GEOLOGY OF THE SEWARD MOUNTAINS, WESTERN PALMER LAND

By D. G. SINGLETON

ABSTRACT. The general geology of the Seward Mountains is described. The oldest and most altered rocks are volcanic and have been related to the more extensive Upper Jurassic Volcanic Group. It is probable that these were intruded by a tonalitic to granodioritic sequence of rocks during the Middle–Upper Cretaceous. Minor basic intrusive activity followed this plutonism. Finally, the (?) Jurassic volcanic rocks were again cut by young basaltic rocks probably during the late Tertiary. The last is a further representative of the broad chain of Cenozoic volcanic activity extending across western Antarctica.

THE Seward Mountains (Fig. 1) are situated between lat. 72°27′ and 72°34′S. and long. 66° 12′–65°55′W. on the western coast of Palmer Land. They were first discovered in 1936 by the British Graham Land Expedition (Rymill, 1938) and named for Sir Albert Charles Seward, Professor of Botany, University of Cambridge, during 1906–36.

After photographic flights by the Ronne Antarctic Research Expedition, 1946–48 (Ronne, 1948), the Seward Mountains were again sighted and fixed by the Falkland Islands Dependencies Survey in 1949 during their traverses along George VI Sound. However, the subsequent positioning of the Seward Mountains on the Directorate of Overseas Surveys 1 : 500,000 series of maps is incorrect and they should be 11 km. to the south-south-east.

In November 1970, P. F. Butler and M. Pawley visited the north-western tip of the Seward Mountains during a west–east gravity traverse across Palmer Land. The author and general assistant were the second group of people to visit this mountain range.

The basic physiography of the Seward Mountains is that of two parallel rock ridges in the size order of large nunataks or cliffs rather than mountains (height 975–1,350 m.). The cross-profiles through these ridges are asymmetrical with steep rock walls on the north sides and gentle snow slopes on the south. Several large isolated nunataks form the northerly and westerly extensions of these ridges. The relief of those parts of the ridges formed by the plutonic rocks is much greater, presumably because of their greater resistance to erosion. The snow surface between the two main ridges descends gently in height from the high plateau in the east towards the west.

GEOLOGY AND PETROLOGY

Gently folded purple and green tuffaceous volcanic rocks associated with altered porphyritic intermediate to basic lavas are exposed along the western extremities of the Seward Mountains (Fig. 1). Heterogeneous plutonic rocks form most of the outcrops to the east but they are not seen in contact with the volcanic rocks. Numerous altered basic dykes cut the plutonic rocks but apparently they do not occur in the volcanic rocks. The latter are also intruded by a possible young basaltic rock at the western tip of the southern Seward Mountains ridge.

Volcanic rocks

The northern outcrops at the western end of the northern Seward Mountains ridge consist of a bedded and gently folded sequence of crystal-tuffs with variable individual thicknesses. This primary bedding between purple and green tuffs is also evident on a smaller scale in the hand specimen and it is believed to reflect the vertical variation in oxidation conditions during the time of deposition. The predominant phenocrysts are discontinuously polysynthetically twinned oligoclase (An_{28}) up to 4 mm. in length which are occasionally oscillatorily zoned (E.4640.1). These are commonly cracked and partially replaced by alkali feldspar (Fig. 2a). Chlorite is also a common alteration product in these crystals and it is particularly significant

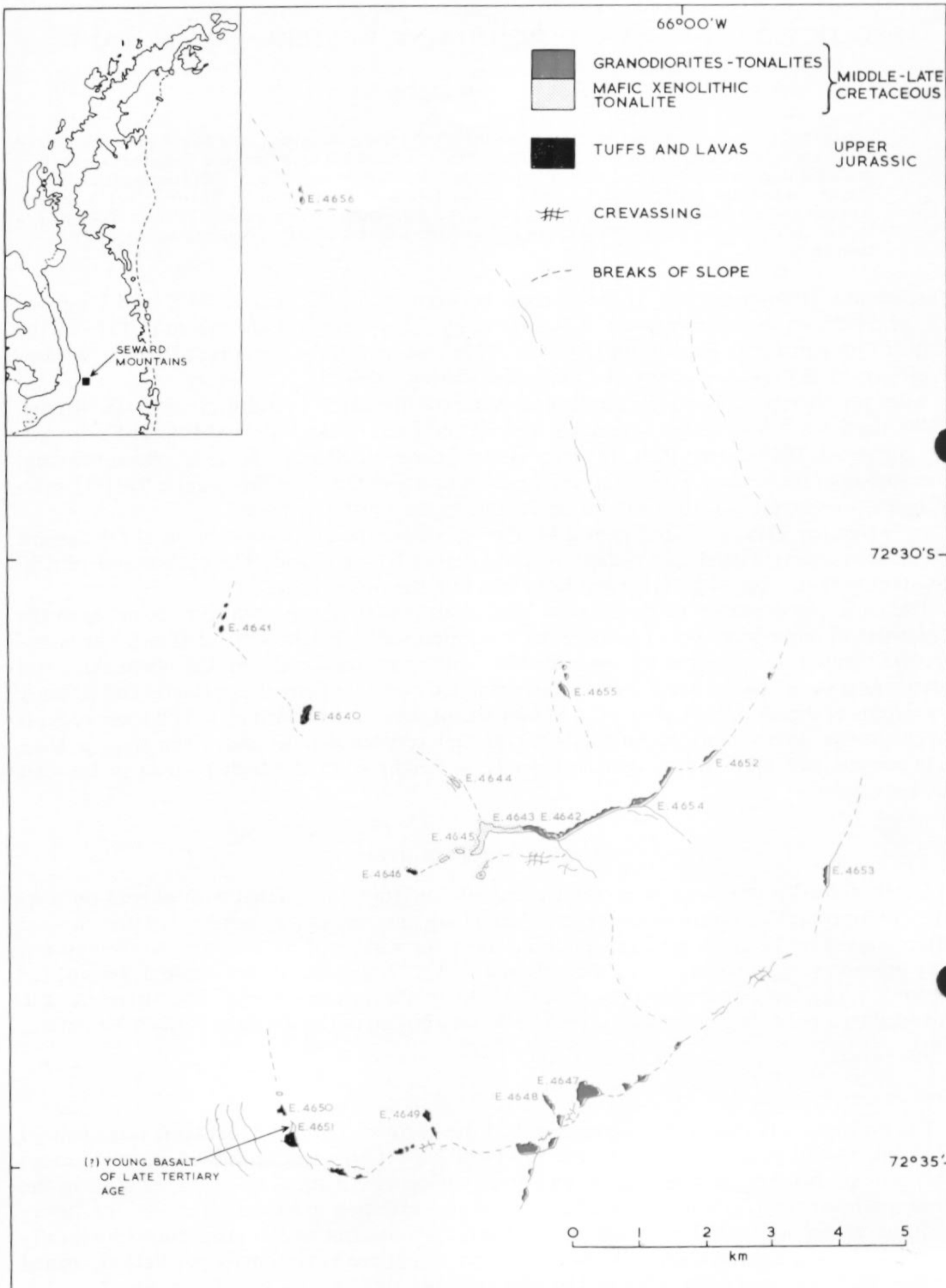

Fig. 1. Geological sketch map of the Seward Mountains showing the locations of the stations visited.

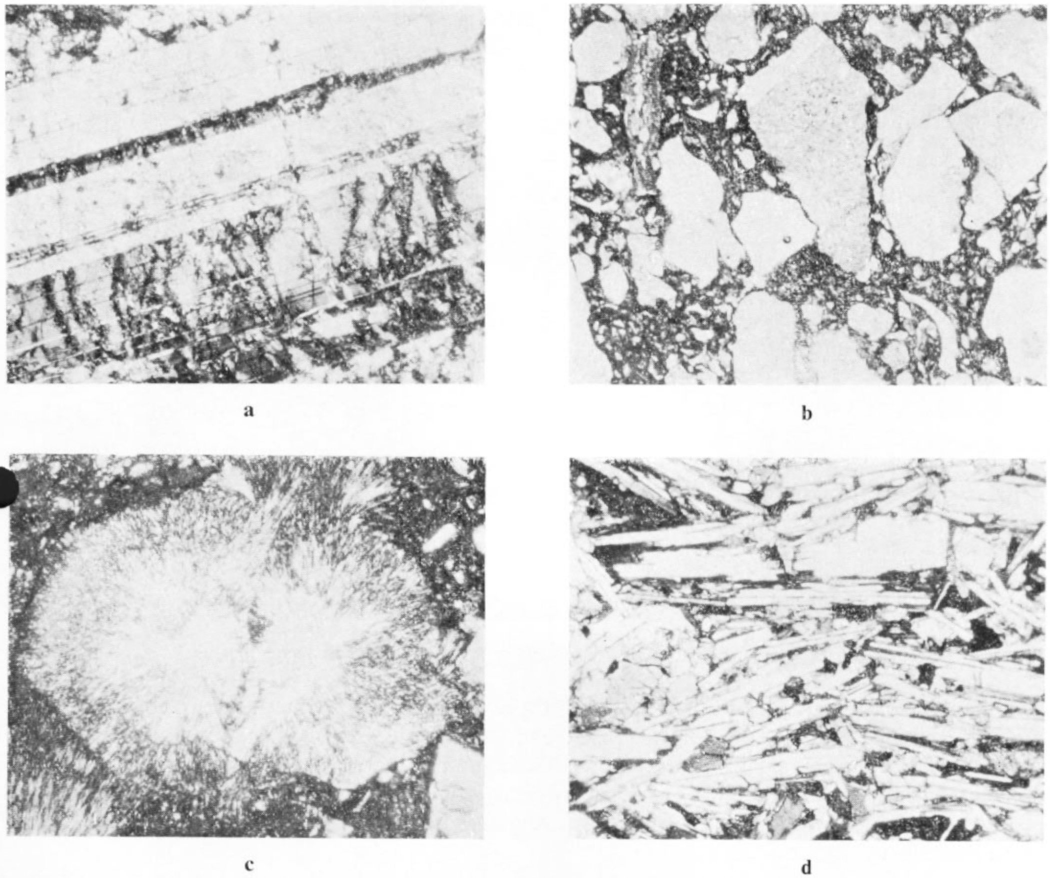

Fig. 2. a. Cracked plagioclase phenocryst in a crystal-tuff (E.4640.1; X-nicols; ×44).
b. Angular tuffaceous, quartz and schistose fragments in a lithic tuff (E.4649.4; ordinary light; ×18).
c. Zeolite fragment in a lithic tuff (E.4649.4; X-nicols; ×44).
d. Flow-aligned plagioclase laths and scattered ferromagnesian minerals in a young basalt (E.4651.1; X-nicols; ×18).

in the groundmass. The small quartzite clasts observed may represent recrystallized original rock fragments. To the west, at the base of the sequence observed there (E.4641), the phenocrysts have been completely replaced by epidote and chlorite. The combination of this with the altered nature of the groundmass makes the rock almost unidentifiable as a tuff. Iron oxide is a common accessory in these rocks.

On the western tip of the southern ridge of the Seward Mountains, pipernoid rocks occur and these have a similar composition to that of the rocks of the northern ridge but they have the characteristic fiamme texture (Fig. 3). These dark vitric lenses, which are generally squeezed around the contained phenocrysts, have a parallel alignment and are believed to be products of the collapse of pumice fragments. Lenticular crystal-lined vesicles are common in the outcrops of this rock.

Immediately to the south, extremely chloritized equivalents of these ignimbritic rocks are interbedded with distinctly green altered intermediate porphyritic lavas. The green colour is largely attributed to the widespread epidotization and chloritization of these rocks and here the phenocrysts have been almost completely pseudomorphed as a result of these processes.

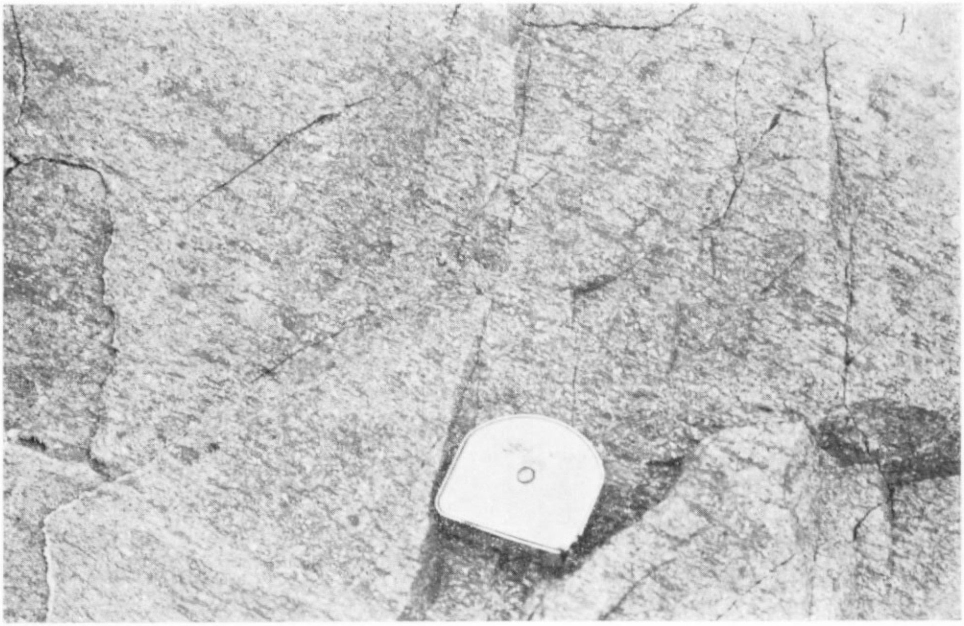

Fig. 3. Fiamme texture in a crystal-tuff. The steel tape is 4 cm. across.

The general texture of the rock is further complicated by the prevalence of irregular amygdaloidal structures containing quartz, epidote, chlorite and calcite. In the less-altered lavas to the east, the phenocrysts are mainly of extremely sericitized and saussuritized plagioclase, with subordinate twinned clinopyroxene (probably augite) and various chloritic pseudomorphs of the latter. The groundmass consists of a very fine indistinct mass of decussate plagioclase, granular chlorite and sericite.

At station E.4649, these lavas are intruded by a lithic crystal-tuff of contrasting composition to that of the other volcanic rocks in the Seward Mountains. This tuff has entered the lavas via a 1 m. vertical pipe and it has then spread laterally in the form of a sill. There are numerous rock and crystal fragments (Fig. 2b and c):

i. Angular and embayed quartz crystals.
ii. Biotite, muscovite and quartz schistose fragments.
iii. Intergrown fragments of amphibole and feldspar.
iv. Zeolitized fragments.
v. Broken and cracked plagioclase crystals partially replaced by alkali-feldspar.
vi. Large fragments of lava and tuff.

It is thought that the quartz, schistose and intergrown fragments may have been derived from "Basement Complex" (Adie, 1955) rocks. The vitric groundmass contains numerous shards.

Main plutonic rocks

Granodiorite forms much of the exposure on the northern ridge of the Seward Mountains. It is a medium-grained leucocratic rock (E.4642.1) composed essentially of polysynthetically twinned and oscillatorily zoned oligoclase (An_{13}) and interstitial incipiently twinned microcline containing inclusions of biotite, hornblende and plagioclase. Some of the quartz has a slightly undulose extinction. Equal proportions of hornblende and partially epidotized and chloritized biotite represent the subordinate mafic minerals. Sphene, apatite and iron ore are

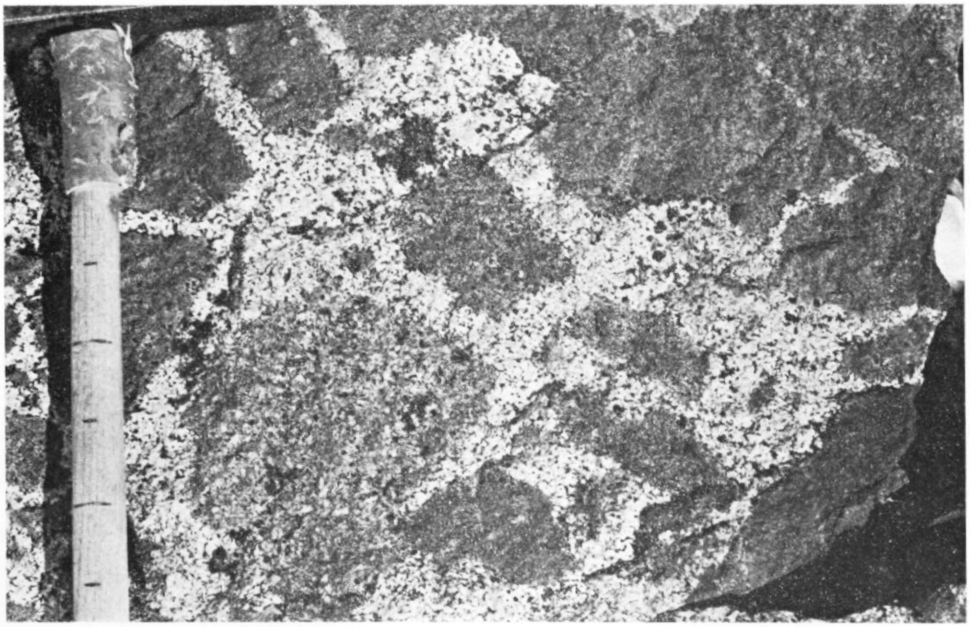

Fig. 4. Tonalitic xenoliths enclosed by more acidic material. The hammer shaft is graduated at 5 cm. intervals.

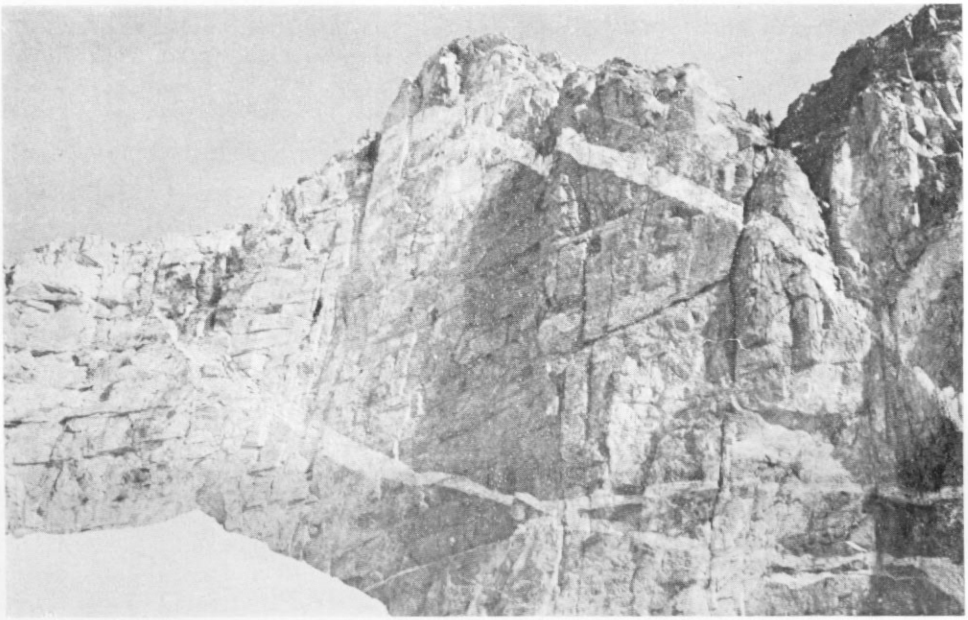

Fig. 5. Heterogeneous mesocratic tonalite and adjacent granodiorite cut by late acid veins. The cliff face is approximately 50 m. high.

the accessory minerals. Fine-grained and generally porphyritic mafic xenoliths are enclosed by this granodiorite. The porphyritic areas of these are of coarse plagioclase crystals (up to 4 mm. in length) and minor interstitial quartz. Some of the plagioclases are patchily replaced by potash feldspar. The tonalitic groundmass has a near granoblastic texture, in which the biotite (subordinate to hornblende) has been almost completely chloritized (penninite) and occasionally prehnitized.

At the western end of this northern ridge, the granodiorite intrudes a complex mesocratic predominantly xenolithic rock believed to be the equivalent of a more homogeneous tonalite which crops out on the nunataks farther west (E.4644 and 4645). The mesocratic homogeneous tonalite (E.4644.1) has an embryonic fabric caused by the preferred orientation of the extensive areas of actinolite. The latter is virtually indistinguishable in containing many inclusions of iron ore and appears to have been partly derived by alteration from pyroxene, which is present as relict forms in some crystals. These actinolitic areas are interstitial to large plagioclase crystals which are polysynthetically twinned, patchily zoned and are partly fractured and deformed. An intricate network of leucocratic granodioritic veins has presumably penetrated this tonalite during its emplacement and resulted in the xenolithic form close to the contact with the granodiorite (Fig. 4). The xenoliths close to the granodiorite are of a similar composition to those that occur within it. There is some evidence of shearing in the banded correlatives of these heterogeneous rocks at the western tip of the northern ridge.

All intrusive rocks of this group are cut by numerous late-stage acid veins (Fig. 5).

The immediate contact between the granodiorite and the xenolithic rock is complicated by the presence of large irregular pockets and dykes of a pink granitic rock in both intrusives. These probably represent late-stage (but older than the acid veins shown in Fig. 5) liquid phases which have intruded and become enclosed in what was probably a fairly mobile intrusive margin between two rock types of probable cogenetic origin. These granites are mineralogically distinct from the granodiorite because of the absence of hornblende and the presence of significant amounts of microperthitic potash feldspar (E.4642.5). Similar minor zones of leucocratic granite intrude the tonalitic rocks (E.4647) on the southern ridge of the Seward Mountains (Fig. 6) but these contain mafic xenolith swarms (Fig. 7). These xenoliths differ from those within the granodiorite of the northern ridge in that they have been amphibolitized and do not contain porphyritic areas.

The tonalite, into which these granitic zones have been emplaced, is similar in colour to the one at station E.4644 but its less altered mineralogy is more akin to that of the granodiorite forming the northern ridge. The feldspar, the dominant felsic mineral, is polysynthetically, pericline and occasionally Carlsbad-twinned andesine (An_{34-42}). There is little evidence of general deformation in these twin lamellae. A preponderance of hornblende has formed later and it contains inclusions of biotite, feldspar and quartz. Biotite, which is subsidiary to hornblende, is undeformed and only marginally chloritized. The presence of occasional remnants of pyroxene in the hornblende suggests that some of the amphibole may be secondary. This tonalite is particularly heterogeneous, banded and xenolithic towards the eastern end of the ridge and this feature probably reflects the suspected multiple-phase style of intrusion.

Young basic plutonic rocks

A mafic fine-grained basalt intrudes the volcanic lavas at the western end of the southern Seward Mountains ridge. The contact is sharp but there has been little thermal effect on the volcanic rocks. There is a similar absence of contact metamorphism in volcanic rocks close to the other older main plutonic rocks. This basaltic rock is believed to be much younger because of the fresh appearance of the ferromagnesian minerals and in particular that of olivine. Light brown pyroxene and subordinate olivine are scattered throughout a mass of large elongated labradorite (An_{58}) crystals, some of which approach 2 mm. in length. These crystals have a coarse flow alignment (Fig. 2d).

Fig. 6. Granitic zone intruding a tonalite at station E.4647. The shaft of the hammer at the lower right-hand side of the zone is 60 cm. long.

Basic hypabyssal rocks

These generally altered basic dykes, which occur only in the main plutonic rocks, range up to 60 cm. in width. These rocks are fine-grained, green to grey and occasionally contain feldspar, pyroxene and amphibole phenocrysts. Polysynthetically twinned plagioclase of an intermediate composition is still recognizable and forms the bulk of these rocks. Epidote and chlorite are common alteration minerals, sometimes masking the whole rock. In some examples, it appears that epidote is present as pseudomorphs after biotite (E.4656.2 and 3) and chlorite after amphibole (actinolite), although these minerals are mainly scattered throughout the groundmass with dusty sericite.

The dykes on the southern ridge of the Seward Mountains have probably been affected by later movement. They have a fine foliation enhanced by the parallel arrangement of coarser

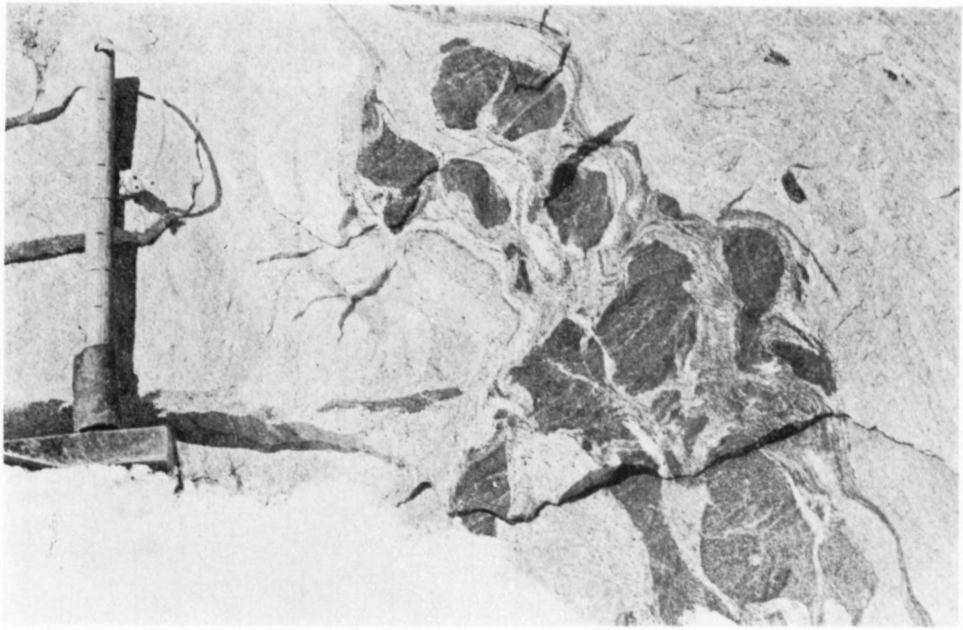

Fig. 7. Xenolith swarm in the granitic zone (E.4647). The hammer shaft is 60 cm. long.

lenses and ribbons of chloritoid, epidote and quartz, presumably formed later in the feldspathic groundmass.

Regional Setting

The Seward Mountains form a southerly extension of the already well-documented geology of the west coast of Palmer Land (Ayling, 1966; Rowe, 1973; Skinner, 1973; Davies, 1976; Smith, 1977).

Most of the volcanism, which was responsible for the tuffs and lavas, was subaerial and probably occurred at a similar time to that responsible for the genesis of the Upper Jurassic Volcanic Group (Adie, 1964; Thomson, 1972). The last has a widespread distribution throughout the Antarctic Peninsula and it has been recognized that the various phases of volcanic activity were probably diachronous (Adie, 1971). Although no centre of eruption has been observed in the Seward Mountains, vents have been reported farther north (Ayling 1966; Skinner, 1973; Wyeth, 1975; Smith, 1977). It has been suggested that this subaerial volcanism occurred during the evolution of an ensialic volcanic arc and it has been attributed to an eastward-dipping subduction zone beneath the Antarctic continental margin (Suárez, 1976).

It is suggested that the undeformed older main plutonic rocks are probably younger than the gently folded (?) Upper Jurassic volcanic rocks in spite of the absence of observed field relationships. Their emplacement is believed to have occurred in several phases and it has had little thermal effect on the volcanic rocks. The tonalite at the western tip of the northern Seward Mountains ridge is probably slightly older than the granodioritic rocks but it is still thought to be part of the extensive gabbro–granite bodies found elsewhere in the Antarctic Peninsula. Five intrusive phases have been identified in these widespread plutonic rocks by Rex (1971) and the last two, covering the Cretaceous–early Tertiary boundary, correspond to the Andean Intrusive Suite (Adie, 1955). The main Seward Mountains plutonic rocks are probably not older than the Middle Cretaceous. In other areas, intrusion of these rocks has caused major thermal metamorphism of the Upper Jurassic Volcanic Group (Adie, 1971) but this is not always so locally (Skinner, 1973). Some of the earlier periods of plutonism recognized by Rex (1971) may be coeval with the volcanicity responsible for the Upper Jurassic Volcanic Group (Suárez, 1976) and consequently the evolution of the younger plutons can also be attributed to continued subduction.

Basic dykes were probably intruded after the last phase of plutonism.

The unaltered basalt, which intrudes the (?) Jurassic lavas on the southern Seward Mountains ridge, may be part of a broad belt of Cenozoic volcanic activity (Adie, 1971; Bell, 1973) which reached its peak in the Upper Miocene.

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