealand (Fleming, 1964). The mainly representing the plutonic intrusives but includ- is strongly suggested by the close agreement between

Range, the Ford Ranges and the Rockefeller Moun-

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acterized by west-northwesterly strikes and steep dips. Fleming, C. A. (1964) History of the bivalve family Trigoniidae

The sandstones are all classified as either arkose or All of the fossils which have been identified from Rock cleavage, which strikes generally parallel to in the south-west Pacific: the geological background to an

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