AUSTRALASIAN ANTARCTIC EXPEDITION
1911-14
UNDER THE LEADERSHIP OF SIR DOUGLAS MAWSON, D.Sc., F.R.S.

SCIENTIFIC REPORTS.
SERIES A.
VOL. IV.

GEOLOGY.

PART 10.

A GROUP OF GNEISSES
(SILLIMANITIC AND CORDIERITIC)
FROM
THE MORAINES AT CAPE DENISON, ANTARCTICA.

BY
DR. C. E. TILLEY (CAMBRIDGE).

WITH ONE PLATE.

PRICE: ONE SHILLING AND SIXPENCE.

Wholly set up and printed in Australia by
THOMAS HENRY TENNANT, GOVERNMENT PRINTER, SYDNEY, NEW SOUTH WALES, AUSTRALIA.
1940.

*62848

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PART 10.

A GROUP OF GNEISSES

(SILLIMANITIC AND CORDIERITIC)

FROM

THE MORAINES, CAPE DENISON, ANTARCTICA.

BY
DR. C. E. TILLEY.

[A.A.E. Reports, Series A, Vol. IV, Part 10, Pages 337–344.
Plate XV.]

Issued, May, 1940.

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A GROUP OF GNEISSES (SILLIMANITIC AND CORDIERITIC).

FROM THE MORAINES AT CAPE DENISON, ANTARCTICA.

BY

DR. C. E. TILLEY (*Cambridge*).

I. INTRODUCTION.

Previous published accounts* of the rock types encountered in the moraines of Cape Denison have covered (*a*) a series of metamorphic limestones, (*b*) amphibolites and related rocks, (*c*) dolerites. An extended account by Stillwell† describes the rock types met with *in situ* at Cape Denison and the neighbouring coast. The following report refers to a series of igneous and para-gneisses occurring in the same moraines.

The collection, representing a selection of gneissic types, consists of twenty-nine rocks, of which somewhat less than half may be described as para-gneisses, the remainder consisting of igneous rocks which have, however, characteristically an abnormal composition.

II. PARA-GNEISSES.

These rocks are typically high-grade metamorphic assemblages characterised by their foliation, coarse grain-size, and the presence of such minerals as sillimanite, cordierite, and garnet. As a group they may be referred to as *sillimanite gneisses*, for sillimanite is present in all available specimens, and the mineral is frequently conspicuous in the hand specimens. The chief ferromagnesian minerals are biotite, garnet and cordierite, with biotite dominant. Quartz, alkali felspar (microline and microperthite), cordierite and andesine are the chief colourless constituents as seen in thin sections.

INDIVIDUAL MINERALS.

Sillimanite is a ubiquitous constituent of the para-gneisses, and occurs either in felted masses together with biotite, as fine inclusions in other minerals or in larger crystals reaching 2–3 mms. in length. In two specimens it is accompanied by *corundum*, idioblastic with positive elongation, the habit being that of squat rhombohedra. In both occurrences the corundum is enclosed in cordierite, and the sliced specimens are devoid of quartz.

Pink *almandine garnets* are conspicuous in many of the hand specimens appearing as small idioblastic dodecahedra or as larger grains (3 to 4 mms. diameter), with typical sieve texture enclosing quartz and elongated in the plane of foliation.

(*) This present report was prepared for publication by Dr. Tilley in 1933 prior to the appearance in print of many of the preceding sections of this volume. [Ed.]

(†) Scientific Reports, Austr. Antarctic Expedition, 1911–14, Ser. A, Vol. III (Geology), Part 1. Parts 2, 3 and 4 contain accounts of rock types from the moraines of Cape Denison.

Cordierite is abundant in some examples. In one rock (100), the mineral occurs in knots reaching 7 mms. in diameter. In thin section this material is fresh and is pinitized only along narrow cracks. Both twinning on (110) and pleochroic haloes around minute zircons are typical. An interesting feature of the cordierites of these rocks is that many of them are optically *positive* with moderately high optic axial angle. This feature is shared also by the cordierites occurring in the igneous rocks to be described. The cordierite, however, is not always fresh. Apart from the usual pinitization along cracks, subsequent hydrothermal action has developed sheaves of light green chlorite intersecting many of the cordierite crystals (612).

In one rock (1270) of composite origin consisting of biotite sillimanite bands veined by pegmatitic streaks, cordierite occurs in large blue crystals associated with quartz and felspar of the pegmatite bands. Cordierite from this rock was separated some years ago by Sir Douglas Mawson, and the purified material was analysed by H. P. White of the Department of Mines, Sydney, New South Wales. This cordierite is of interest as an *optically positive* variety. In thin section it is colourless and but little affected by pinitization. The refractive indices are α 1·534, γ 1·543. 2V = 76°. The analysis is as follows :—

	(1)	(2)	Mol. Prop. (1).	
SiO_2	47·96	50·15	799	5
Al_2O_3	31·52	33·07	309	1·97
Fe_2O_3	1·03	1·52	6	
FeO	3·24	2·22	45	2·27
MnO	1·09	0·12	15	
MgO	12·16	11·01	304	
CaO	abs.	0·29		
Na_2O	0·33	0·14	5	1·0
K_2O	tr.	0·08		
TiO_2	abs.	0·38		
H_2O+	2·80	1·37	155	
H_2O-		0·09		
	100·13	100·44		

(1) Cordierite from garnet-biotite-sillimanite gneiss (1270), Cape Denison. Analysis shows BaO, K_2O, P_2O_5, in traces. Li_2O (spectroscopic).

(2) Cordierite from cordierite anthophyllite gneiss, Attu, S.W. Finland. (Pehrmann: Acta Acad. Aboensis Math. et Physica. 1932. Vol. 6, No. 11, p. 5.)

This analysis is comparable with that of a cordierite from an anthophyllite gneiss from Attu, S.W. Finland. The latter cordierite is also of an optically positive character.

Detailed correlation of the optical and chemical characteristics of cordierites has yet to be made out. A preliminary essay has been made by Pehrmann (*op. cit.*) but with many conflicting data. It would appear, however, that iron-poor cordierites show a positive character, on the other hand, cordierites are recorded as positive containing 7 per cent. Fe. Many of the analyses depart considerably from the ideal composition Al_3Mg_2 $(AlSi_5O_{18})$; in particular the rôle of water in cordierite has yet to be elucidated.

Biotite is the only conspicuous mica of these sedimentary derived rocks. *Muscovite* as a primary metamorphic mineral is present in only one example (680).

FELSPARS.

Microcline and *microperthite* are the dominant felspars but a potash felspar is absent in 100, 609, 806 and 907. The plagioclase is *andesine,* clear and usually with albite twinning. Both *myrmekite* and *antiperthite* are found but are not common.

Magnetite is a constant accessory but becomes an important constituent of one garnet-cordierite-sillimanite gneiss (907). The hand specimen of this rock is a banded type cut transverse to the banding by a cordierite-bearing pegmatite. The rock contains dark bands rich in magnetite which stand out on weathered surfaces. In thin section the magnetite is partly surrounded by fringes of cordierite, the whole being enclosed in quartz, or again, the magnetite may form the core to grains of garnet showing a dendritic intergrowth with fine magnetite (*cf.* also 806). (Plate XV, fig. 1.)

The para-gneisses here described present no very marked similarity to the metamorphosed aluminous sediments of the Cape Gray area[1] east of Commonwealth Bay, though they resemble them in their general high-grade metamorphism. The rocks from the moraines at Cape Denison appear to be uniformly richer in sillimanite and no cyanite is recorded. They can, however, be tentatively ascribed to the same series of metamorphosed sediments, of which examples in place are recorded from the Cape Gray promontory.

III. IGNEOUS ROCKS.

More than half of the specimens in the collection are types with igneous affinities, but none of them can be considered normal igneous rocks. They are characteristically coarse-grained acid rocks, but contain minerals usually regarded as foreign to normal igneous rocks. Of these minerals *cordierite* is the most conspicuous example.

The majority of the rocks are sufficiently coarse-grained and rich in quartz and felspar to come within the category of pegmatites, and most of them might be well designated as *cordierite pegmatites.*

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(1) Stillwell *op. cit.* p. 146 *et seq.*

A few are conspicuously banded and of a pronounced migmatitic character, being made up of material similar to the para-gneisses with injections of pegmatite. More usually the abnormal minerals such as cordierite are evenly distributed in the rocks, as though they were direct crystallisations from the melt.

Petrographically, they may be divided into—

(*a*) Garnet gneiss (168);
(*b*) Sillimanite pegmatite (487);
(*c*) Cordierite pegmatites (the majority of the rocks).

(a) *Garnet gneiss.*

Of the two rocks referred to under (*a*) and (*b*) above, the first is a coarse gneissose rock composed of quartz, microperthite, almandine and biotite. Bands rich in garnet and biotite alternate with bands rich in microperthite and quartz. The latter appear to have been the last to consolidate, as a transgressive relation to the garnetiferous bands is in places obvious. The whole rock gives the impression of a primary gneissic foliation, deformation continuing to a late stage when quartz and microperthite were crystallising from the residual solution.

(b) *Sillimanite pegmatite.*

The second rock deserving notice is a coarse pegmatite with large pink microcline crystals reaching 2 inches in diameter and garnet up to $\frac{3}{4}$-inch diameter, the remaining minerals being quartz, magnetite, some white mica and "faser Kiesel" developed along shear zones. In thin section the quartz areas contain numerous needles of sillimanite and fine plates of muscovite. The "faser Kiesel" zones are seen to be felted areas of sillimanite which, under the influence of shear, have been largely replaced by orientated sericite. Muscovite as a late stage crystallisation occurs in patches associated with quartz and microcline. The rock is a sillimanite pegmatite which has suffered shearing.

(c) *Cordierite pegmatites.*

The remaining rocks are coarse pegmatites in which cordierite is usually a prominent constituent, as seen in hand specimens. This mineral occurs either as clear transparent crystals of a blue colour, or as idiomorphic to subidiomorphic black crystals averaging $\frac{1}{2}$-inch in diameter, but crystals of larger size, 1-inch or more, are also found. In a few examples the habit of the crystals is readily made out as prismatic with a prominent development of the forms 110, 010, 100, together with another prism form (? 130)—conforming to the common habit of cordierite crystals. The black colour of the crystals is due to the alteration or replacement by pinite, in which finely divided magnetite may appear.

The chief minerals of these rocks are microcline-microperthite, quartz and cordierite, while biotite, sillimanite, magnetite and muscovite appear in subordinate though varying amount. Garnet is uncommon.

The cordierites range from clear fresh crystals, which are usually optically positive like the example referred to among the para-gneisses, to turbid crystals, in which residuals of cordierite are surrounded by a pinitic decomposition product. This is not infrequently accompanied by finely-divided magnetite. In extreme examples the pinite pseudomorphs completely replace the cordierite substance.

Two rocks are built essentially of quartz and cordierite and appear to represent extreme members of the cordierite-bearing pegmatite group (Plate XV, fig. 2). Plagioclase (andesine) is usually very subordinate among the felspars, but in one rock (497) it takes the places of the usually predominant microperthite. Sillimanite, the second abnormal mineral of these igneous rocks, is commonly found as swarms of inclusions in the cordierite. but similar fine swarms may appear in the microperthite or at the borders between felspar and cordierite or between felspar grains.

ORIGIN OF THE CORDIERITE PEGMATITES.

Rocks of the type of the cordierite pegmatites described above have not been recorded by Stillwell among the rocks collected *in situ* from the Cape Denison area. The presence of idiomorphic cordierite in these coarse-grained pegmatitic rocks makes clear that this mineral crystallised direct from the melt and does not represent cordierite mechanically incorporated from metamorphosed sediments. The presence of this mineral and sillimanite is to be regarded rather as evidence that aluminous material has been incorporated by reaction and subsequently precipitated.

Though all these rocks are erratics, it seems clear that they have been drawn from a common area. The veins of pegmatitic material in the para-gneisses are similar to and carry the same blue cordierite as that of the cordierite pegmatites themselves. Possibly, too, the abundance of iron ore in some of these rocks is to be traced to the magnetite sometimes richly present in the para-gneisses. We can conclude that both groups of rocks have been drawn from an area comprising aluminous sediments now converted into foliated gneisses and injected by granitic and pegmatitic solutions which have formed rocks of migmatitic type and have reacted with the aluminous minerals of the sediments.

Some of the para-gneisses with lenticles of pegmatite carrying blue cordierite resemble very closely the cordierite gneisses of Degerφ, near Helsingfors. The pegmatitic patches of these Finnish rocks have been attributed to differential anatexis in which the lower melting components (quartz-felspar assemblages) have segretated from the para-gneiss itself.

We are not in a position to decide whether any such process has been operative in the case of these Antarctic rocks. Their high grade of metamorphism makes this possibility not unlikely, nevertheless, the occurrence of coarse pegmatite rocks among the collection makes evident the existence of discrete intrusions injected into a sedimentary terrain from which this collection of rocks has been derived. If the process of differential anatexis has operated in this region, its effects are overshadowed by those associated with the intrusion of igneous rocks.

PLATE XV.

Fig. 1. Cordierite-magnetite-sillimanite gneiss. A banded para-gneiss, layers rich in magnetite accentuating the banding × $\frac{4}{5}$

2. Cordierite-quartz rock. Subidiomorphic crystals of cordierite (dark) completely replaced by pinite in a base of quartz × $\frac{7}{10}$

Sydney: Thomas Henry Tennant, Government Printer—1940.

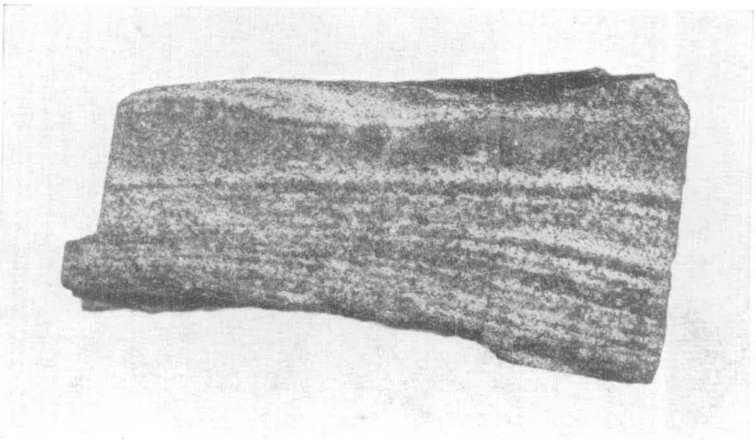

Fig. 1.

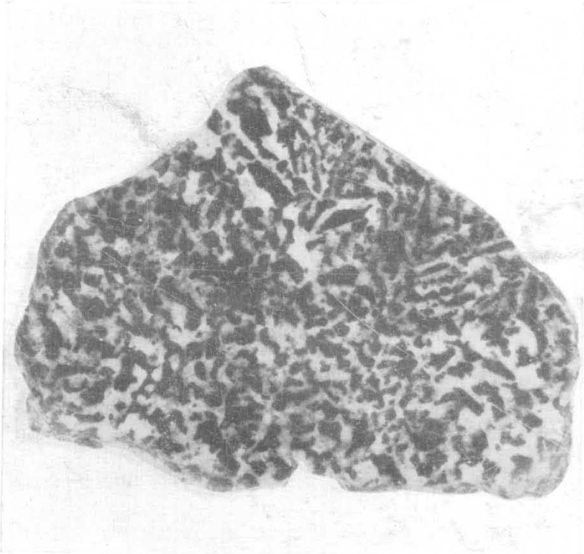

Fig. 2.

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