REPORT ON ANTARCTIC FIELDWORK
THE GEOLOGY OF THE CENTRAL BLACK COAST, EASTERN PALMER LAND

B. C. STOREY *and* H. E. WEVER

British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 OET, UK

P. D. ROWLEY

United States Geological Survey, Denver, Colorado 80225, USA

and

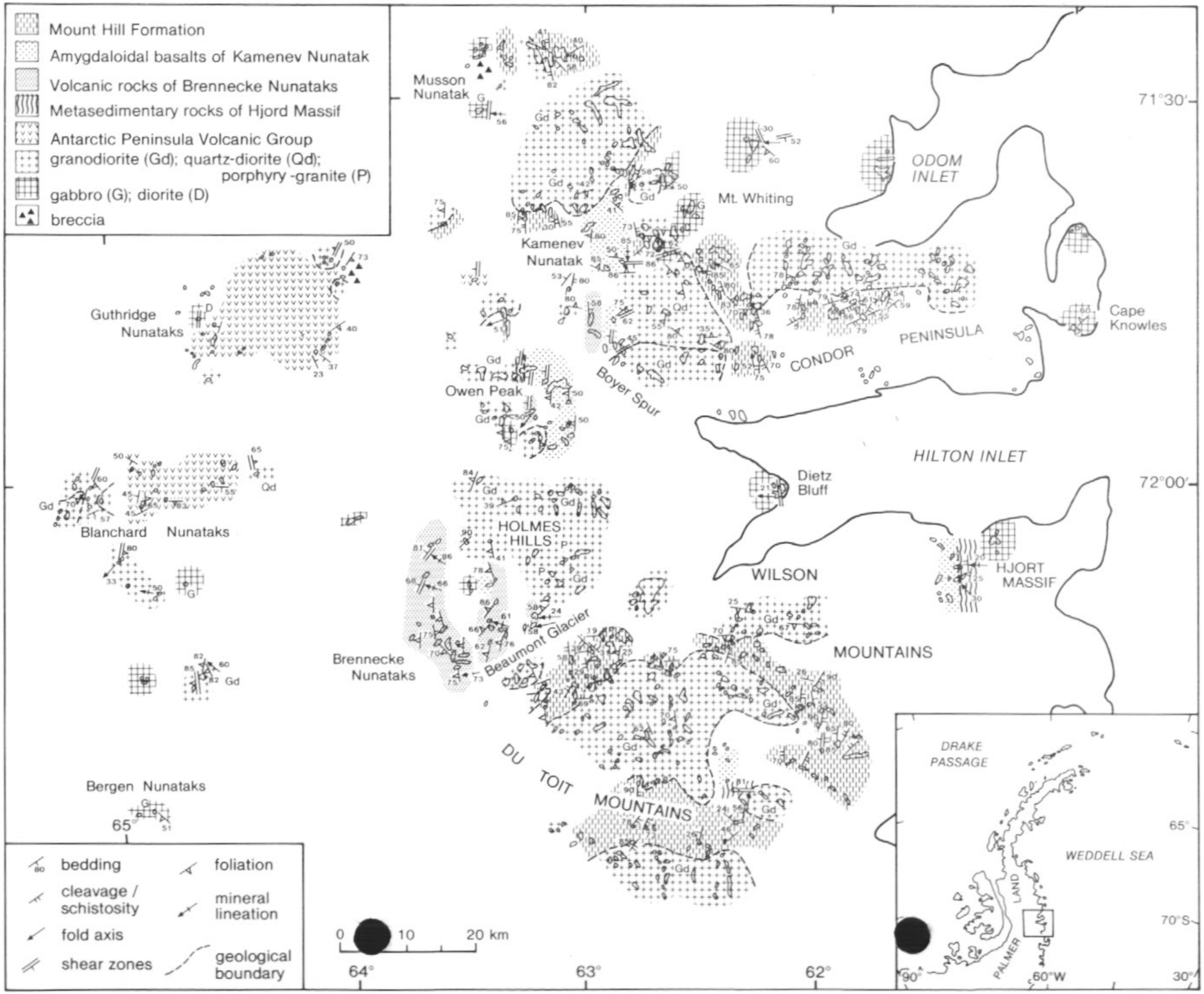
A. B. FORD

United States Geological Survey, Menlo Park, California 94024, USA

ABSTRACT. The geology of the previously unmapped, central Black Coast has similarities with both the northern and southern regions. It represents a transition from a northern region dominated by sheared plutonic and volcanic rocks with subordinate deformed sedimentary rocks and post-tectonic Cretaceous granitoid plutons, to one dominated by deformed back-arc basin sedimentary rocks, subordinate volcanic-arc rocks and large post-tectonic granitic plutons. A new mappable unit of pre-tectonic amygdaloidal basalts, a major episode of shear zone deformation and a new sequence of metasedimentary rocks, have been recognized. The field work may provide valuable constraints on the early arc magmatism and the development stages of the Jurassic back-arc basin on the east coast of Palmer Land.

INTRODUCTION

During the 1986–87 field season a joint British Antarctic Survey–US Geological Survey field party mapped the geology of the central part of the Black Coast (71° 30′–72° 30′S) the remaining, large, geologically unknown part of the Antarctic Peninsula (Fig. 1). Prior to this project the area to the north was mapped by British Antarctic Survey geologists (Singleton, 1980; Meneilly, 1983; Meneilly and others, 1987), whereas the southern Black Coast was mapped by US Geological Survey parties (Williams and others, 1972; Rowley and Williams, 1982; Rowley and others, 1983). Singleton mapped three major rock units in the northern area: (1) a metamorphic complex, (2) metasedimentary and metavolcanic (including greenstone) rocks of the Mount Hill Formation, and (3) Upper Jurassic–Lower Cretaceous intrusive rocks. In addition, rocks of the Antarctic Peninsula Volcanic Group occur along the spine and western side of the peninsula (British Antarctic Survey, 1982). Meneilly (1983) recognized major shear zones within the metamorphic complex and concluded that much of the metamorphic complex formed by ductile shearing of Lower Jurassic plutons (Meneilly and others, 1987). The geology of the southern Black Coast is dominated by a suite of Lower Cretaceous granitoids, the Lassiter Coast Intrusive Suite (Vennum and Rowley, 1986). The granitic rocks intrude deformed sedimentary rocks of the Middle to Upper Jurassic Latady Formation (Williams and others, 1972), interpreted by Suarez (1976) as a back-arc basin deposit. The western edge of the Latady Formation interdigitates with a sequence of silicic and intermediate volcanic rocks, the Mount Poster Formation (Rowley and others, 1982) of the Antarctic Peninsula Volcanic Group.


Mount Hill Formation
Amygdaloidal basalts of Kamenev Nunatak
Volcanic rocks of Brennecke Nunataks
Metasedimentary rocks of Hjord Massif
Antarctic Peninsula Volcanic Group
granodiorite (Gd); quartz-diorite (Qd); porphyry-granite (P)
gabbro (G); diorite (D)
breccia
Musson Nunatak
Kamenev Nunatak
Mt. Whiting
ODOM INLET
Cape Knowles
Guthridge Nunataks
Owen Peak
Boyer Spur
CONDOR PENINSULA
HILTON INLET
Dietz Bluff
Blanchard Nunataks
HOLMES HILLS
WILSON MOUNTAINS
HJORT MASSIF
Brennecke Nunataks
Beaumont Glacier
DU TOIT MOUNTAINS
Bergen Nunataks
71°30′
72°00′
65°
64°
63°
62°
0 10 20 km
bedding
cleavage / schistosity
fold axis
shear zones
foliation
mineral lineation
geological boundary
DRAKE PASSAGE
WEDDELL SEA
PALMER LAND
65°
70°S
90°
60°W
30°

Part of the geology of the northern Black Coast has been correlated with the southern area. Singleton (1980) compared the back-arc metasedimentary rocks of the Mount Hill Formation with the Latady Formation and concluded that some of the intrusive rocks were similar to the Lassiter Coast Intrusive Suite. The volcanic rocks of the Mount Poster Formation are included in the widespread group of Jurassic to Tertiary volcanic rocks, the Antarctic Peninsula Volcanic Group, which is part of the Mesozoic calc-alkaline magmatic arc (Thomson, 1982). However, there are some important differences in geology between the two areas: a metamorphic complex similar to that described by Singleton (1980) has not been mapped, nor have the major shear zones of Meneilly (1983) been recorded in the southern Black Coast.

The purpose of this joint field project was to correlate the geology of the northern and southern Black Coast regions by mapping the previously unvisited, central part of the Black Coast, and by revisiting key localities in the northern and southern regions for in-field comparison. With the exception of areas of difficult access on the eastern margin, much of the central Black Coast area was mapped. The combination of skidoo transport and Twin Otter air-supported geology proved to be very successful. The Twin Otter was used to visit the distant key localities in the north and south of the area, and for remote localities along the central spine of the peninsula.

Field Relations

The geology of the central Black Coast (Fig. 1) is dominated by plutonic rocks that range in composition from gabbro to granite. Although many are large, undeformed granitic plutons, which may be correlatives of the Lassiter Coast Intrusive Suite, some are foliated and variably deformed by shear zones. The plutonic rocks intrude the widespread sequence of deformed sedimentary rocks, and hornfels are common along the pluton contacts. The sedimentary rocks are predominantly black shales, and prior to a detailed petrographic analysis and comparison of the Mount Hill and Latady formations we use the term Mount Hill Formation for them. Volcanic rocks assigned to the Antarctic Peninsula Volcanic Group were mapped along the central spine of the peninsula.

In addition to the above rocks, three other mappable units occur within the central Black Coast. The largest of these is a sequence of dark-coloured, conspicuous amygdaloidal rocks that we informally refer to here as the *amygdaloidal basalt of Kamenev Nunatak*, after its type locality (Fig. 1). They are interbedded in the southern part of the area with the second unit, a sequence of grey, silicic, porphyritic volcanic rocks referred to as the *volcanic rocks of Brennecke Nunataks*. Sedimentary rocks form a small part of both sequences. Both rock units are lithologically similar to the metavolcanic rocks included by Singleton in the Mount Hill Formation, and both units are interbedded with this formation in the field area. The third unit crops out only on the eastern side of the Hjort Massif (Fig. 1). It is a deformed sequence of metasedimentary rocks with a lithology that is unlike either the Mount Hill or Latady formations; we refer to this unit as *the metasedimentary rocks of Hjort Massif*. It is overlain by as much as 160 m of the amygdaloidal basalt of Kamenev Nunatak; the nature of this contact is as yet unclear.

The age and precise relationship of these three informal units with respect to the volcanic rocks of the Antarctic Peninsula Volcanic Group, the Mount Poster Formation, and the sedimentary rocks of the Latady and Mount Hill formations, are uncertain and will await further studies. However, it is considered at this stage that both the amygdaloidal basalt of Kamenev Nunatak and the volcanic rocks of Brennecke Nunataks are contemporaneous with the Mount Poster Formation, and are part of the Antarctic Peninsula Volcanic Group. Correlations of the meta-sedimentary rocks of Hjort Massif are uncertain.

Mafic and felsic dykes intrude most of the above lithologies. Although many are undeformed, some are incorporated as amphibolite and schist within the foliated plutons and gneissic granitoids. Some mafic dyke suites are clearly associated with large gabbro bodies.

The structure of the central Black Coast is dominated by a main penetrative cleavage in the Mount Hill Formation and deformation within major shear zones along the eastern margin of the plateau. The shear zones are variable in orientation and contain protoliths of the plutonic rocks, the amygdaloidal basalt of Kamenev Nunatak and the volcanic rocks of Brennecke Nunataks. The main lithologies in the zones of intense deformation are schist and mylonite. Not all of the plutonic rocks are affected by the shear zones; some contain xenoliths of deformed rocks and are clearly post-tectonic with respect to the shear zone deformation. In other places the relationships are unknown, and consequently some plutonic rocks cannot clearly be divided into a pre- and post-tectonic suite.

Breccia were mapped at two localities (Fig. 1). Their origin is uncertain and they may be tectonic breccia or diatremes.

Amygdaloidal basalt of Kamenev Nunatak

This unit consists of interlayered amygdaloidal and massive, non-vesicular, aphanitic, meta-basaltic rocks. White to green coloured, quartz and epidote filled, amygdales are conspicuous (Fig. 2) but not ubiquitous. Relics of angular, plagioclase phenocrysts are preserved in some places. These basaltic rocks are thought to be formed as composite lava flows. The meta-basalt is variably deformed and shows in some places a distinct fabric with elongated amygdales; it grades into amphibole–schist or amphibolite. In many places the basalts are transformed into basic hornfels.

At the type locality, Kamenev Nunatak, the dark meta-basalt is interlayered with grey, foliated tuffaceous breccia and fine-grained laminated tuff. Also at Boyer Spur amygdaloidal basaltic lava flows are interbedded with a sequence, less than 100 m thick, of deformed, dark grey sandstone, thinly layered quartzite and quartz–pebble conglomerate.

Volcanic rocks of Brennecke Nunataks

The volcanic rocks of Brennecke Nunataks are predominantly fine-grained, variably foliated andesite and dacite. These buff- and grey-coloured rocks contain in most places 1–3 mm long phenocrysts of plagioclase and/or quartz. The rocks are variably deformed and occur at many localities as L–S tectonite and schist of intermediate composition. At the southern part of Brennecke Nunataks, foliated porphyritic metavolcanic rocks are interlayered with schist, L–S tectonite and deformed conglomerate. At the northern side of Brennecke Nunataks a massive dacitic rock occurs adjacent to a welded pyroclastic deposit intercalated with black shales.

Mount Hill Formation

The sedimentary rocks of the Mount Hill Formation are mainly fine-grained and the dominant lithology is a black, highly cleaved shale/slate with interlaminated siltstone, and occasional white–buff-coloured quartzite. Grey-green sandstone occurs

Fig. 2. Amygdaloidal basalt of Kamenev Nunatak. The scale is 10 cm long.

as small lenses throughout the sequence and forms both thin- and thick-bedded graded units. Cross-lamination and intraformational shale clasts are common and calcareous nodules are rare. The only fossils discovered during the season were belemnite guards and some poorly preserved (?) plant fragments.

Green volcanic beds are interbedded with the sedimentary rocks at some localities. Soft-sediment deformation structures along the margins of some volcanic beds indicate contemporaneous sedimentary and volcanic activity.

A penetrative S_1 slaty cleavage is ubiquitously present in the fine-grained lithologies; D_1-related macro-folds are rare. The orientation of the S_1 cleavage is variable and may in part be controlled by the granitic plutons. Recorded bedding-cleavage intersection lineations are both gently and steeply plunging. F_2 crenulations are common and non-cylindrical F_2 folds commonly occur along the margins of plutons. On the northern margin of the Beaumont Glacier, F_1 folds are isoclinal, and F_2 medium-scale, moderately plunging folds deform the bedding and cleavage.

Near the margins of the plutons, the formation is thermally metamorphosed, and andalusite, cordierite, garnet and biotite-bearing slate, schist and gneiss are common.

The protolith of the dark-coloured, banded gneiss is at some localities uncertain, but generally assumed to be a high-grade metamorphic rock of the Mount Hill Formation.

Metasedimentary rocks of Hjort Massif

The metasedimentary rocks form a gently westwards-dipping sequence, as much as 250 m thick and 10 km wide, along the eastern margin of the Hjort Massif. The metasedimentary rocks (Fig. 3) consist of highly deformed, interbedded green to

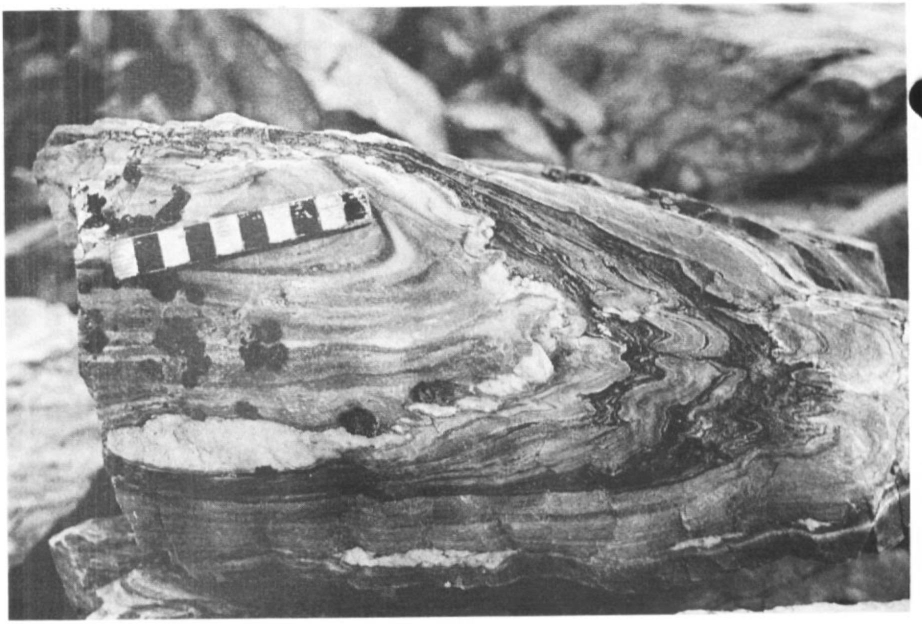


Fig. 3. Folded quartz-rich metasedimentary rocks of Hjort Massif. The scale is 10 cm long.

black phyllite, laminated quartzite and siltstone, pale-coloured sandstone as much as 3 m thick and local green metavolcanic beds. Thin concordant quartz veins and quartz pods as much as 10 cm long are common within the sedimentary rocks. A penetrative S_1 slaty cleavage is subparallel to bedding, it has a well-developed stretching lineation, and is associated with disrupted F_1 isoclinal and tight folds of the sandstone beds. The S_1 cleavage is folded and crenulated by eastward-verging F_2 folds.

Amygdaloidal basalt of Kamenev Nunatak, about 160 m thick, overlies the metasedimentary rocks of Hjort Massif. Although the main boundary between the basalts and the metasedimentary rocks appears to be slightly discordant, the succession is tentatively interpreted as a normal stratigraphic succession. Arguments in favour of such an interpretation are:

(i) there are no indications to suggest a tectonic or intrusive emplacement of the amygdaloidal basalt;

(ii) the deformation history of the amygdaloidal basalt and the metasedimentary rocks appears to be the same;

(iii) the amygdaloidal basalt is interbedded with 2–10 m thick layers of laminated, quartzitic meta-siltstone, which do not show signs of an intrusive or tectonic contact.

A sequence of deformed quartz-rich medium to dark grey sandstone, thinly bedded quartzite and quartz–pebble conglomerate with concordant quartz–feldspar veins, crops out west of Boyer Spur, and there are highly deformed schist and paragneiss in the Du Toit Mountains. These may be equivalent to the metasedimentary rocks of Hjort Massif.

Antarctic Peninsula Volcanic Group (APVG), Undifferentiated

Volcanic rocks of silicic to intermediate composition occur along the spine of the peninsula (Fig. 1) and to the south, including the isolated Jensen Nunatak (73° 04′ S, 66° 05′ W), Mount Vang (73° 26′ S, 67° 69′ W), Gunn Peaks (73° 25′ S, 66° 36′ W), Galkin Nunatak (73° 27′ S, 65° 55′ W), Toth Nunatak (73° 33′ S, 64° 57′ W) and the unnamed nunataks at 72° 58′ S, 65° 36′ W are part of the APVG. Most of these rocks are gently folded and are predominantly welded ash-flow tuff of rhyolite to dacitic composition. Volcanic breccia mainly of mudflow origin as well as lava flows, ranging in composition from rhyodacite to andesite, are also present. Some of the volcanic breccia contains as much as 70% subangular granitic clasts. At Gunn Peaks thin-bedded graded tuff is interlayered with thin-bedded chert and limestone; some of these specimens were collected for possible microfossils.

Plutonic rocks

The plutonic rocks of the central Black Coast can be divided into four major groups: (1) gabbro/diorite; (2) foliated quartz diorite and gneissic granitoid; (3) tonalite/granodiorite; (4) pink porphyritic granite.

(1) *Gabbro/diorite*. Large and heterogeneous gabbro-to-diorite plutons occur on the eastern margin of the central Black Coast and along the central spine of the peninsula. The large plutons are variable in composition and texture, and contain both leucocratic and melanocratic variants. At two localities the gabbro is intruded by granodiorite with a sharp boundary. The gabbro at Mount Whiting is layered and contains some magnetite-rich bands, and the gabbro north of Musson Nunatak has large, 10 m, ultramafic inclusions. In many places the gabbro contains coarse hornblende–plagioclase pegmatitic phases. They are invariably altered, Cu and Fe staining is common, and some are deformed by large ductile shear zones. The gabbro at Cape Knowles, which occurs on the southern margin of a large aeromagnetic anomaly (Renner and others, 1985), has an alignment fabric and is cut by foliated pegmatite.

(2) *Foliated quartz diorite and gneissic granitoid.* Foliated and sheared quartz diorite forms isolated exposures within the Guthridge and Blanchard nunataks along the central spine of the peninsula, and forms a large pluton along the Condor Peninsula. The fabric is defined by aligned mafic minerals, biotite and hornblende, and by deformed mafic xenoliths showing oblate strain.

Two foliated, grey- and white-coloured granitoids are found interlayered on the western side of the Mount Whiting gabbro pluton. The gneissic layering ranges in thickness between 1 and 15 cm, it is folded and cut by late pyrite-filled veinlets.

(3) *Tonalite/granodiorite*. Large homogeneous tonalite and granodiorite plutons are a characteristic feature of the geology of the central Black Coast. The tonalites and granodiorites intrude both the gabbro and the meta-sedimentary rocks of the Mount Hill Formation; within the latter they form large thermal aureoles. They

contain abundant mafic xenoliths that in some places are aligned parallel to the margins of the pluton. These plutons, although for the most part undeformed, are not entirely post-tectonic, e.g. the western margin of the Holmes Hills and Owen Peak pluton is foliated and cut by discrete shear zones. Similarly, an east–west-oriented shear zone deforms part of the Wilson pluton. And the unnamed nunataks, respectively 10 km and 25 km south of the Blanchard Nunataks, contain gneiss and schist. However, some plutons are clearly post-tectonic; examples of these intrude a shear zone south-west of Mount Whiting and the shear zone in the Wilson Mountains. Similar granitoid plutons intrude the foliated plutons and volcanics along the central spine of the peninsula.

(4) *Pink porphyritic granite*. Conspicuous pink porphyritic orthoclase feldspar granite occurs within the Holmes Hills and within the northern Du Toit Mountains. It is very coarse grained; feldspar phenocrysts are as much as 6 cm long. Because of the isolated and rare occurrence of the porphyritic granite, its relationship to the other plutonic rocks is still uncertain.

Dykes

Porphyritic dykes of mafic, intermediate and felsic composition intrude all the lithologies in the central Black Coast. As with the plutonic rocks, there is more than one episode of dyke emplacement. Some mafic and intermediate dykes present within the Mount Hill Formation are pre-tectonic and some mafic and felsic porphyry dykes, included within the gneissic granitoids and diorites, are sheared and foliated.

The Mount Whiting gabbro is cut by a mafic suite that at one locality forms as much as 80% of the exposure. Some of the dykes are foliated; the gabbro is preserved as distinct lenses within the dyke complex. In comparison, a small number of mainly intermediate and felsic dykes intrude the large granitoid plutons. The felsic dykes generally cut the mafic ones. Although dyke trends are variable, the majority are steeply dipping and strike either north or north–north-west.

Breccia

Breccia occurs at two localities: 8 km north of Musson Nunatak and on the eastern side of Guthridge Nunataks (Fig. 1). Both breccias are similar and contain large angular clasts of a wide range of lithologies including granodiorite, gabbro, granitic gneiss and metasedimentary rocks. The breccia near Musson Nunatak also includes large ultramafic clasts (Fig. 4) and is closely associated with a foliated porphyritic felsite dyke. The breccias are clast supported, and contain a small proportion of matrix that predominantly consists of comminuted crystal and lithic fragments in a green chloritic groundmass. They may be diatremes, and the association with the large felsite dyke supports this conclusion. Alternatively they may be fault breccias similar to those described by Meneilly (1983) from Engel Peaks, and represent high level equivalents of the ductile shear zones. The presence of a large number of variably sheared clasts supports this interpretation.

Shear zones and faults

Ductile shear zones cut most rock types within the central Black Coast. These include the gabbro of Musson Nunatak, an east–west striking zone south-west of Mount Whiting, and volcanic and plutonic rocks in a north–south corridor between Musson Nunatak and Brennecke Nunataks on the eastern margin of the plateau.

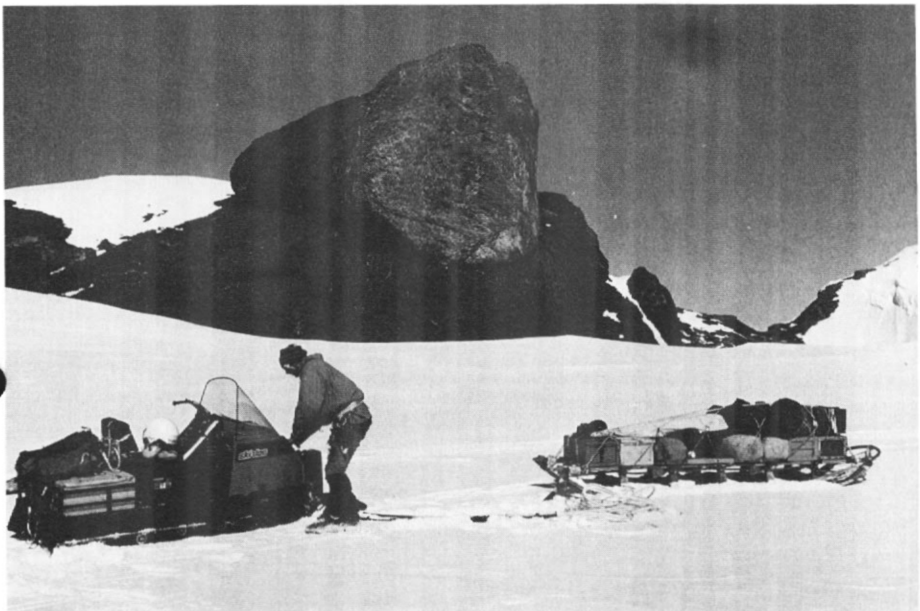


Fig. 4. Large mafic pod (black) within the breccia (grey) near Musson Nunatak.

Within these zones the volcanic and plutonic protoliths are variably deformed to L–S tectonite, schist, mylonite and gneiss. Shear criteria are common and include shear band foliations, asymmetric pressure shadows, folds and *en echelon* vein arrays. The overall kinematics of the shear zones are complex; the main lineations are predominantly steeply plunging and include both normal and reverse movements; sinistral and dextral strike-slip components are also common. The strain is mainly prolate, and many deformed amygdaloidal basalt, and conglomerates were sampled for detailed strain measurements. The shear zone south-west of Mount Whiting contains many undeformed protolith lenses. These are mainly dykes, amygdaloidal basalt and gabbro, but some are ultramafic in composition. Late faults are common and predominantly show apparent dextral offset.

Discussion

The mapping of the central Black Coast region has recognized for the first time a mappable unit of pre-tectonic amygdaloidal basaltic rocks, has identified a major episode of shear-zone deformation, has in part differentiated between an early pre-tectonic and a later post-tectonic magmatic suite, and has discovered an undescribed sequence of metasedimentary rocks (Hjort Massif). Amygdaloidal basalt had previously been recorded to the north but had been included in the Mount Hill Formation by Singleton (1980) and Meneilly (1983), together with silicic volcanic rocks resembling the volcanic rocks of Brennecke Nunataks. Similar lithologies previously mapped as Mount Poster Formation (Rowley and Williams, 1982) were also observed in the southern Black Coast.

The deformed plutonic rocks (Fig. 5) and shear-zone tectonites are most likely correlative with the metamorphic complex of Singleton (1980), which was reinterpreted as shear zones by Meneilly (1983) and was revisited by the authors

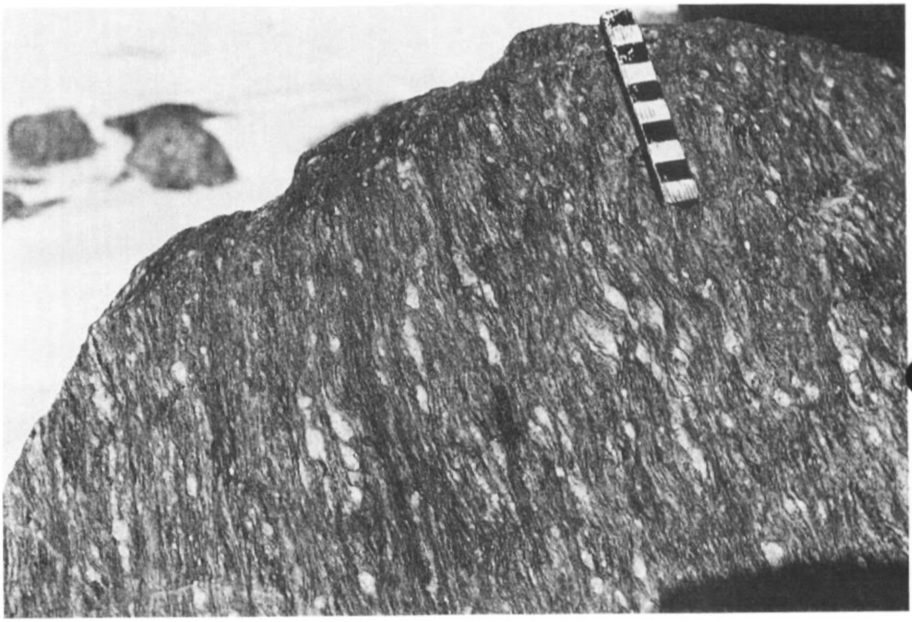


Fig. 5. Sheared granite, showing a normal fault sense of displacement, in the northern part of the Black Coast. The scale is 10 cm long.

during the valuable period of air support. This is an important episode of shear-zone deformation along the eastern margin of Palmer Land, and may represent an important tectonic boundary separating the Antarctic Peninsula from the Weddell Sea.

The central Black Coast has many geological similarities with both the northern and southern Black Coast regions, and forms a transition between a northern terrain that is characterized by sheared plutonic and volcanic rocks and lesser volumes of deformed back-arc basin sedimentary rocks (Mount Hill Formation) and post-tectonic granitic plutons, and a southern terrain that is dominated by deformed back-arc basin sedimentary rocks, subordinate volcanic arc rocks and large post-tectonic Cretaceous granitoids. Although the deformed back-arc basin sedimentary rocks, the deformed volcanic rocks and the post-tectonic granitoid plutons occur throughout the Black Coast region, the sheared plutonic and volcanic rocks have not been mapped in the southern region. The major difference is consequently the absence of shear-zone deformation in the southern region. The shear zones in the north have exposed a deeper structural level and uplifted a suite of deformed plutonic rocks not exposed in the southern region. This change in geology also corresponds to a higher, more deeply dissected topography in the north compared to the south.

There is also a change in the volcanic protoliths southwards. In the north the amygdaloidal basalt forms a mappable unit, whereas to the south they are subordinate to the more widespread silicic and intermediate volcanic rocks.

The age of the deformation and of the protoliths is uncertain. The deformation may be related to late Jurassic to early Cretaceous folding (Williams and others, 1972) of the back-arc basin sedimentary rocks, in which the volcanic and plutonic rocks deformed by simple shear and the sedimentary rocks deformed by folding and cleavage formation. This is consistent with the age of shearing in the Engel Peaks area, where a Lower Cretaceous pluton is deformed (Meneilly and others, 1987).

The age and tectonic significance of the volcanic and plutonic protoliths will await a chemical and isotopic study. They may either be part of a pre- or syn-back-arc-basin related magmatic arc that was subsequently deformed during closure of the basin or it is possible that the mafic components, i.e. the amygdaloidal basalt of Kamenev Nunatak and the large gabbro bodies and associated dyke complexes, are part of the magma emplaced during the extensional, formational phase of back-arc basin development. Therefore this field season may provide valuable constraints on the early arc magmatism and the development stages of the back-arc basin on the east coast of Palmer land. Prior to this, the geology of the back-arc basin province has been related to its infilling and the post-basin magmatism only.

Acknowledgements

We are very grateful to Tony Simpson and Peter Marquis for their enthusiastic support throughout the season; to Richard Hasler and Martin Bailey for the excellent Twin Otter air support; and to John Hall and the many members of Rothera base for their assistance both before and during the field season.

References

British Antarctic Survey. 1982. British Antarctic Territory geologic map, Sheet 5, northern Palmer Land: BAS 500G Series, 1:500,000. Cambridge: British Antarctic Survey.

Meneilly, A. W. 1983. Deformation of granitic plutons in eastern Palmer Land. *British Antarctic Survey Bulletin*, No. 61, 75–9.

Meneilly, A. W., Harrison, S. M., Piercy, B. A. *and* Storey, B. C. 1987. Structural evolution of the magmatic arc in northern Palmer Land, Antarctic Peninsula. (*In* McKenzie, G. D. *ed. Gondwana six: structure, tectonics and geophysics, Geophysical Monograph* **40**, Washington; American Geophysical Union, 209–19).

Renner, R. G. B., Sturgeon, L. J. S. *and* Garrett, S. W. 1985. Reconnaissance gravity and aeromagnetic surveys of the Antarctic Peninsula. *British Antarctic Survey Scientific Reports*, No. 110, 50 pp.

Rowley, P. D., Schmidt, D. L. *and* Williams, P. L. 1982. Mount Poster Formation, southern Antarctic Peninsula and eastern Ellsworth Land. *Antarctic Journal of the US*, **17**, 38–9.

Rowley, P. D., Vennum, W. R., Kellogg, K. S., Laudon, T. S., Carrara, P. E., Boyles, J. M. *and* Thomson, M. R. A. 1983. Geology and plate tectonic setting of the Orville Coast and eastern Ellsworth Land, Antarctica. (*In* Oliver, R. L., James, P. R. *and* Jago, J. B. *eds. Antarctic earth science*, Australian Academy of Science and Cambridge University Press, 245–50.)

Rowley, P. D. *and* Williams, P. L. 1982. Geology of the northern Lassiter Coast and southern Black Coast, Antarctic Peninsula. (*In* Craddock, C. *ed. Antarctic geoscience*, The University of Wisconsin Press, 339–48.)

Singleton, D. G. 1980. The geology of the central Black Coast, Palmer Land. *British Antarctic Survey Scientific Reports*, No. 102, 50 pp.

Suarez, M. 1976. Plate tectonic model for southern Antarctic Peninsula and its relation to southern Andes. *Geology*, **4**, 211–14.

Thomson, M. R. A. 1982. Mesozoic paleogeography of West Antarctica. (*In* Craddock, C. *ed. Antarctic geoscience*, The University of Wisconsin Press, 331–7.)

Vennum, W. R. and Rowley, P. D. 1986. Reconnaissance geochemistry of the Lassiter Coast Intrusive Suite, southern Antarctic Peninsula. *Geological Society of America Bulletin*, **97**, 1521–33.

Williams, P. L., Schmidt, D. L., Plummer, C. C. *and* Brown, L. E. 1972 Geology of the Lassiter Coast area, Antarctic Peninsula: preliminary report. (*In* Adie, R. J. *ed. Antarctic geology and geophysics*, Oslo, Universitetsforlaget, 143–8.)