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THE CRYSTALLINE ROCKS OF EAST GREENLAND BETWEEN LATITUDES 74°30′ AND 75° N.

BY

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WITH 25 FIGURES IN THE TEXT
AND 5 PLATES

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PREFACE

This paper is based upon work done during the Summer of 1948 whilst I was acting as geologist to the Leeds University Greenland Expedition under the leadership of Mr. W. R. B. Battle. The party of four comprising the expedition arrived in Greenland towards the end of July. After establishing a base camp in the Tyrolerdal we split into two groups, the leader and Mr. J. Haines travelled to the Pasterze area to do glaciological work and Mr. D. S. Brock and myself traversed northwards into the Svejstrups Dal—Grandjeans Fjord country to do geological and general survey work. In view of the somewhat limited time at my disposal, amounting, in all to about three weeks, only a general geological reconnaissance was made and much detailed work remains to be done.

I should like to express my thanks and those of the Leeds party as a whole to the Danish Peary Land Expedition who made our work in East Greenland possible. I wish to thank Mr. W. R. B. Battle for giving me the opportunity of accompanying the expedition and Mr. D. S. Brock for pleasant companionship and help during the course of the field work.

The thin sections of the Greenland rocks described in this paper were prepared by Mr. T. F. Johnston and I wish to tender my thanks to him for this work.

The maps given in this paper are based upon the official Danish 1:250 000 maps of Greenland. I wish to thank the Geodetic Institute of Denmark for permission to make use of these maps.

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I. INTRODUCTION

The area of country described in this paper extends from the Tyrolerfjord northwards to the Grandjeans Fjord, between latitudes 74°30′ and 75° N. On the west the area is bounded by the inland ice, on the east by the Mesozoic and Tertiary rocks of Wollaston Foreland, Lindemans Fjord, and Fligelys Fjord. For convenience of description this country will be generally referred to as the 'Svejstrups area'.

Very little previous geological work has been done in the Svejstrups area though a considerable amount is known concerning the geology of the crystalline rocks in the country to the south. The first scientific expedition to visit this part of East Greenland was the German Koldewey Expedition of 1870—72. A short geological account was subsequently given by Lenz (1874, pp. 481—96). It was not until 1926 that anything further was done. In that year the Cambridge East Greenland Expedition under J. M. Wordie penetrated to the Clavering Ø area and the Kejser Franz Josephs Fjord. Wordie (1927) has given an account of this expedition and a brief geological description. Specimens collected from Clavering Ø and Wollaston Foreland during the expedition have been described in detail by Wiseman (1932, pp. 331—33). Backlund (1930, 1932) has given accounts of the metamorphic rocks of Clavering Ø, Payers Land, and Hudson Land. Teichert (1933, pp. 14—26), a member of the Treaarsexpeditionen til Christian den X's Land 1931—34, has described the geology of the Wordies Gletscher area of Payers Land. Mittelholzer (1941), a member of the Geologisk Ekspedition til Østgrønland 1938—39, has given an account of the crystalline rocks of Clavering Ø and Payers Land.

The Mesozoic and Tertiary rocks of the coastal lands between latitudes 74° and 75° N. have been thoroughly described by Maync (1940 etc.) and Vischer (1943 etc).

There are two major morphological units in North-East Greenland, namely a pre-glacial peneplain surface and a system of fjords and related valleys. The peneplain is defined by the general accordance of summit levels over wide areas. The peneplain attains its maximum altitude (2,000—2,500 m) in the inner Kejser Franz Josephs Fjord region. From this area it slopes gently eastwards falling to about 1,000 m in a distance of 200 km (1 in 130). Further north in the area dealt with in this paper the slope is also about 1 in 130, the peneplain falling from 1,750 m to 1,000 m in a distance of about 90 km.

In the Svejstrups area the peneplain lies at an average altitude of 1,000—1,750 m. The highest land lies adjacent to the inland ice (Ledesia Bjerg 1,670 m, Formanden 1,700 m). The main summits of the area are: Th. Thomsens Land 1,600 m, Payers Land 1,700 m, Gross Glockner 1,300 m, Munin 1,199 m, Hugin 1,100 m, Bavnen 1,250 m, Westendspids 1,404 m, Svejstrups Bjerg 1,400 m, and Hohe Kugel 1,337 m.

The East Greenland peneplain is deeply dissected by a series of fjords and related valleys. In the present area there are three major fjords and two valleys. From north to south they are the Grandjeans Fjord, Svejstrups Dal and Lindemans Fjord, and Tyrolerdal and Tyrolerfjord—Young Sund. Accounts of the morphology of the Tyrolerfjord—Young Sund area have already been given (Ahlmann, 1941, pp. 163—76; Flint, 1948, pp. 126—28 and 168—70). The Tyrolerfjord is typical of those of East Greenland, being an overdeepened U-shaped trough sharply intersecting the peneplain surface.

The Svejstrups Dal is a true fjord valley rising very gently from its termination at Lindemans Fjord. At a distance of 24 km from the fjord it is only 150 m above sea-level and at 48 km is at a height of 250 m. The Svejstrups Dal is asymmetric in cross-section where it runs parallel to the strike of the metamorphic rocks and U-shaped where it crosses the strike obliquely or at right angles. The Svejstrups Dal is a strike valley in the upper and lower parts of its course, the dip slopes being on the west and south sides of the valley respectively.

The Grandjeans Fjord, which has a length of 70 km (44 miles), lies mainly transverse to the strike and has a typical U-shaped fjord cross-section. The upper part of the fjord cuts abruptly into the peneplain surface here at an average altitude of 1,200 m.

There is no visible tectonic control of the fjords and valleys in the Svejstrups area of North-East Greenland. Both in the Tyrolerfjord and the Svejstrups Dal the fold structures are continuous across the troughs and faulting if present must have been very slight. Crush zones without appreciable movement could be present but they have not been noted. Most observers consider that glacial erosion has played some part in the origin of the fjords and related valleys though extremists such as Backlund (1930, pp. 290—95) have preferred an almost entirely tectonic origin. A widely held view is that the fjords are glacially deepened fluvial valleys and from observations of the fjords and related valleys of the Svejstrups area the author is in full agreement with this theory.

Two final features of the morphology of the Svejstrups area may be noted. The margins of the crystalline rocks in this area are generally marked by fault scarps trending between N.E. and N.W. (Vischer, 1943, p. 25). One of these faults (the post-Devonian Main Fault of Vischer) is not marked by any scarp but has a wide crush zone and has localized a series of aligned gorges and valleys.

II. STRATIGRAPHY

a. General.

In North-East Greenland between latitudes 74°30′ and 75° N. there are two major geological units, namely the basement crystalline rocks and the Mesozoic and Tertiary sediments and volcanics. The latter occupy the coastal areas on Clavering Ø, Wollaston Foreland, and Kuhn Ø. The stratigraphy and tectonics of these rocks have been worked out in some detail by Vischer (1938—1943) and Maync (1938—1940). A summary geological map and sections is contained in Vischer's 1943 paper. Permian, Triassic, Jurassic, Cretaceous, and Tertiary sediments occur which are largely shallow water or continental deposits. There are many gaps and unconformities in the succession. Largely through the writings of Vischer the area has been made classical ground for the illustration of block-faulting and its relationship to sedimentation. Tertiary basalts in the form of lava flows, sills and dykes are of widespread occurrence particularly on Clavering and Sabine islands and Wollaston Forland.

The crystalline rocks occupy the country extending westwards from the Mesozoics to the inland ice in a belt about 45 km wide. Inliers of crystalline rocks stand up as tilted fault blocks within the Mesozoic sediments faulted on their eastern margins.

The crystalline basement is composed of regionally metamorphosed sedimentary and igneous rocks. The youngest group of rocks are those of the Eleonore Bay Formation generally taken to be of Young Pre-Cambrian age. The crystalline rocks of the Svejstrups area are older than this Formation. On structural and petrographical grounds they have been divided into two main divisions, namely a Basement Series consisting predominantly of orthogneisses, and an upper (Tyroler) series consisting of both orthogneisses and paraschists or gneisses.

b. Basement Series.

Basement gneisses occur in three areas, namely in the vicinity of the Pasterze, Zackenberg and north of the Tyrolerfjord, and in the upper Tvegegletscher.

Pasterze. Only a very cursory examination was made of the rocks in this area. In Ulændedal the Basement Series consists predominantly of dioritic hornblende-gneisses, plagioclase-amphibolites and hornblende-schists. Psammitic and pelitic schists are of subordinate occurrence.

Zackenberg. Much of the mountain of Zackenberg and the country lying to the north of the Tyrolerfjord extending eastwards from Gieseckes Bjerg is composed of orthogneiss. The most widespread type is a medium-grained, grey hornblende or hornblende-biotite gneiss of dioritic to quartz-dioritic composition. The gneisses generally exhibit a well-defined plane banding due to segregation of leucocratic and melanocratic minerals into layers. Subordinate to the dioritic gneisses are more acid biotite orthogneisses. Amphibolites and ultrabasic hornblendite lenses and sills are of frequent occurrence.

Schists of sedimentary origin are much subordinate to the orthogneisses. The prevalent type is a rather coarse-grained garnetiferous psammitic schist. Pelitic schists also occur.

Tvegegletscher. Rocks from the upper part of the Tvegegletscher, adjacent to the inland ice, are predominantly dioritic hornblende and hornblende-biotite orthogneisses, and plagioclase amphibolites. Granite-gneisses are of subordinate occurrence. Pelitic and psammitic schists are present in small amounts.

The gneisses from the above three areas can be matched fairly closely and although their equivalence has not been established with certainty on structural grounds they are tentatively grouped together under the designation Basement Series.

c. Tyroler Series.

In the country lying between the Tyroler and Grandjeans Fjords there occurs a group of schists and gneisses partly of sedimentary and partly of igneous origin which will be termed the Tyroler Series. The following subdivisions of the series have been distinguished:

Tyroler Series (at least 4,500 m)	5[1]) Westendspids Pelitic Group	(at least 2,000 m)
	4 Tyrolerdal Banded Psammitic/Pelitic Group	
	3 Tyrolerdal Group (1,500 m)	
	2 Tvege Banded Psammitic/Pelitic Group (at least 1,000 m)	
Basement Series		

[1]) The numbering corresponds with that on the map and sections of Plate I.

Tvege Banded Group.

This group is magnificently exposed on the valley walls of the Upper Svejstrups Dal adjacent to the Tvegegletscher. The pelitic rocks weather to a rusty brown colour, psammitic schists are light coloured, and amphibolites and hornblende schists are dark. This gives the valley walls a brilliantly banded, multicoloured appearance. The group consists of alternating bands of psammitic and pelitic schists with individual units up to 100 m thick. Semi-pelitic schists are common throughout the group. Intimate banding of psammitic, pelitic and semi-pelitic schists is of frequent occurrence. The schists are garnetiferous and usually contain injected white pegmatite occurring in the form of lit-par-lit bands and augen. Amphibolites and hornblende schists are of ubiquitous occurrence throughout the group. The former generally occur in the form of huge boudinage lenses exceptionally up to 100 m in width. These basic rocks are nearly always garnetiferous.

Tyrolerdal Group.

The Tyrolerdal Group consists of psammitic and semi-pelitic schists, hornblende, hornblende-biotite and biotite orthogneisses, and amphibolites, hornblende schists and other basic and ultrabasic rocks. Pelitic schists are rare.

The hornblendic gneisses closely resemble types occurring in the Basement Series. A characteristic feature in some areas is their complex interbanding with psammitic and semi-pelitic schists. An excellent exposure of a banded complex of hornblendic gneisses and psammitic schists is afforded by the glacially scraped valley floor immediately opposite the Kløftgletscher in the Tyrolerdal. Other banded complexes show a rapid alternation of hornblende-gneisses, hornblende-biotite, biotite-hornblende and biotite gneisses with psammitic schists, quartz-biotite-granulites[1]) and more rarely pelitic schists. The hornblende bearing rocks within the banded complexes range from hornblendites to acid hornblende-granulites containing only small amounts of hornblende. The psammitic and semi-pelitic schists are frequently delicately banded with hornblende layers sometimes less than a millimetre in width. The rocks of these banded complexes may be entirely of sedimentary origin. The intimate and at times exceedingly delicate banding of definitely sedimentary schists with the hornblendic rocks seems impossible of explanation by any other theory. The original dominantly arenaceous sediments may have been intimately banded with marly layers. In this connection it may be pointed out that the shales from which the schists

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[1]) The term "granulite" as used in this account signifies a fine-grained psammitic rock without conspicuous schistosity.

of the Tvege and Tyrolerdal Banded Groups were derived must have been somewhat calcareous, for hornblende is a frequent, though very subordinate, component of some of the schists. The banded hornblendic complexes of the Tyrolerdal Group appear to be closely comparable to the hornblendic complexes within the Moine Series of Sutherland, Scotland (Read and Phemister, 1925, pp. 14—20; Read and others, 1926, pp. 141—45; Read, 1931, pp. 51—69). Read considers that certain of the hornblendic rocks of this area are of sedimentary origin. PHEMISTER (1948, p. 20—21) prefers to regard the banded complexes as resulting from metamorphism of a series of sediments containing bands of tuffs, lavas and associated minor intrusions.

In the Tyrolerdal near the base of the Tyrolerdal Group there are a few thin limestone bands not exceeding 2 m in thickness which are interbedded with psammitic schists. One of these limestone bands outcrops just below the eastern moraine of the Kløftgletscher. Thin bands of calc-silicate rock, rarely more than a few centimetres in thickness, are of fairly frequent occurrence within psammitic and semi-pelitic schists.

In the upper Svejstrups Dal the Tyrolerdal Group is well exposed on the south side of the valley. It consists of psammitic and semi-pelitic schists, fine-grained biotite granite-gneisses, quartz-dioritic to dioritic hornblende and hornblende-biotite-gneisses, hornblende-schists, amphibolites and ultrabasic rocks. The amphibolites occur in large lenticular masses of which a conspicuous example is that on the south side of the Svejstrups Dal immediately to the east of S 5 glacier and at a height of 3,000 m. The whole group of rocks has been intensely injected and cut by discordant pegmatites and veins and dykes of granite. On the west side of Trinity Gletscher the Tyrolerdal Group consists predominantly of hornblende gneisses and quartz-feldspar-biotite granulites, the two types being frequently interbanded.

On the east side of Trinity Gletscher, medium to coarse-grained hornblende and hornblende-biotite gneisses have been intensely permeated by potassic material resulting in the development of large pink porphyroblasts of microcline. Two conspicuous amphibolite bands up to 50 m thick occur on the south side of the Svejstrups Dal immediately to the east of Trinity Gletscher. They occur near the base of a large series of hornblende gneisses. Below the amphibolites are flaggy granulitic schists and pelitic schists.

The Tyrolerdal Group outcrops almost continuously along the lower Svejstrups Dal. An excellent section is afforded by the stream flowing into the Svejstrups Dal on its north side about 5 km below Trinity Gletscher. The gorge in the lower part of the stream course is cut in highly-inclined, flaggy granulitic schists which have been intensely injected and permeated by granitic material (Fig. 1).

The western ridge of the peak 1,246 m consists of granulitic, semi-pelitic and subordinate pelitic schists. Hornblende-gneisses are of frequent occurrence. An interesting feature of the hornblende gneisses is the occurrence within them of narrow bands, never more than a few centimetres in width, of garnet-quartz-hornblende-sphene rock.

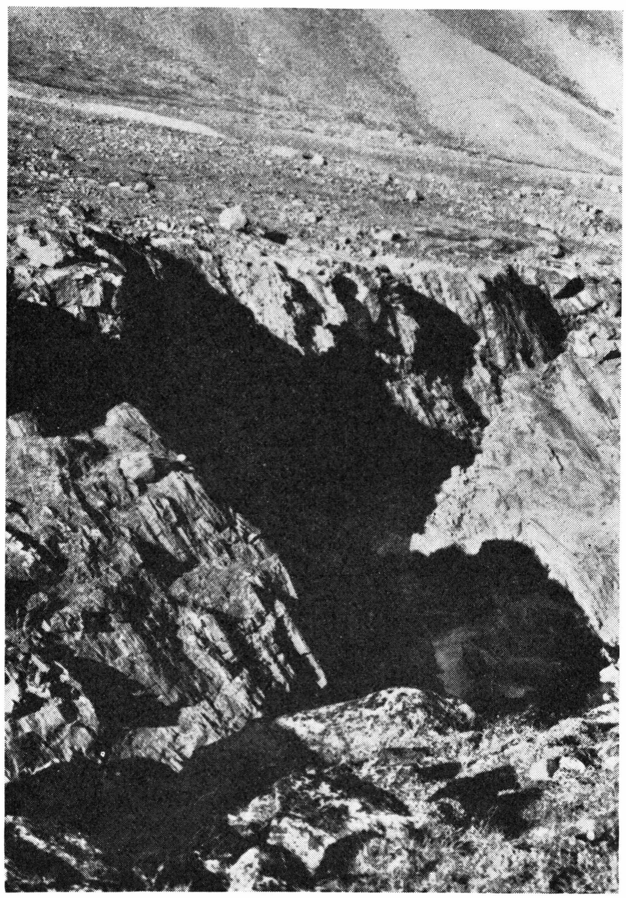

Fig. 1. Flaggy, injected granulitic schists in the gorge of the valley west of peak 1,246 m in the central Svejstrups Dal.

The lower part of Odins Dal immediately north of the Svejstrups Dal affords a continuous section in the Tyrolerdal Group through a height of 300 m. The rocks are predominantly flaggy granulitic schists sometimes banded with hornblende gneisses and containing numerous small sills of amphibolite and hornblende-schist (Fig. 12). Injection is very intense throughout the section.

The dip-slopes on the south side of the lower Svejstrups Dal consist of injected granulitic and pelitic schists, hornblende, hornblende-biotite

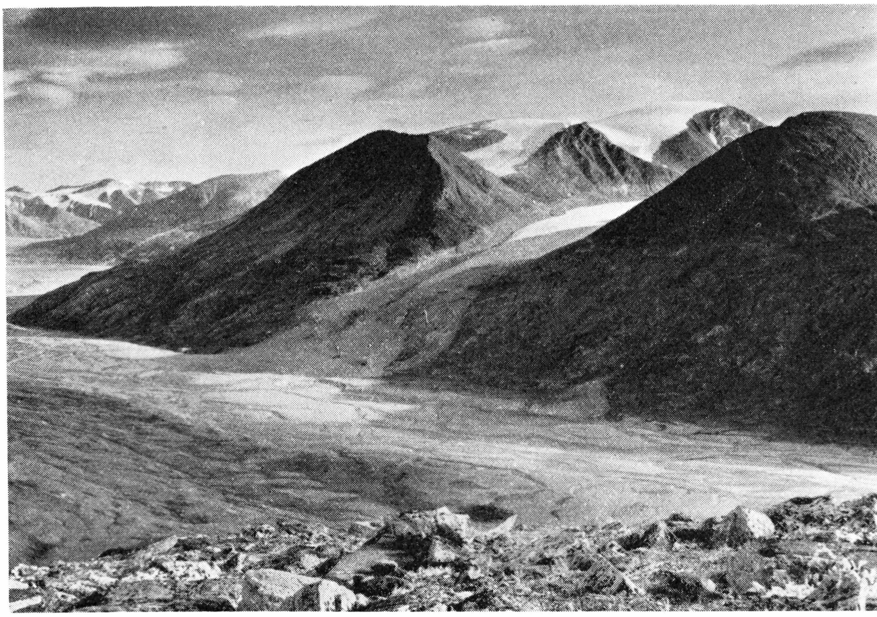

Fig. 2. The lower Svejstrups Dal. The prominent peak on the right is Svejstrups Bjerg (1,400 m). Abandoned lateral and terminal moraine of glacier S_{11} extend well beyond its present position. The prominent dark band on the south side of the valley (left) is a large sill of amphibolite. Dombjerg appears on the left skyline.

and biotite gneisses, and amphibolites. A conspicuous band of quartzite about 30 m thick occurs in the corrie north of the peak 1,337 m. Much of the dip-slope of the valley between Lindemans Fjord and glacier S_{10} is formed by a large sill of garnet-amphibolite up to 100 m in thickness (Fig. 2), Diapthoresis is very common within the rocks of this area. On the east ridge of peak 1,337 m there is a zone of thrusting trending N.W.—S.E. marked by a belt about 40 m wide of intensely sheared, in part mylonitized, rocks. Near the margin of the A. P. Olsens Land ice-cap the dominant rock type is a pink coloured rather fine-grained biotite-granite-gneiss.

At the head of Lindemans Fjord on the north-east side of peak 1,075 m the large amphibolite still referred to above and the schists forming the north slope of the peak are faulted by a N.W.—S.E. fracture zone. To the east of this zone is a series of coarse-grained dioritic, quartz-dioritic or syenodioritic hornblende gneisses forming large smooth slabs on the east face of peak 1,075 m. Svejstrups Bjerg (1,400 m) is largely composed of hornblende and biotite orthogneisses.

A traverse was made from the Svejstrups Dal to the Grandjeans Fjord via the Ødedal. In the valley leading from the Svejstrups Dal to the col at the head of the Ødedal the dominant rock types above the lower gorge are hornblende and biotite orthogneisses frequently showing development of porphyroblasts of potash feldspar. On the col at about 900 m the gneisses are sheared and epidotized for a width of 100 m along the line of the 'post-Devonian main fault'. To the west of this fault the principal rock types are hornblende-biotite and biotite gneisses traversed by numerous pink aplite and granite veins and dykes and showing development of microcline porphyroblasts. To the east of the fault the prevalent rock type is a plane-banded, rather basic hornblende-gneiss. Orthogneisses form much of the western slopes of the Ødedal as far as the Grandjeans Fjord. Psammitic, and more rarely pelitic schists are of subordinate occurrence.

The Tyrolerdal Group appears to comprise much of the country in the vicinity of the upper Grandjeans Fjord from Maagenæs to the Heinkels Gletscher.

The Tyrolerdal Group is well exposed on both sides of the Tyrolerdal and Tyrolerfjord (Migmatite Series of Mittelholzer, 1941) where, along with the Tyrolerdal Banded Group it forms a series of major open folds (Figs. 5, 6). The rocks of the group are intensely injected.

Tyrolerdal Banded Group.

This group is similar to the Tvege Group, consisting largely of an alternating series of pelitic, semi-pelitic, and psammitic schists and subordinate hornblende gneisses, biotite gneisses and amphibolites. Pelitic schists are generally predominant amongst the rocks of sedimentary origin forming individual bands up to 100 m thick.

In the Tyrolerdal and Tyrolerfjord the Banded Group is composed predominantly of garnetiferous muscovite-biotite and biotite schists, semi-pelitic schists and psammitic schists. A typical section in the group, taken from the south side of the Tyrolerdal to the west of the Copeland Gletscher, is shown below:—

Pelitic schist with thin bands of hornblende-schist.
Medium-grained garnet-amphibolite 20 m.
Muscovite-biotite-granulite with thin partings of semi-pelitic schist 1 m.
Banded group of pelitic, semi-pelitic and psammitic schists 3 m.
Garnetiferous muscovite-biotite-schist $^3/_4$ m.
Garnetiferous hornblende-biotite-gneiss $1^1/_2$ m.
Biotite-granulite $^1/_3$ m.
Garnetiferous schist.

In the upper Svejstrups Dal the Tyrolerdal Banded Group occupies in general the upper half of the valley walls on the south side of the river. The alternation of psammitic with pelitic schists gives the group a mar-

Fig. 3. The southern scarp-face of Gere (902 m) in the lower Svejstrups Dal composed largely of psammitic and pelitic schists (dark) of the Tyrolerdal Groups.

kedly banded appearance. In the central Svejstrups Dal pelitic and psammitic schists form much of the mountain of Bavnen (1,250 m), the actual summit being composed of flaggy granulitic schists which are occasionally quartzitic. Boudinages of amphibolite are common in the lower part of the group and there is a sill of enstatite-olivine-pyroxene rock near the col between Bavnen and peak 1,246 m.

The Banded Group is magnificently exposed on the south face of Gere (902 m) in the lower Svejstrups Dal (Fig. 3). Rusty weathering bands of schist alternate with light coloured granulites. Amphibolites and hornblende-schists are of common occurrence.

Pelitic, psammitic, and semi-pelitic schists occupy much of the country lying between the Grandjeans Fjord and the Svejstrups Dal. Orthogneisses are of subordinate occurrence. Good sections are afforded by the streams flowing eastwards from the Bavnen—1,246 m range of hills and by the Odins Dal river. The north-east facing dip-slopes are largely covered by frost-mantle debris and there are few *in situ* exposures. In the Odins Dal river north of the point 407 m highly garnetiferous muscovite-biotite-schists and flaggy granulites are the principal rock types. On the slopes north of Hugin (1,100 m) rusty or purplish-coloured schists, semi-pelitic, and more rarely psammitic schists are the main rock types. The north ridge of Munin is composed of similar rocks and there are some conspicuous bands of amphibolite.

A traverse was made from Odins Dal to the Westendspids and between points 407 m and point 331 m in Blaabærdalen the principal rock type is a semi-pelitic schist grading into granulite or true schist. Calc-silicate bands occur within the more siliceous schists.

Westendspids Pelitic Group.

The Tyrolerdal Banded Group passes upwards into the Westendspids Group which consists predominantly of muscovite-biotite, biotite, and semi-pelitic schists. Amphibolites and psammitic schists are of much subordinate occurrence. This group occupies much of the high ground in eastern Th. Thomsens Land and weathers out to a dark somewhat purplish colour. All the high ground between Hohe Kugel (1,337 m) and the Westendspids (1,404 m) is composed of schist. At least 1,500 m of pelitic and semi-pelitic rocks are exposed on the Westendspids.

Dombjerg paraschists.

The upper 2,000 m of the mountain of Dombjerg (1,444 m) south of Lindemans Fjord is composed of semi-pelitic and pelitic schists and subordinate granulites and quartzites. The position of this group of rocks within the Tyroler Series is not known with certainty but they probably belong to one of the lower groups.

d. Wider relationships.

Clavering Ø and Payers Land.

The following correlations between the rocks of the Svejstrups area and those of Clavering Ø and Payers Land (Mittelholzer, 1941) are suggested.

Clavering Ø	Svejstrups area	Payers Land
Absent	Absent	Upper Eleonore Bay Formation
		Quartzite-phyllite Series
	Westendspids Group	
Biotite gneiss Series		Rusty Series
	Tyrolerdal Banded Group	
		Migmatite Series Transition zone
	Tyrolerdal Group Tvege Group	
Hornblende gneiss Series	Basement Series	Western crystallines

The paraschists of Dombjerg are almost certainly to be correlated with the biotite gneiss series of Clavering Ø.

Grandjeans to Bessels Fjord.

Unfortunately very little is known concerning the stratigraphy of this area. It is probable that the rocks of the Tyroler Series occupy much of the country between the two fjords. The quartzites and phyllites of the Bessels Fjord area (TEICHERT, 1933, pp. 30—1) may be equivalent to the quartzite-phyllite series of Payers Land (MITTELHOLZER, 1941, pp. 17—18), KOCH (1929, pp. 55—56) has recorded weakly metamorphosed rocks from Hochstetters Forland which he considers are part of the Eleonore Bay Formation. Weakly metamorphosed sediments also referred to the Eleonore Bay Formation occupy much of Store Koldewey island (Koch, 1929, p. 66).

Muskusoksefjord Inlier.

Rocks from the Muskusoksefjord inlier have been described by WISEMAN (1932, pp. 321—31). They include gneisses and schists of both igneous and sedimentary origin. The author has examined the rock collections made by the Cambridge Expeditions of 1926 and 1929. Most of the Muskusoksefjord specimens can be matched by rock types from the Svejstrups area. The enstatite-hornblende-peridotite described by WISEMAN (p. 330) may be related to the enstatite bearing rock of the central Svejstrups Dal.

Kejser Franz Josephs Fjord.

Most of the rock types collected by the Cambridge Expeditions in the Kejser Franz Josephs Fjord area can be matched by Svejstrups types. Particular mention should be made of the similarity, both megascopical and microscopical, which exists between cataclastic rocks from the zones of shearing in the Svejstrups area and the zone of shearing on the eastern margin of the 'Central Metamorphic Complex' (WISEMAN, 1932, pp. 33—37).

In the Svejstrups area the Eleonore Bay Formation is underlain by the Tyroler Series. In the Kejser Franz Josephs Fjord (Gregory Valley) ODE (1939, p. 22; 1944, p. 236) has described a continuous succession from the Petermann Series down into the Gregory Series. He regards the uppermost beds of the former series as equivalent to the quartzite series of the Eleonore Bay Formation (1944, p. 241). It seems probably therefore that the Tyroler Series is in part equivalent to the Gregory Series. The metamorphic grade of the two series is similar (almandine garnet to sillimanite) and lithologically there appears to be close correspondence, the Gregory Series consisting of garnetiferous paragranulites, quartzites, pelitic schists and calc-schists.

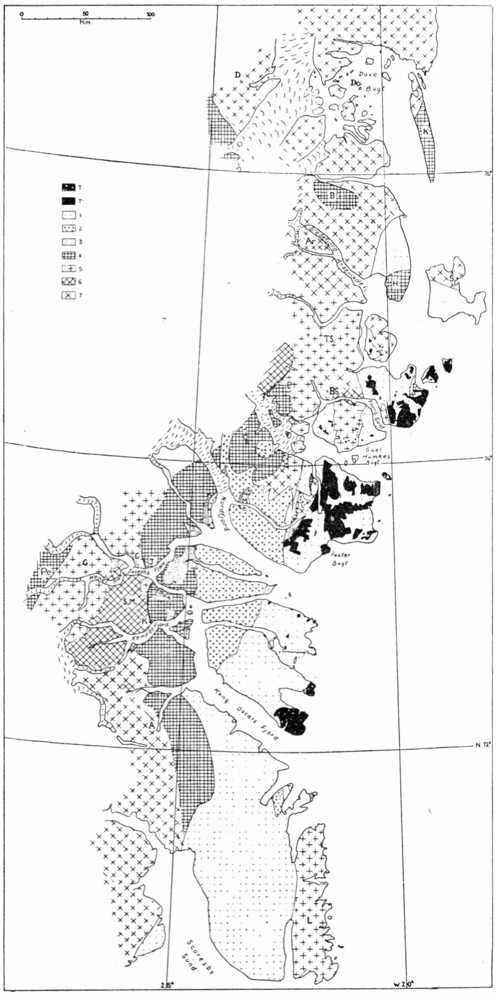

Fig. 4. Stratigraphical map of Central and North-East Greenland. T′. Tertiary basalts. T. Tertiary plutonic complexes.

1. Post-Devonian.
2. Devonian.
3. Ordovician and Cambrian.
4. Young Pre-Cambrian meta-sediments of low metamorphic grade (Eleonore Bay Formation and Petermann Series).
5. Meta-sediments and orthogneisses of high metamorphic grade (probably Young Pre-Cambrian).
6. Older Pre-Cambrian basement gneisses.
7. Undifferentiated crystalline rocks mainly of groups 5 and 6.

Do. Dove Bugt. High grade gneisses and schists of igneous and sedimentary origin (MITTELHOLZER, 1941).

D. Dronning Louises Land. Low-grade meta-sediments probably equivalent to the Petermann Series.

The Basement Series of the Svejstrups area may correspond in part to the Basement Series (ODELL, 1944, p. 223) (or Sylva Maria Group of WEGMANN, 1935, p. 31) of the Kejser Franz Josephs Fjord.

Scotland.

The crystalline rocks of North-East Greenland can be closely matched by types from the Scottish Highlands. The acid to basic orthogneisses of the Basement Series and Tyroler Series are comparable to those of the Lewisian gneiss of the North-West Highlands. Paragneisses and schists of the Tyroler Series are both megascopically and in thin section identical to the common types of the Moine Series. Thin bands of calc-silicate are common to both series. Mention has already been made of the banded hornblendic complexes which are a feature of the Moine Series of Sutherland and the Tyroler Series. Hornblende-schists and amphibolites of the two series are identical.

The Eleonore Bay Formation is probably to be correlated in part with the Dalradian Series of Scotland.

The stratigraphical relationships of the Svejstrups area to the remainder of North-East Greenland are shown in Fig. 4.

K. Store Koldewey. Low-grade meta-sediments probably of the Eleonore Bay Formation (KOCH, 1929).
B. Bessels Fjord. Low-grade meta-sediments (TEICHERT, 1933).
Ar. Ardencaple Fjord. High-grade crystalline rocks.
H. Hochstetters Forland. Eleonore Bay Formation (KOCH, 1929).
S. Shannon. Gneiss complex (LENZ, 1874).
T.S. Tyroler Series. High-grade meta-sediments and orthogneisses.
B.S. Basement Series. Hornblende orthogneisses predominant.
P. Payers Land. Low-grade Eleonore Bay rocks underlain by high-grade meta-sediments and orthogneisses (TEICHERT, 1933; MITTELHOLZER, 1941).
M. Muskusoksefjord Inlier. High-grade orthogneisses and meta-sediments (WISEMAN, 1932).
J. Junctiondal, Kejser Franz Josephs Fjord. Low-grade meta-sediments of the Eleonore Bay Formation thrust over high-grade crystalline rocks (PARKINSON and WHITTARD, 1931).
K. Kempes Fjord. Eleonore Bay Formation thrust over high-grade crystallines of the Sylva Maria Group of probably Old Pre-Cambrian age (WEGMANN, 1935).
S.M. Sylva Maria Group. Probably Old Pre-Cambrian (WEGMANN, 1935). Basement Series of ODELL (1944).
G. Isfjord zone etc., of WEGMANN (1935). Gregory Series of ODELL (1944) consisting of paragranulites and schists of high metamorphic grade.
Pe. Petermann Series. Low-grade meta-sediments (WORDIE and WHITTARD, 1930).
A. Alpefjord. Eleonore Bay Formation separated from high-grade crystalline rocks by a reversed fault (PARKINSON and WHITTARD, 1931).
L. Liverpool Land. High-grade schists and gneisses of igneous and sedimentary origin (KRANCK, 1935).

III. STRUCTURE

a. Folding.

The rocks of the Svejstrups area were folded and metamorphosed during the Caledonian orogeny. The fold axes in the Tyroler Series trend generally between N.E. and N.N.E. and the pitch of the folds lies between N.E. and N.N.E. and the pitch of the folds lies between 5 and 30 on the average. In the Svejstrups area the Caledonian movement was towards the W.N.W. and the folds are sometimes overturned in this direction. The folding may be described as open, consisting of major anticlines and synclines measuring several kilometres from crest to crest. The dominant feature of the structure is the Payers Land syncline. The axis of this fold extends from southern Payers Land north-eastwards into the Svejstrups Dal and it pitches at a very low angle towards the south-west. In Payers Land it exposes weakly metamorphosed rocks of the Eleonore Bay Formation (Mittelholzer, 1941, pp. 8—9). The synclinal axis continues towards the south-west into Stenos Land where the outcrop of the Eleonore Bay Formation broadens out.

The map (Plate I) and sections show the general structure of the Svejstrups area. A description will be given of each section.

Section 1 (A-B). Upper Svejstrups Dal to the Tyrolerdal.

This section has been drawn from observations made of the structures exposed on the east side of the upper Svejstrups Dal and the Verbindungstal (this latter name has been proposed by Mittelholzer for the short valley connecting the Tyrolerdal and Svejstrups Dal; it is not named on the map). The rocks of the Tyroler Series here form the gently dipping western limb of the Payers Land syncline. The section is approximately parallel to the axis of the syncline so that its pitch is represented by the dips of the Tyroler Series along the valley walls. The average pitch over a distance of 20 km is 5°—10°. The true dip of the rocks varies from 10° to 30° towards the E.S.E. An interesting feature of the section is the occurrence of two fold-axes crossing the regional strike approximately at right angles. These are shown on section 1,6 km and 25 km respectively from the terminus of the Tvegegletscher.

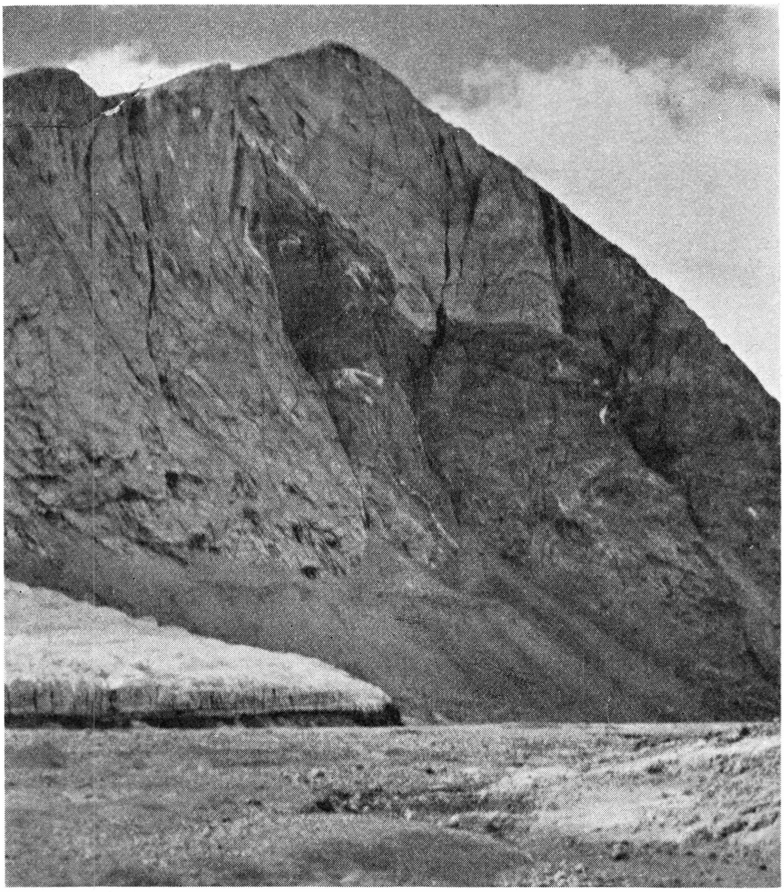

Fig. 5. Small overfold on the eastern limb of the Payers Land syncline in the Tyrolerdal. The Tyrolerdal Banded Group (dark) is composed largely of pelitic, semi-pelitic, and psammitic schists; the Tyroler Group (light) of hornblende gneisses and psammitic schists (section 2, Plate II). Large white pegmatites occur within the schists. Terminal bulb of Copeland Gletscher on the left.

Section 2 (C-D). Tyrolerdal and Tyrolerfjord.

This section is approximately at right angles to the fold-axes. It shows a series of major anticlines and synclines mainly within the lower groups of the Tyroler Series. The folds pitch at small angles, rarely greater than 20°. The major fold is the Payers Land syncline which has a gently-dipping western limb and an overturned eastern limb (Fig. 5). To the west of the syncline the folding in the Basement Series is very open and to the east the Tyroler Series forms a series of major open folds (Fig. 6).

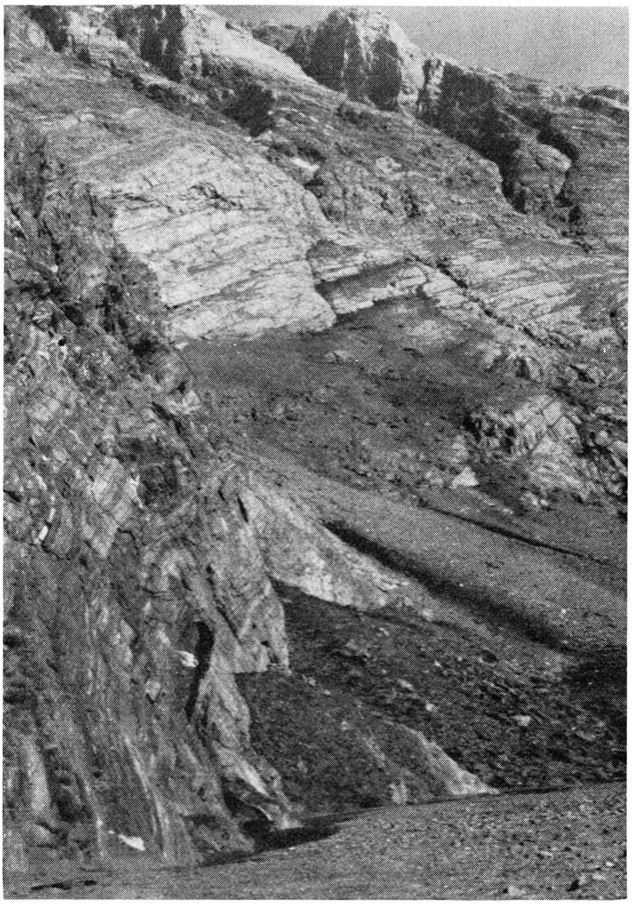

Fig. 6. The western limb of a major anticline in the Tyrolerdal Groups at the head of the Tyrolerfjord.

Section 3 (E-F). Svejstrups Dal.

This section lies generally at right angles to the fold-axes. In the upper Svejstrups Dal, as in the Tyrolerdal, the dominant structural feature is the Payers Land Syncline. The western limb dips gently E.S.E., the eastern limb is highly-inclined and slightly overturned. The detailed structure of the eastern limb of the syncline is shown in Figs. 7, 8. The Payers Land syncline is succeeded to the east by a major complex anticline the eastern limb of which probably forms a back-fold though other structural interpretations may be possible as a result of rurther detailed mapping. In the lower Svejstrups the folding is very open. The The simplicity of the structure is more apparent than real and nappe structures are probably present though further detailed mapping is required before they can be proved.

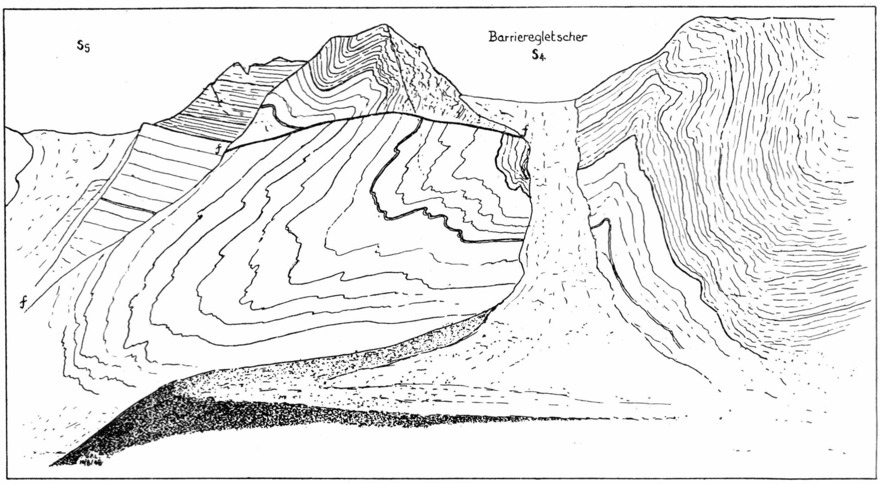

Fig. 7. The eastern limb of the Payers Land syncline in the Svejstrups Dal near Barrieregletscher. Overturning is towards the west. The rocks are intensely injected and flow-folding has occurred. The heavy line on the upper part of the cliffs denotes a fault (f).

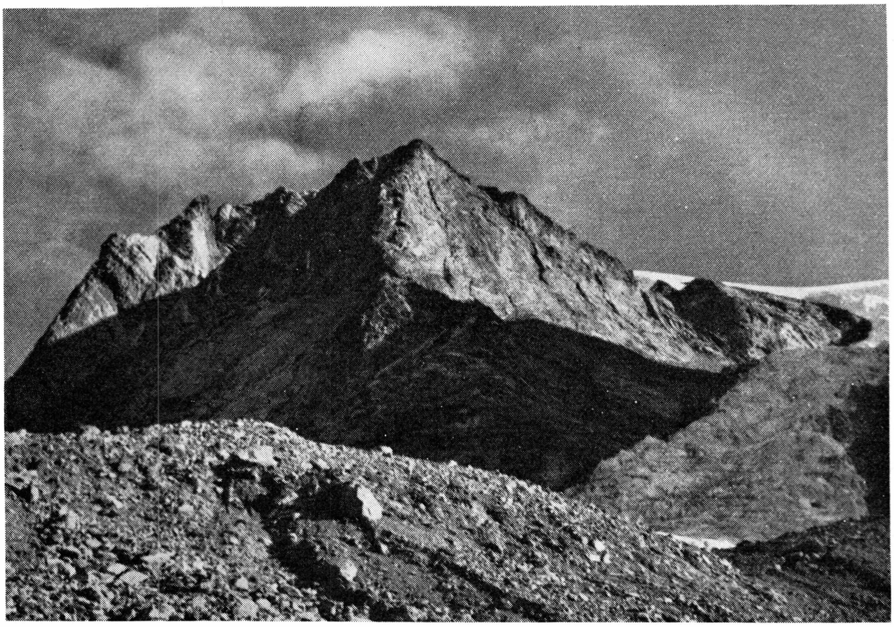

Fig. 8. Barriere Gletscher in the Svejstrups Dal with large lateral moraine (c. f. Fig. 35).

Viewed broadly the Svejstrups area can be divided into two main structural units, namely a central belt of intense folding (Payers Land syncline and folds to the east of it) and two flanking belts within which the rocks are more gently dipping and the folding either very open or consisting of recumbent folds. The folding along the central belt is most intense in the Tyrolerdal and Tyrolerfjord and less intense further north in the Svejstrups Dal (c. f. sections 2 and 3 of Plate I).

The structural and age relationships of the Basement to the Tyroler Series.

The Basement Series consists of a group of rocks which are from structural considerations the oldest in the Svejstrups area. In Ulændedal, Pasterze, the Tyroler Series is thrust over the Basement Series and a similar relationship has been described by Mittelholzer (1941, p. 21) from north Clavering Ø (presuming the Zackenberg hornblende-gneiss series is to be correlated with the Pasterze rocks). In south Payers Land the contact of the Basement Series (Western crystallines) with the Lower Eleonore Bay Formation must be tectonic and probably equivalent to the thrust zone separating the Basement from the Tyroler Series in Ulændedal.

The strike of the Basement Series in the Zackenberg area is E.N.E.—E.S.E. and the strike of the Tyroler Series on Clavering Ø between N.N.E. and N.E. The former strike direction is characteristic of the Old Pre-Cambrian gneisses of East Greenland (Wegmann, 1936, p. 39; Wager, 1947, p. 10; Fig. 9). If the Zackenberg gneisses are of Old Pre-Cambrian age (as is suggested by their general composition) then they were probably folded during a pre-Caledonian orogeny, and later injected and probably re-folded during the Caledonian orogeny. If the Pasterze gneisses are of Old Pre-Cambrian age then their original strike direction appears to have been completely obliterated by later Caledonian folding. The relationships between basement gneisses and the upper gneisses and schists (Tyroler Series) in the Svejstrups area and probably also in much of East Greenland may be analogous to that which exists between the Moine and Lewisian rocks in the Northern Highlands of Scotland. Here inliers of the latter have been folded along with the Moine during Caledonian orogeny and are also affected by contemporaneous regional injection. Generally the strike of the Lewisian inliers conforms to that of the adjacent Moine but there are exceptions.

b. Faulting.

Contemporaneous with the Caledonian folding.

In the central Svejstrups Dal a fold-fault (lag) occurs on the south side of the valley immediately east of Barriere Gletscher (Fig s. 7, 8). The fault, which is marked by a slight amount of crush and epidotization,

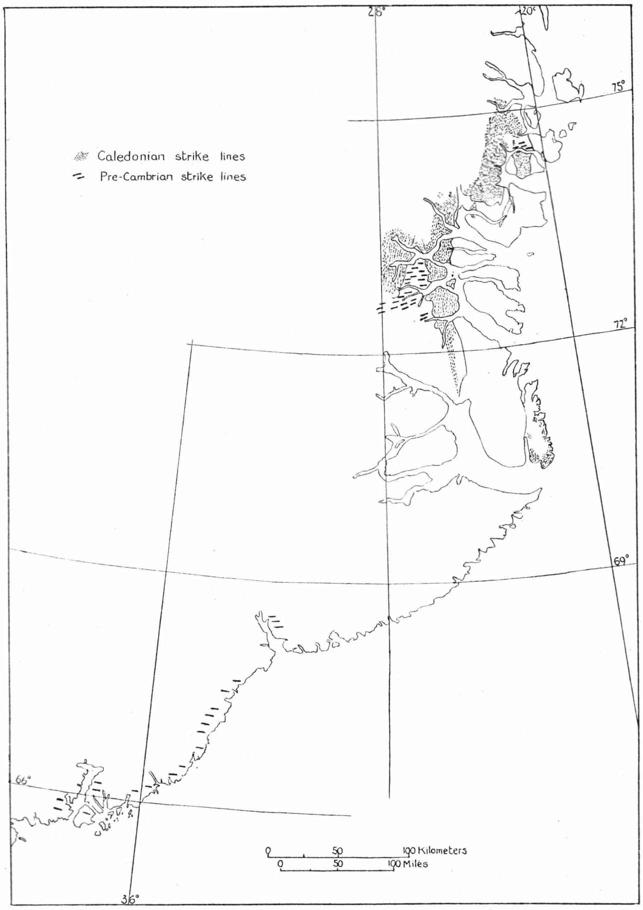

Fig. 9. Strike directions of Pre-Cambrian and Caledonian metamorphic rocks in East Greenland.

follows the axial plane of an overturned anticline. The displacement amounts to about 300 m. The upper unreversed limb has been thinned out and the lower limb of the fold has moved towards the west relative to the upper limb.

Late Caledonian thrust-faulting.

Faulting which is post-folding and metamorphism and probably of late Caledonian age is of widespread occurrence. The faults are in most cases thrusts heading in a general easterly direction. Diapthoresis resulting from these movements is very widespread.

A major zone of thrusting separates the Tyroler from the Basement Series in the Pasterze area. The same thrust zone probably separates the Eleonore Bay Formation from the 'Western crystallines' in the southern part of Payers Land and it does not appear improbable that this thrust system may be equivalent to that described from the Kejser Franz Josephs Fjord—Alpefjord area (Parkinson and Whittard, 1931, pp. 661—65) which separates the Eleonore Bay Formation from high-grade crystalline rocks of Suess Land.

It may be noted that the Caledonian orogeny in East Greenland appears to be comparable in its general chronology with that in the Scottish Highlands where the main period of folding and metamorphism was later followed by post-crystalline thrust movements.

Post-Caledonian normal faults.

Faults of post-Devonian age with a general N—S trend are a major tectonic feature of East Greenland. In the present area they have been described in some detail by Vischer (1943). They are normal faults downthrowing towards the east. The most powerful has been named by Vischer the post-Devonian main fault. This fault was examined by the author in the Svejstrup Dal and the Ødedal. It has a very wide shatter zone exceptionally up to 300 m in width. There appears to be no single well-defined fracture but an intricate series of shear zones, along some of which intense mylonitization has taken place. There is widespread alteration of the rocks along the crush zone, the two most marked types of alteration being albitization and hematitization, the latter imparting a red colour to the affected rocks. The fault is markedly linear, its course being marked by a series of aligned gorges and valleys. The above characteristics of the fault are closely comparable to those accompanying tear-faults probably of Mercynian age in the Scottish Highlands (Kennedy, 1946, pp. 43—57) and it is suggested that the post-Devonian main fault may belong to this class of faults. Unfortunately no definite evidence for a horizontal displacement has yet been obtained. The normal faulting postulated by Vischer may be posthumous.

c. Wider relationships.

From the stratigraphical map (Fig. 4) it will be seen that in East Greenland belts of high-grade crystalline rocks alternate across the strike with belts of weakly metamorphosed rocks of the Eleonore Bay Formation and Lower Palaeozoic. In a broad way therefore it is possible to distinguish a series of major culminations and depressions in the Caledonides of East Greenland. One of the major synclinal axes is the Payers Land syncline which exposes the Eleonore Bay Formation southwards from Payers Land for a distance of 400 km. The outcrop of the Eleonore Bay Formation terminates at its northern end in Payers Land, the S.S.W. pitch of the syncline bringing in high-grade crystalline rocks in the country to the north. South of Payers Land the syncline loses its essential identity being replaced by a series of open folds much interrupted by post-Devonian faults. On the eastern side of this major synclinal structure high-grade metamorphic rocks appear in the Muskusoksefjord inlier and in Hudson Land.

Further south in the Kejser Franz Josephs Fjord—Alpefjord area the Eleonore Bay Formation and Lower Palaeozoic rocks are disposed in a series of open folds measuring approximately 11 km from crest to crest (Parkinson and Whittard, 1931, p. 665; Teichert, 1933). No high grade crystalline rocks are exposed east of the belt of Eleonore Bay and Lower Palaeozoic rocks but it is probable that they underlie the Devonian and post-Devonian sediments and are continuous with the gneisses of Liverpool Land and Hudson Land.

Very little is known concerning the structure of the country to the north of the Svejstrups area. The 'Pre-Cambrian sediments' of the Bessels Fjord area (Teichert, 1933, pp. 30—31) may probably lie along the prolongation of the Payers Land syncline. Photographs of the Ardencaple Fjord country (Boyd, 1948, figs. 80—89) indicate that the folding is very open the banding on the walls being very flat. The possible existence of large scale nappe structures cannot however be ruled out.

IV. REGIONAL INJECTION COMPLEX

Over much of the Svejstrups area the rocks of the Tyroler and Basement Series have been injected by granitic material resulting in the formation of composite or migmatite gneisses. The injection is considered to have been largely contemporaneous with the main period of Caledonian folding and metamorphism.

a. Extent.

Throughout the entire area of country which was examined injection of some sort occurs though it is of very varying intensity. The total area of injected rocks between latitudes 74°30′ and 75° N. exceeds 2,500 sq.km. The injection complex extends both north and south beyond the present area. The general distribution of the injection is shown on Plate II.

In the Ulændedal (Pasterze) the hornblende gneisses are injected by white granite and pegmatite veins and dykes. The hornblende and hornblende-biotite gneisses of the upper Tvegegletscher show a certain amount of white injection. The Zackenberg gneisses lie within an area of very intense injection and are largely composite (Fig. 10).

Injection is intense throughout the Tyroler Series. No schists remain uninjected and the psammitic rocks have been permeated and injected over a very wide area.

b. Nature of the injection.

The injection complex results from the invasion of a wide variety of country rocks by granitic material. This material occurs in three main ways: (1) as concordant lit-par-lit veins and segregations mainly within pelitic and semi-pelitic schists, (2) permeating and soaking the country rocks without conspicuous segregation of material, and (3) as discordant and concordant dykes, veins and sheets of pegmatite, granite and aplite.

The most characteristic rocks of the injection complex are the lit-par-lit injection schists in which the pegmatite material follows the foliation planes of the schist (Fig. 16). In some cases it remains discrete

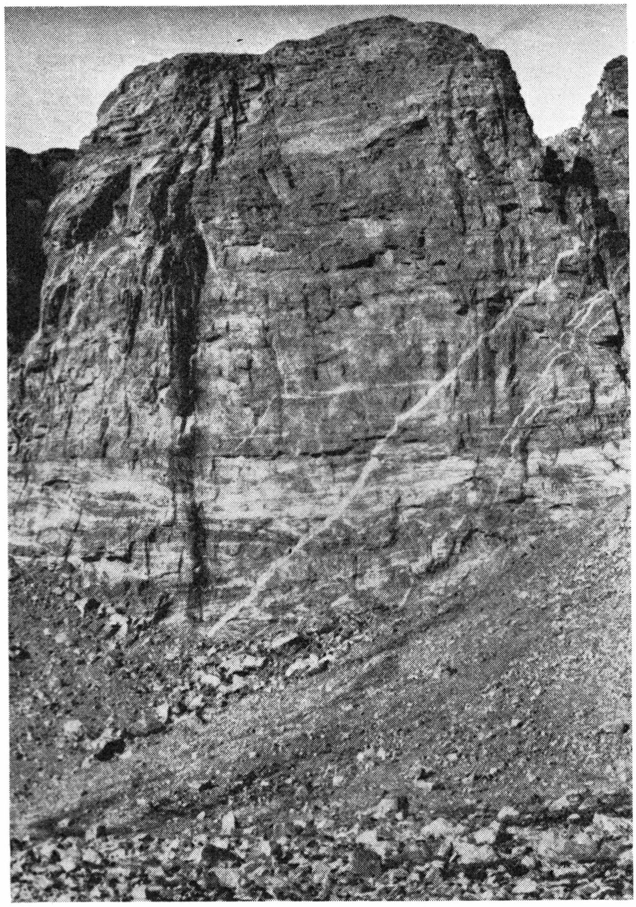

Fig. 10. Concordant and discordant injection in hornblende gneisses on the south slopes of Orienteringsspids, Zackenberg. The mainly concordant injection is most intense at the base of the cliff and is cut by the transgressive pegmatites.

forming thin disconnected bands, but more commonly it is segregated into lenticular augen exceptionally up to 15 cm in width but more commonly averaging 0.5 to 3 cm. These augen may be completely isolated or they may be connected at their nodes by narrow veins. Where the injection is intense the pegmatite may become markedly predominant in bulk over the original schist. Augen injection gneisses occur throughout the injection complex but are best developed in the schists of the Tvege and Tyrolerdal Banded Groups. Granulitic schists within the injection complex are permeated by granitic material unaccompanied by segregation in the general case. Concordant veining of the psammitic schists is of frequent occurrence.

The hornblende gneisses and amphibolites within the injection complex are more resistant to injection processes than the schists and it is only in areas of very intense injection that they have been markedly transformed.

A characteristic type of injection process in the Svejstrups area is seen in the development of feldspar augen and porphyroblasts within all types of rocks. Two distinct types of feldspar occur, namely oligoclase and microcline. Augen of oligoclase are developed throughout the injection complex in pelitic and semi-pelitic schists and more rarely in other rocks. The development of augen and porphyroblasts of microcline is much more localized. A well-defined belt of microcline porphyroblastesis extends from the Grandjeans Fjord southwards to the Tyrolerfjord and beyond.

Belt of Microline Porphyroblastesis.

Though porphyroblastesis and augening by microcline occurs in many parts of the injection complex it is most markedly developed in a belt of country extending from at least as far north as the Grandjeans Fjord southwards through the central Svejstrups Dal to the Tyrolerfjord and into Payers Land and Hudson Land, a total distance of 110 km (Plate II). Mittelholzer (1941, p. 13) has described this belt of porphyroblastesis in the area south of the Tyrolerfjord. It appears probable that the belt of porphyroblastesis lies between definite stratigraphical horizons within the Tyroler Series. This is certainly true of the northern portion of the belt and the southern portion almost certainly lies along the same line of strike. The belt of porphyroblastesis runs parallel to the strike throughout its length. In the northern area the porphyroblastesis affects mainly hornblende and hornblende-biotite gneisses and more rarely psammitic and pelitic rocks.

On the eastern slopes of the peak 1,203 m south of the Grandjeans Fjord the gneisses have been invaded by pink granitic material and there is development of microcline augen and porphyroblasts. Similar injection with occasional development of porphyroblasts occurs within the gneisses on the west side of the Ødedal. In the central Svejstrups Dal porphyroblastesis within hornblende and hornblende-biotite gneisses occurs between glaciers S 7 and S 8. The microline porphyroblasts which occur in this area are exceptionally up to 10 cm in length.

In the lower Svejstrups Dal at the head of Lindemans Fjord the hornblende gneisses contain porphyroblasts of microcline up to 5 cm in length. These gneisses are probably equivalent in part to the hornblende-gneiss affected by porphyroblastesis in the central Svejstrups Dal.

Discordant intrusions within the injection complex.

Late stage transgressive granite, aplite, and pegmatite intrusions in the form of dykes, veins, and sheets are common throughout the injection complex.

Fig. 11. Pegmatite complex cutting mainly hornblende gneisses on the north face of the 1,372 m peak of Zackenberg above the Store Sødal. The pegmatites (which are not too easily seen in the photograph) dip towards the west.

Granite. Sheets of pink coloured granite occur over a wide area of the injection complex but are never abundant. They are most frequent in the Zackenberg-Clavering Ø area (Backlund, 1930, pp. 246—67; 1932, pp. 15—38; Mittelholzer, 1941, pp. 25—31.

Pegmatite. Pegmatites are widely and abundantly distributed throughout the injection complex (Plate II). Belts of specially intense pegmatite injection occur in the Zackenberg area and in the central Svejstrups Dal. Similar pegmatite belts are a feature of Scottish injection complexes (Read, 1931, pp. 143—44; Kennedy, 1940). The Svejstrups Dal pegmatite belt is well exposed on the south face of the peak 1,246 m. Two main groups of white pegmatites can be distinguished. One group consists of thin pegmatites rarely exceeding 3 m in width which have very variable trend and dip, and a second group consists of large pegmatites sometimes exceeding 10 m in thickness which are either horizontal or concordant to the foliation of the gneisses and schists and have considerable lateral extent.

The Zackenberg area of pegmatite injection is extensive covering much of Zackenberg itself and parts of north Clavering Ø. The pegmatites are magnificiently exposed on the north face of the 1,372 m peak of Zackenberg (Fig. 10, 11). A great network of thin pegmatites occupy the cliff face for a height of 1,100 m. The pegmatites on the whole dip at about 60° towards the west. There is no upwards diminution in the intensity of pegmatite injection.

Pegmatites are sporadically distributed throughout the Odins Dal—Westendspids country and within the Tyrolerdal and Svejstrups Dal. The majority of the pegmatites are white coloured muscovite and/or biotite-oligoclase types. Quartz pegmatite dykes, and veins, occur throughout the injection complex.

Aplite. Aplite dykes and veins occur throughout the complex and are particularly abundant and well exposed in the lower Tyrolerdal. Two main types occur, namely pink coloured muscovite-biotite-aplites and white muscovite and/or biotite-oligoclase-aplites.

Structures associated with the injection complex.

The rocks within the areas of most intense injection exhibit structures indicating that they were in a semi-plastic state during the period of injection. Flowfolding occurs on both a large and a small scale superimposed on the major fold structures which were initiated slightly earlier than the regional injection. Such flow-folding is well seen in the upper Svejstrups Dal on the south walls of the valley (Figs. 7, 8), in the lower Odins Dal (Fig. 12), in the Tyrolerdal opposite the Kløftgletscher and elsewhere. It is most marked within pelitic and semi-pelitic schists which are most susceptible to injection.

Two structures characteristic of areas of intense injection are boudinage and injection breccias (agmatites). These structures are particularly well-developed where injection resistant bands of rock such as amphibolite, hornblendite, quartzite, lie within schists and other rocks easily suceptible to injection. Flowage of injection-gneisses round such resistant bands commonly forms boudinage structure and in extreme cases the resistant bands may be split up and blocks become completely isolated within the injection-gneisses to form injection-breccias or agmatites (Fig. 13).

c. Age relationships.

The regional injection is considered to have been largely contemporaneous with the main period of Caledonian folding and metamorphism. That injection took place before stress had entirely ceased is shown by the nature of the injection material, which is always sheared, and by the flow-folding which accompanied the injection. It appears however to be later than the initial periods of folding and metamorphism since the foliation in the schists and other rocks must have been present to enable lit-par-lit veining and injection to take place. The injection complex is

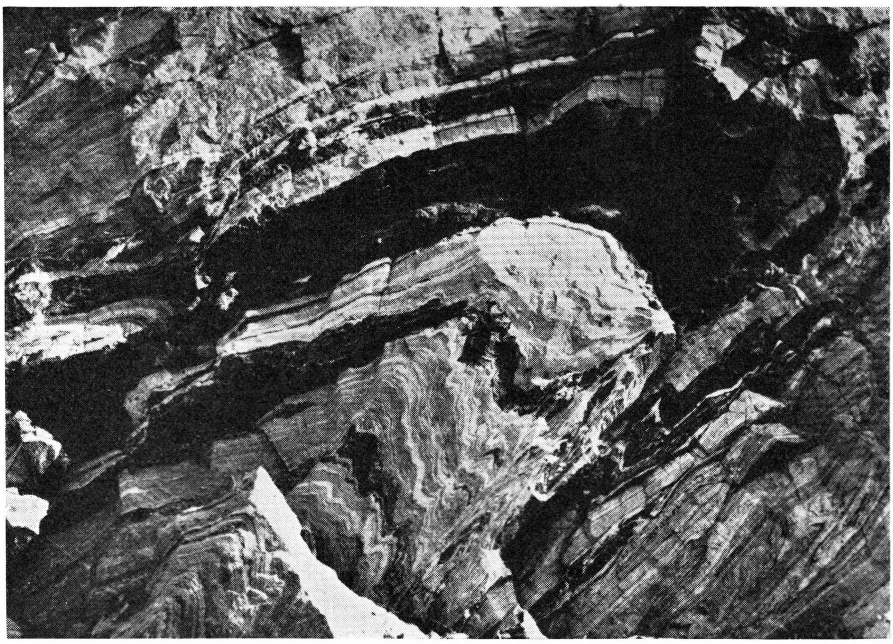

Fig. 12. Intense lit-par-lit injection in psammitic schists, hornblende gneisses, and amphibolites in the lower Odins Dal near the Svejstrups Dal. The latter have proved somewhat resistant to the injection. Flowfolding has occurred. Width of section 2 m.

Fig. 13. Injection-gneisses near the Kløftgletscher, Tyrolerdal. Intense flowage of the gneisses has led to disruption of amphibolite bands and formation of agmatites. Width of section 3 m.

earlier than the late Caledonian thrusting since injection-gneisses have been sheared and granulitized during these movements.

Two distinct types of acid igneous material occur within the complex, namely trondhjemitic and adamellitic to granitic. The transgressive pegmatites, aplites, and granite sheets and the microcline porphyroblastesis of the latter type post-date the schists and gneisses injected by the trondhjemite material.

d. Wider relationships

The inset to Plate II shows the areas in East Greenland where injection, of either Pre-Cambrian or Caledonian age, is known to occur. The Svejstrups injection complex extends further to the north and to the south beyond the present area. Only to the south has it been described in any detail. The list below is a summary of the areas of regional injection in East Greenland.

Dove Bugt. Mittelholzer (1941, p. 36) has mentioned injection-gneisses as occurring in Mørkefjord and on Godfred Hansens Ø.

Bessels Fjord-Grandjeans Fjord. Injection rocks have been described and figured by Teichert (1933) from certain parts of this area.

Falskebugt, Wollaston Forland. Wiseman (1932, pp. 321—23) has described lit-par-lit injection-gneisses from this area.

Clavering Ø. Injection occurs throughout the crystalline rocks of Clavering Ø (Backlund, 1932, pp. 18—22; Mittelholzer, 1941, pp. 20—32). There are several large sheets and intrusions of granite.

Payers, Stenos, and Hudson Lands. The high-grade crystalline schists and gneisses of this area appear to be regionally injected according to descriptions by Backlund (1930, pp. 246—56; 1932, pp. 22—38) and Mittelholzer (1941, pp. 8—13).

Muskusoksefjord inlier. From Wiseman's descriptions (1932, pp. 321—31) it appears that little injection has occurred in the rocks of the inlier. Some of the specimens from the inlier are certainly composite gneisses resulting from injection processes.

Kejser Franz Josephs Fjord. Injection-gneisses from this area have been described by Backlund (1930, pp. 217—46), Wegmann (1935, pp. 30—31), Odell (1944, pp. 227—29) and Huber (1950). Some of these gneisses for example those forming the Sylva Maria Group of Wegmann may have been affected by both Pre-Cambrian and Caledonian regional injection. Composite gneisses collected by the Cambridge Expeditions west of Deceit Bay, Kempes Fjord contain potash feldspar porphyroblasts and augen closely resembling types from the microcline porphyroblastesis belt of the Svejstrups area.

Liverpool Land. KRANCK (1935) has described wide areas of injection-gneisses from the east and west coasts of Liverpool Land, which he considers to be of Caledonian age.

Summary. Although much further geological exploration of East Greenland remains to be done it is apparent from even the few descriptions which are available that the regional injection complex is very extensive. Injection has been described from areas as far apart as Dove Bugt and Liverpool Land and the injection complex thus extends at least 800 km (500 miles) along the Caledonides of East Greenland.

Regional injection occurs in Pre-Cambrian and Caledonian orogenic zones throughout the world. Close comparison can be drawn between the injection complex of the Svejstrups area in the North-East Greenland and the Caledonian Moine injection complex of the Scottish Highlands (PHEMISTER, 1948, pp. 29—33) and Ireland (ANDERSON, 1948) with which the author is familiar. Identical augen injection rocks, porphyroblast gneisses, permeation gneisses, and discordant pegmatite, aplite and granite intrusions occur in both complexes.

V. PETROGRAPHY

a. Basement Series.

The dominant type of orthogneiss within the Basement Series is a medium-grained hornblende or hornblende-biotite-gneiss of dioritic composition. With increase of quartz and biotite the hornblende-gneiss grades into a quartz-dioritic hornblende-biotite-gneiss. The common accessory minerals are sphene, magnetite, pyrite, and apatite.

1847[1]). This rock is a medium-grained hornblende-plagioclase gneiss from the nunatak 1,581 m in the upper Tvegegletscher. It consists of plagioclase, hornblende biotite, and accessory minerals. Quartz is present in accessory amount. Plagio-clases average 0.5—1.5 mm in length and are slightly sericitized; they approximatein composition to An 34[2]); their twin lamellae are bent indicating postcrystallization deformation. The plagioclases in some cases are slightly antiperthitic. Hornblende occurs in generally xenoblastic crystals up to 6 mm in length but averaging 1—2 mm (Fig. 14); it has X pale brown, Y green, Z green and $\widehat{zc}$ 23°. Biotite is present in very small amount almost completely pseudomorphed by chlorite. Apatite is a very abundant accessory (Fig. 14) occurring in euhedral crystals up to 0.3 mm in length. Pyrite is likewise very abundant and probably of secondary origin. Sphene and Magnetite are the other accessories. The rock is cut by veins of clinozoisite. A mode[3]) of this rock is given in Table 2, I.

1851. From the same locality as the previous rock. This is a hornblende-biotite orthogneiss with an average grain size of 1—2 mm. The texture is slightly granulitic. Plagioclase is andesine (An 35) and is frequently antiperthitic containing large irregular patches of microcline. Quartz is present in small amount. Hornblende forms xenoblastic crystals up to 4 mm in length and with X pale brown, Y pale olive green, Z green. Biotite flakes have X pale brown, YZ very deep brown. Apatite is an abundant accessory mineral forming stumpy crystals up to 0.2 mm in length (Table 2, II).

1850. Hornblende-biotite-gneiss from the upper Tvegegletscher. This rock shows good plane-banding; leucocratic bands 1—2 mm in width alternat-

[1]) Numbers refer to rock specimens and thin sections at the Department of Geology, University of Leeds.

[2]) Plagioclase in this and other rocks was determined by measuring the maximum extinction of the albite twinning or using combined albite-carlsbad twinning. In many cases the indices on 001 cleavage fragments were determined, and Tsuboi's tables used to determine the composition.

[3]) Modes quoted in this paper were determined by measuring thin sections on an integrating stage. They are given as volume percentages.

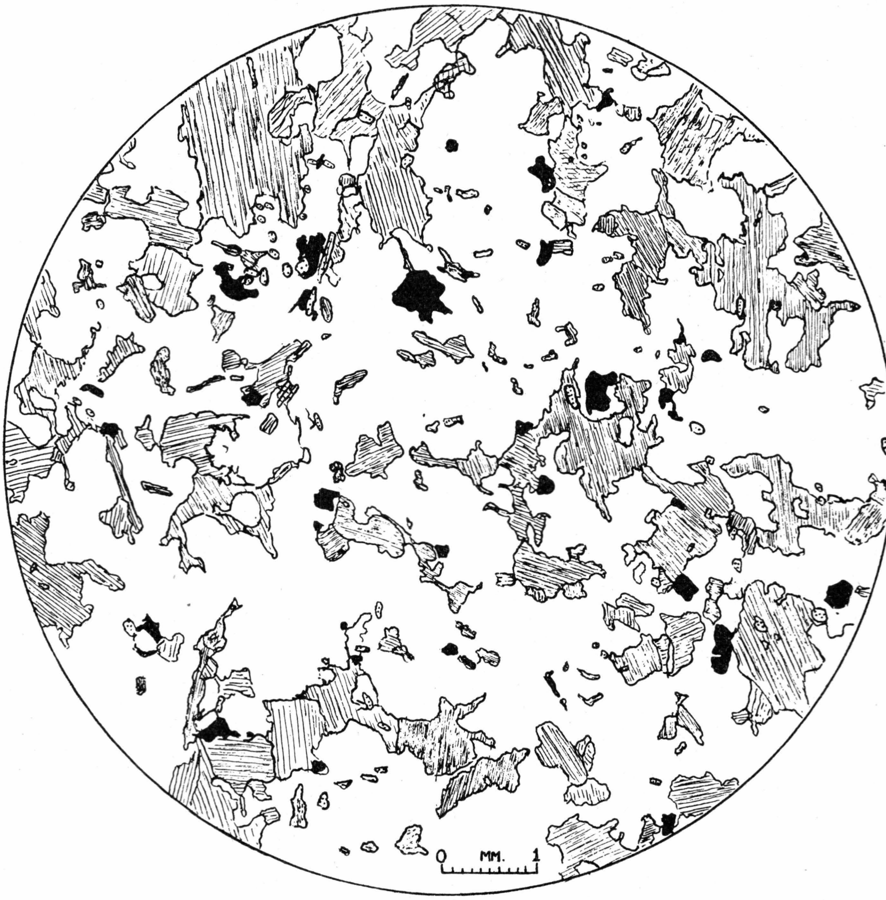

Fig. 14. Texture of hornblende-gneiss, upper Tvegegletscher. Hornblende (lined) pyrite and magnetite (black), apatite (stippled). Leucocratic constituents mainly, plagioclase and a little quartz.

ing with mafic layers. The antiperthitic plagioclase (An35) is very fresh. Quartz is more abundant than in the previous two rock types and a small amount of microcline is present. Hornblende crystals are up to 4 mm in length and contain inclusions of apatite surrounded by haloes. Apatite is an abundant accessory mineral (Table 2, III).

1349. Microcline-granite-gneiss from the upper Tvegegletscher. The rock is markedly leucocratic and contains bands rich in quartz. The texture is granoblastic. Quartz averages 0.1—0.5 mm in diameter and is frequently enclosed within feldspar. Both microcline and orthoclase are present and the latter is perthitic. Plagioclase (An16) is much subordinate to potash feldspar. Biotite is the only dark constituent (Table 2, IV).

The hornblende gneisses of the Pasterze area are similar to those described above from the Tvegegletscher and descriptions need only be given of three special types.

1324. Hornblende-pyroxene-gneiss from Ulændedal. This is a well banded basic gneiss. Plagioclase occurs in fresh laths 0.5—2 mm in length; it is andesine-oligoclase with n′g 1.550[1]), n′p 1.544 (001). A little quartz is present. Hornblende forms well-shaped crystals 1—2 mm in length with X pale brown, Y green, Z deep green. Augite occurs in small crystals generally less than 1 mm in length. Accessory minerals are sphene and zircon the former occurring in rounded crystals up to 0.5 mm in diameter (Table 2, v).

1824. Tremolite-schist from Ulændedal. This rock consists almost entirely of a colourless amphibole and a little plagioclase. The tremolite occurs in well-shaped crystals averaging 1—2 mm in length. They show no pleochroism and have β 1.649. Plagioclase forms about 10 % of the rock and is labradorite (An 50).

1344. Quartz-garnet-pyroxene rock from Ledesia Bjerg (1,670 m). This rock was collected for the author and its field relations are not known. It consists of a coarse-grained aggregate of quartz, garnet, pyroxene, calcite and scapolite. The pyroxene occurs in crystals up to 2 mm in length and has β 1.696; it is deep green in colour and in thin section very pale green and faintly pleochroic. The properties indicate a diopside with about 30 % of the Hedenbergite molecule (Winchell, 1944, p. 226). Reddish coloured garnet is the main constituent of the rock. It is markedly poikilitic enclosing quartz, pyroxene and scapolite. The quartz occasionally forms a type of intergrowth with the garnet. Scapolite occurs in ragged crystals up to 4 mm in length which contain numerous inclusions of quartz. It is partially altered to calcite and zeolite. The scapolite is uniaxial negative with indices less than balsam indicating that it is dipyre. The rock contains several small patches of pyrite and molybdenite.

The genesis of this interesting rock cannot of course be discussed until its field relations are known. The occurrence of the ore minerals pyrite and molybdenite and of calcite, diopside, scapolite and garnet strongly suggest that it may be a skarn rock. Such rocks have already been described from East Greenland (Kranck, 1935, p. 10, pp. 59—60). Molybdenite occurs in metamorphosed Cambrian limestones adjacent to a granite batholith in Morocco (Heim, 1934, pp. 78—79). The molybdenite is associated with garnetite rocks as in the Greenland case. Elsewhere in the world molybdenite frequently occurs at granite/limestone contacts.

The hornblende gneisses of the Zackenberg area are similar to those occurring in the Pasterze and Tvegegletscher country. Ultrabasic hornblendite rocks are of frequent occurrence.

1312. Hornblende-gneiss from 1,000 m on the south slopes of Zackenberg (Orienteringsspids). This rock is fairly typical of the hornblende-gneiss series. It consists of hornblende, plagioclase, orthoclase and quartz. Plagioclase crystals average 2—3 mm in length and are oligoclase (An 15); they are intensely sericitized and clouded by opaque material probably iron ore. Quartz shows a tendency to aggregate into groups of crystals up to 3 mm in diameter; it is sometimes replaced by plagioclase. Hornblende crystals have been largely

[1]) Refractive indices were determined by the immersion method and are correct to ± 0.003.

replaced by chlorite. Accessory minerals are allanite, which occurs in zoned crystals averaging 0.1 mm in length and sometimes containing small inclusions of zircon, and apatite (Table 2, VI).

1329. Hornblendite from 500 m on the south slope of the Orienteringsspids. Large blades of hornblende exceptionally up to 2 cm in length make up much of the rock; the pleochroism is X pale brown, Y green, Z deep green. The hornblende is much altered along cleavage cracks to epidote and sphene is also a frequent alteration product. Plagioclase much altered to zoisite and sericite occurs interstitially to the hornblende. Biotite is present in small amount and has been largely altered to chlorite. Apatite is an abundant accessory mineral sometimes forming crystals up to 0.5 mm in length (Table 2, VII).

1325. Hornblendite from the south slopes of Zackenberg. This rock differs from the above in being finer in grain and containing slightly more plagioclase. The plagioclase is intensely sericitized and has n'g 1.550, n'p 1.542 indicating a calcic oligoclase. Hornblende has β 1.657 and $\widehat{zc}$ 20°. Biotite has been entirely pseudomorphed by chlorite (Table 2, VIII).

b. Tyroler Series.

1. Paraschists.

Psammitic schists.

Rocks of this group are common throughout the Tyroler Series. The more quartzose varieties are massive quartz-feldspar-granulites or quartzites grey or white in colour and containing little or no mica. By increase in mica and feldspar these quartzose granulites grade into flaggy quartz-feldspar-biotite and quartz-feldspar-muscovite-biotite-granulites. Further increase of mica and feldspar produces the semi-pelitic schists. Quartz-feldspar-granulites

1334. This rock is a granoblastic aggregate of quartz, feldspar, biotite and muscovite. Quartz is the principal constituent of the rock occurring in sutured grains averaging about 0.3 mm in diameter but occasionally occurring as in crystals up to $^1/_2$ cm across. Plagioclase (acid oligoclase) forms crystals up to 3 mm in length. Biotite occurs in flakes averaging 0.4—1.5 mm and has the following pleochroism; X pale yellow, Y and Z reddish brown. It is sometimes altered to chlorite and rutile. Fresh laths of muscovite average 0.5 mm in length. Accessory minerals are zircon and magnetite (Table 3, I). This rock comes from the upper Svejstrups Dal near glacier S3.

1322. Coarse-grained quartzose granulite from the valley north of 1,246 m peak in the central Svejstrups Dal. The rock consists of a granoblastic aggregate of quartz, feldspar, and biotite. Quartz grains average 2 mm in length and slightly elongated. A very small amount of plagioclase is present; it is a sodic oligoclase and has been partially altered to clinozoisite. Biotite is the only mica present and has X pale yellow, Y and Z reddish brown. Magnetite is the inly accessory mineral (Table 3, II).

1841. Granulite from 750 m on the south slopes of Dombjerg. Quartz forms about 70 $^0/_0$ of the rock occurring in rounded grains 0.5—1 mm in diameter. Plagioclase (An 13) forms about 20 % of the rock. Microcline is present in very small amount. Biotite is the only mica. Garnet is present in small amount.

Quartz-feldspar-mica-granulites

1340. Quartz-feldspar-muscovite-granulite from the upper Odins Dal stream about 4 km north of point 407 m. This rock shows a good schistosity. In thin section it is a granoblastic aggregate of quartz, feldspar and mica the individual crystals averaging 1—2 mm in length. The quartz crystals are markedly sutured and interlocking. Plagioclase exceeds microcline in amount. Muscovite forms fresh laths 0.5—1 mm in length which sometimes contain small inclusions of quartz. Biotite is subordinate to white mica; it contains pleochroic haloes probably round zircon inclusions. The parallel arrangement of the mica flakes imparts a good schistosity to the rock. Accessory minerals are sphene and zircon (Table 3, iii).

1832. Quartz-feldspar-biotite-muscovite-granulite from the summit of Munin (1,199 m). Quartz is the principal constituent of the rock in crystals averaging 2—4 mm in diameter which are sutured at their margins. A small amount of potash feldspar and plagioclase is present. Muscovite flakes are 0.5—1.5 mm in length and show replacement by quartz. Biotite is slightly greater in amount than muscovite and has X colourless, Y and Z reddish brown. Accessories are sphene, magnetite, garnet, and zircon.

1835. Quartz-feldspar-biotite-granulite from the Tyrolerdal Group in the upper Svejstrups Dal. Rounded quartz crystals form about 70 % of the rock. Poikiloblastic garnet forms about 1—2 % of the rock. Accessories are zircon, magnetite, and epidote.

Semi-pelitic schists.

Semi-pelitic schists are intermediate in composition and texture between the granulitic schists and the true pelitic schists. They contain more mica and feldspar than the granulites. The dominant feldspar is oligoclase and potash feldspar is very rare or absent.

1789. Semi-pelitic schist from the summit of Bavnen (1,250 m). The main constituents are quartz and mica. The former occurs in crystals averaging 0.5 mm in diameter and shows no tendency to be elongated. Fresh biotite and muscovite are present in about equal amounts and are in parallelism imparting a good planar schistosity to the rock. The two micas are frequently intimately intergrown. Oligoclase is the only feldspar present. Garnet crystals are up to 0.6 mm in length and show slight elongation along the foliation. Accessory minerals are zircon, magnetite and apatite.

1316. Garnetiferous semi-pelitic schist from the ‘col’ between Odins Dal and Blaabærdalen. This rock consists of a granoblastic aggregate of garnet, biotite, oligoclase, quartz, and chlorite. The quartz is partially sutured and occurs in crystals varying from 0.5 to 2 mm in diameter. Plagioclase (An 20) is partially sericitized. A little orthoclase is present. Biotite is the only mica and has been partially or entirely pseudomorphed by chlorite. Garnet forms rounded or elongated crystals partially chloritized along fractures. Epidote is a common accessory mineral. This rock comes from the vicinity of a shear zone which accounts for the considerable amount of diapthoresis (Table 3, iv).

1837. Biotite-hornblende-schist from 750 m on the eastern ridge of Gere (902 m). Quartz occupies about 30 % of the section, plagioclase (An 20) about 40 %. Hornblende occurs in xenoblastic crystals averaging 0.5—1 mm in length and with X colourless, Y pale green, Z green. Biotite is slightly subordinate in amount to hornblende forming 5—10 % of the rock. Magnetite and apatite are accessory minerals. The presence of hornblende in this rock indicates that the original sediment was somewhat calcareous.

Pelitic schists.

The pelitic schists are highly micaceous, thoroughly schistose rocks, invariably garnetiferous. The garnets may attain extraordinary dimensions. On the summit of 1,246 m peak in the central Svejstrups Dal and in the upper Odins Dal area near pt. 407 m well formed rhombic dodecahedra of garnet attain a diameter of 8 cm and 4 cm is quite common. The principal feldspar in the schists is acid plagioclase. Both muscovite and biotite occur and the latter is generally predominant. Schists composed largely of only one kind of mica are rare. Throughout much of the Svejstrups area the pelitic schists have been modified by injection processes and are more correctly described as injection and augen gneisses.

1821. Biotite-muscovite-schist from a point 1/2 km northeast of pt. 407 m in the Odins Dal. Quartz and micas are the principal constituents, the former occurring in crystals averaging 2.5 mm in length. Plagioclase (acid oligoclase) is the only feldspar present. Biotite is the dominant mica; it has the following pleochroism; X colourless, Y and Z reddish brown. Accessory minerals are magnetite, garnet, and zircon.

1317. Garnetiferous-biotite-hornblende-schist from the west side of the Svejstrups Dal immediately below the Tvegegletscher. Quartz and plagioclase are present in about equal amounts in crystals averaging 2 mm in length. The latter shows abundant fine albite twinning which is a characteristic feature of the plagioclases in pelitic schists. Biotite is the most abundant constituent of the rock occurring in flakes 0.1—1 mm in length which have a distinctive pleochroism; X pale yellow-brown, TY and Z deep reddish-brown. The reddish-brown colour for the maximum absorption is very distinctive and closely resembles that of hornfels biotite. The rock contains a few scattered xenoblastic crystals of hornblende up to 5 mm in length showing alteration to biotite (Table 3, v).

Limestones.

Linestones are rare in the Tyroler Series. They have only been found in the lower Tyrolerdal of which a typical example is described below.

1786. Diopside marble from below the Kløftgletscher, Tyrolerdal. Calcite is the principal constituent of the rock forming ragged crystals averaging 1.5 mm in diameter. Poikiloblastic diopside forms stout prismatic crystals up to 3 mm in length. Chlorite occurs in flakes up to 1 mm in length which show a pale green pleochroism. A few flakes of white mica are present.

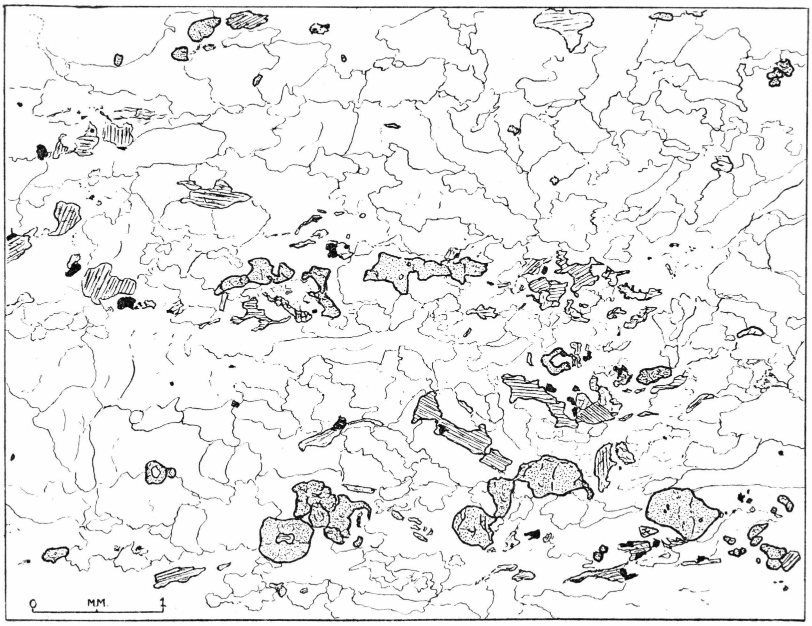

Fig. 15. Calc-silicate granulite. Hornblende (lined), garnet (stippled), magnetite (black). Leucocratic constituents mainly quartz, and a little plagioclase.

Calc-schists.

Thin bands of calc-silicate granulite occur sporadically within the paragranulites of the Tyroler Series particularly in the Tyroler Banded Group. They consist of quartz, biotite, hornblende, feldspar, garnet and zoisite and represent thin sedimentary bands of slightly argillaceous calcareous sandstone. Similar rocks have been described from the Moine Series in the Scottish Highlands (Flett, 1912, pp. 42–45; Read, 1931, pp. 131–33; Kennedy, 1949).

1326. Calc-silicate schist on the south side of Ulændedal. This rock is shown in Fig. 15. The principal constituents are quartz, plagioclase, garnet, and hornblende. Quartz is much the most abundant mineral occurring in elongated crystals 1—3 mm in length. Plagioclase (acid oligoclase) is present in small amount. Hornblende forms xenoblastic crystals averaging 0.5 mm in length; it is much altered to magnetite and chlorite; the pleochroism is X pale brown, Y green, Z deep green. Small pink crystals of almandine garnet are scattered throughout the rock and frequently contain inclusions of quartz and feldspar. Biotite, zoisite, and chlorite occur in accessory amounts (Table 3, vi).

1319. Calc-schist from the 'col' between Odins Dal and Blaabærdalen. This rock is richer in biotite and plagioclase than the preceeding. Quartz crystals average about 1 mm in diameter. Plagioclase (sodic oligoclase) is abundant in crystals averaging 0.5 mm in length. Biotite is more common than hornblende which occurs in xenoblastic crystals 0.5—2 mm in length.

Garnet occurs abundantly in small pink crystals not exceeding 0.5 mm in diameter (Table III, VII).

1321. From the same locality as the above. Plagioclase is a sodic oligoclase partially altered to sericite. Hornblende and biotite occur in about equal amounts. Garnet crystals up to 2 mm in diameter are partially chloritized. Epidote and zircon occur as accessories (Table 3, VIII).

Garnet-hornblende-plagioclase-quartz rocks occurring within the Tyroler Series, as thin bands not exceeding a few centimetres in width, are probably of sedimentary origin. They do not resemble the normal calc-silicate granulites, being richer in plagioclase, garnet, and hornblende. They are banded with psammitic and pelitic schists. Two typical examples will be described.

1332. From the lower Tyrolerdal near the head of the fjord. This rock is well banded showing alternation of mafic and leucocratic layers. The texture is granoblastic and the average grain size is 0.5—1.5 mm. Quartz forms about 30 % of the rock. Plagioclase (An 26) is extensively sericitized. Hornblende crystalsen close garnet and feldspar. Garnet is abundant in rounded or slightly elongated crystals 0.4—1 mm in diameter. They are partially altered to chlorite and epidote. Biotite has been largely replaced by chlorite. Accessory minerals are sphene, magnetite, and hematite (Table 3, IX).

1314. This rock is from the Tyrolerdal Group on the west side of Trinity Gletscher. The banding is very marked. In texture and composition this rock is similar to the previous type. Hornblende and plagioclase are present in somewhat greater amount (Table 3, X).

2. Orthogneisses.

The orthogneisses of the Tyroler Series embrace a wide range of rock types ranging from acid to ultrabasic. The prevalent types are hornblende and hornblende-biotite gneisses representing original dioritic to granodioritic igneous intrusions. Amphibolites and hornblende-schists are very common throughout the series and represent pretectonic or syntectonic basic sill and dyke intrusions. The orthogneisses are commonly garnetiferous, the basic rocks are nearly always so.

Biotite gneisses.

Most of the rocks of this group are of granodioritic or more acid composition with potash feldspar either equal to, or not markedly less in amount than plagioclase. Hornblende is absent or subordinate to biotite. Four representative types will be described in some detail.

1337. Biotite-hornblende-gneiss (granodioritic) from the small valley 3 km N.N.E. of 1.246 m peak in the Central Svejstrups Dal. The principal constituents of this rock are quartz, feldspar, and biotite. The quartz crystals average 1—1.5 mm, exceptionally up to 5 mm in length. Plagioclase (sodic oligoclase) is the dominant feldspar forming fresh laths 1—2 mm in length. It is myrmekitic at its contact with potash feldspar. Microline-microperthite is an important constituent of the rock though subordinate in amount to plagioclase. Hornblende and biotite are present in very small amounts. Hornblende has a deep green pleochroism. Sphene, zircon, and apatite occur as accessories (Table 2, ix).

1800. Biotite-gneiss from the lower Odins Dal near the Svejstrups Dal. This rock is less leucocratic than the first type and does not contain any hornblende. Plagioclase, potash feldspar, quartz, and biotite are the principal constituents in order of abundance. The average grain size is about 2 mm. Plagioclase is calcic oligoclase and is partly altered to sericite and clino-zoisite; it is slightly myrmekitic. Perthitic orthoclase is abundant and exhibits distinct replacement relationships towards plagioclase indicative of late stage crystallization. Biotite flakes up to 2 mm in length show a fairly good parallelism. Sphene is an abundant accessory forming euhedral crystals exceptionally up to 1 mm in length. Other accessories are zircon, allanite, and apatite (Table 2, x).

1840. Biotite-gneiss (quartz-dioritic) from the central Svejstrups Dal. This rock is a medium to fine-grained, well-foliated biotite orthogneiss. Quartz crystals average 0.5—1 mm in diameter. Plagioclase (An26) is the principal constituent of the rock. Biotite is abundant in flakes averaging 2 mm in length and with X light brown, Y and Z very deep brown. Main accessory mineral is apatite, whilst zircon is rare (Table 2, xi).

1839. Biotite-gneiss from the east slopes of 1,203 m peak south of the Grandjeans Fjord. Quartz forms about 25 % of the rock occurring in intensely strained crystals 1—2 mm in diameter. Plagioclase (An26) is slightly sericitized. A few rounded and isolated myrmekite grains are present in the section. Microcline is present in about equal amount to plagioclase. Biotite has been largely altered to chlorite, rutile occurring in sagenite webs, and prehnite. Accessory minerals are apatite, magnetite, sphene, and allanite.

Hornblende and hornblende-biotite gneisses (dioritic to quartz-dioritic)

The gneisses of this group frequently show a well-defined plane-banding due to alternation of leucocratic and melanocratic layers. Linear schistosity is well-developed in some types. These gneisses range in composition from quartz-diorites to basic diorites. The dominant type contains hornblende, biotite, plagioclase and a little quartz. Potash feldspar is rare or absent. The plagioclase is generally an andesine about An35 and the range of composition is An25 to An40. Zoning of the plagioclase is rare. Accessory minerals are sphene, magnetite, garnet, allanite and zircon. Typical examples are described below.

Hornblende-biotite gneisses.

1820. Hornblende-biotite-gneiss from the Odins Dal immediately east of Munin. The average grain size is 1—2 mm. Apart from the ferromagnesian minerals there is no tendency for the crystals to show any parallel orientation. Quartz occurs in rounded crystals averaging 1 mm in diameter and showing marked strain extinction. Plagioclase (An36) is much altered to zoisite and sericite. Hornblende encloses small grains of quartz and feldspar; it has X colourless, Y green, Z deep-green. The biotite is partially chloritized. Accessories are garnet, apatite, and sphene (Table 2, XII, XII a).

1818. Biotite-hornblende-gneiss from the east side of the col between the Ødedal and Svejstrups Dal. This rock is well banded. The average grain size is 1 mm. Quartz (36 %) and plagioclase (An 30) are the principal constituents. Biotite is split by prehnite wedges. Hornblende is present in subordinate amount to biotite and contains numerous inclusions of quartz. Accessory minerals are sphene and abundant apatite (Table 2, XIII, XIII a).

1313. Hornblende-biotite-gneiss from the west side of glacier N 2. This rock shows a well-defined linear schistosity. Quartz crystals are small, averaging 0.2—0.6 mm in diameter and they are frequently enclosed in plagioclase. Plagioclase is andesine (An 35, n'g 1.552, n'p 1.545 for 001). The andesine sometimes contains basic cores of acid labradorite. Hornblende is markedly xenoblastic and full of inclusions of plagioclase and quartz. Biotite forms idioblastic laths up to 3 mm in length. The biotite and hornblende are frequently segregated into bands up to 5 mm in width. Accessory minerals are sphene, magnetite, apatite, and zircon. Sphene is particularly abundant as an accessory mineral occurring in subhedral crystals averaging 0.1 mm in diameter. It is frequently enclosed in hornblende along with zircon (Table 2, XIV).

1852. Hornblende-gneiss from the Tyrolerdal Group near S3 glacier. The average grain size is 2 mm. Plagioclase is andesine (An 35) and is slightly altered to zoisite. Hornblende forms xenoblastic flakes. Accessories are pyrite and apatite both very common (Table 2, XV).

1315. Hornblende-gneiss from the east slope of 1,203 m peak south of the Grandjeans Fjord. This rock is rich in hornblende which occurs in bands alternating with quartzo-feldspathic material. Quartz commonly occurs enclosed within hornblende and plagioclase. The latter is andesine (An 35, n'g 1.553, n'p 1.545 for 001). Hornblende shows alteration to a secondary tremolitic amphibole with pale green pleochroism. Accessory minerals are sphene (abundant) and small amounts of magnetite and pyrite (Table 2, XVI, XVI a).

1823. Hornblende-gneiss from the head of the Ødedal. The rock shows marked banding due to segregation of hornblende, and quartz and feldspar. Hornblende forms xenoblastic crystals enclosing quartz; it is partially altered to chlorite, iron ore, and epidote. Sphene is an abundant accessory along with small amounts of allanite (Table 2, XVII).

1836. Hornblende-gneiss from the Tyrolerdal Banded Group in the Lower Tyrolerdal. The rock shows marked banding of leucocratic and melanocratic constituents. Quartz occupies about 5—10 % of the rock. Plagioclase is a sodic andesine much altered to sericite. Hornblende is the dominant ferromagnesian mineral. Accessory minerals are pyrite and sphene.

1849. Hornblende-biotite-gneiss from the Tyrolerdal Group near S3 glacier in the upper Svejstrups Dal. The principal constituents of the rock are plagioclase and hornblende. The former is andesine (An 40). A little biotite is present though much subordinate to hornblende. Sphene is very abundant as an acessory mineral (about 1 %) occurring in crystals up to 0.5 mm in length (Table 2, XVIII).

1846. Hornblende-biotite-gneiss from the valley north of Bavnen. Quartz is present in very small amount. Plagioclase (An 30) crystals average 1—3 mm and are up to 5 mm in length. They are frequently antiperthitic. Hornblende forms stout laths 2—3 mm in length and have X colourless, Y pale green, Z deep green, $\widehat{zc}$ 22°. Biotite is much subordinate to hornblende. Sphene and apatite are both common as accessory minerals in crystals up to 0.5 mm in length. The rock is cut by veins of pure albite.

1348. Hornblende-gneiss (syenodioritic) from the east side of peak 1,075 m in the lower Svejstrups Dal. This gneiss has an unusual composition, it being a syenodioritic gneiss with little or no quartz and both potash feldspar and plagioclase. Plagioclase (An26) forms large crystals exceptionally up to 5 mm in length. The potash feldspar is microcline. Hornblende forms stout laths up to 2 cm in length which do not exhibit any marked tendency to lie in parallelism. Hornblende has X pale brown, Y green, Z deep green, $\widehat{zc}$ 22°, β 1.680. A very small amount of biotite is present. Accessory minerals are abundant. Sphene occurs in crystals up to 2.5 mm in length and well-formed crystals of allanite are up to 0.5 mm in length; they have a distinct pleochroism with X yellow, Y dark brown, Z dark brown and sometimes are slightly zoned. Other accessory minerals are magnetite, apatite, and zircon (Table 2, xix).

Amphibolites and hornblende-schists.

The amphibolites are generally massive showing little or no conspicuous linear schistosity such as that possessed by the schists. These basic rocks consist largely of plagioclase, hornblende, biotite and smaller amounts of quartz, garnet and accessory minerals. The garnet crystals sometimed attain considerable dimensions, those in the large sill on the south side of the lower Svejstrups Dal are up to 5 cm in diameter. The plagioclase in these basic rocks ranges from basic oligoclase to labradorite. Common accessory minerals are sphene and magnetite, and less commonly rutile, apatite, and epidote. A typical exemple is described below.

1848. This rock comes from a large amphibolite sill in the Tyrolerdal Group on the north side of the Svejstrups Dal near glacier N2. Hornblende is the principal constituent occurring in well-formed laths up to 3 mm and averaging 1—2 mm in length and having X very pale brown, Y pale green, Z green. Plagioclase forms about $40\,^0/_0$ of the rock; it is andesine (An36). Accessory minerals are magnetite and apatite (Table 2, xx).

A rock (1838) closely resembling the hornblende-schists in texture and field occurrence comes from the Tyrolerdal Banded Group in the lower Svejstrups Dal. On slicing it proved to be composed largely of a colourless amphibole and plagioclase. The latter forms about $30\,^0/_0$ of the rock and is an acid labradorite extensively sericitized. The amphibole is colourless in section and forms stout laths up to 3 mm in length; it has $\widehat{zc}$ 18, β 1.694 and probably belongs to the tremolite-actinolite group. Quartz is present in very small amount (2—$4\,^0/_0$).

1169. Quartz-garnet-sphene-hornblende rock from the Tyrolerdal Group on peak 1,246 m. This rock is of rather exceptional composition and somewhat obscure paragenesis. It occurs as thin bands within hornblende gneisses and consists of an equigranular aggregate of garnet, amphibole, quartz, and sphene. Garnet is the principal constituent of the rock (about $60\,^0/_0$) occurring in reddish crystals averaging 1.5 mm in diameter. It is sometimes markedly poikiloblastic containing inclusions of quartz, calcite, sphene, and magnetite. Quartz occurs in only small amount in the general mass of these rocks but is more abundant within coarse-grained bands up to 1 cm in width which occasionally occur. Along with quartz these bands contain garnet and hornblende. Hornblende occupies about 15—20 % of the rock and has X colourless, Z pale green, Y pale olive green, $\widehat{zc}$ 19°, β 1.675. In the coarse-grained bands previously referred to, it occurs in idioblastic crystals up to 6 mm in length. A few small crystals of basic oligoclase are present partially altered to zoisite and calcite. Sphene is common in small well formed crystals averaging 0.15 mm in diameter. A little penninite is present, probably secondary after biotite (Table 2, XXI).

The genesis of this rock is somewhat obscure. Its occurrence within gneisses of definitely igneous character seems to rule out the possibility of a sedimentary origin. Further its mineralogy is closely comparable to that of the gneisses.

Ultrabasic rocks.

Ultrabasic rocks are not common in the Tyroler Series. They are mainly hornblendites, hornblende-biotite, and hornblende-biotite-plagioclase types similar to those in the Basement Series. An interesting type comes from the Tvege Banded Group in the upper Svejstrups Dal immediately below the Tvegegletscher.

1165. This rock is largely composed of well lineated prismatic crystals of pale green amphibole colourless in thin section. It has $\widehat{zc}$ 17° and β 1.649 properties relating it to the tremilite-actinolite group of amphiboles. The amphibole is partially altered to talc, clinozoisite and calcite. This rock occurs as a small sill within paragranulites and schists.

An interesting rock (1320) comes from the lower part of the Tyrolerdal Banded Group exposed on the south face of the peak 1,246 m in the central Svejstrups Dal. It occurs as a large sill within pelitic and psammitic schists. The rock is massive throughout and may be entirely post-metamorphic in age.

1320. The main constituent of the rock is augite which forms well shaped crystals up to 5 mm in length which are frequently poikilitic, enclosing small rounded grains of olivine. Enstatite occurs in prismatic crystals up to 2.5 mm in length, colourless in thin section. Olivine sometimes forms large crystals up to 2.5 mm in length, but more frequently occurs as small grains averaging 0.1—0.5 mm in diameter. It shows alteration along cracks to opaque ore. A few laths of basic plagioclase have been noted. Picotite is an abundant accessory mineral forming rounded or square-shaped grains averaging 0.05 mm in diameter (Table 2, XXII). This rock is shown in Plate V, 3.

An enstatite-olivine-hornblende rock probably related to the above type has been described by WISEMAN (1932, pp. 330—31) from the Muskusoksefjord inlier. BACKLUND (1932, p. 36) mentions similar rocks to the Musk-Ox types as occurring in the Wordies Gletscher area, which he considers to be pre-metamorphic. The Svejstrups Dal rock can be matched by ultrabasic types belonging to the Ach'uaine hybrid suite of Sutherland, Scotland (Read, 1926, pp. 157—59).

3. Cataclastic Rocks.

Cataclastic rocks resulting from post-crystalline deformation without any subsequent crystallization are widely developed in the Svejstrups area. In thin section such rocks are characterized by the partial granulation of crystals, bending of twin lamellae of feldspars and the development of further twinning, and intense straining of quartz. The earliest stages of deformation are marked by only slight rock cataclasis. Quartz in psammitic schists developes highly sutured margins and shows marked undulose extinction. As the deformation becomes more pronounced a typical mortar structure is developed. Feldspar, and more rarely quartz porphyroclasts lie within a crushed matrix. Under the effects of further differential movement the porphyroclasts are progressively streaked out and flaser rocks and ultimately true mylonites are formed. Rocks showing incipient cataclasis and mylonitization are described below.

1843. Cataclastic granulite-schist from 1,000 m on the south-east shoulder of the Gross Glockner. The rock is highly quartzose and biotite and muscovite are present in very small amount. Oligoclase (10 %) is dominant over microcline (about 3 %). The quartz shows incipient cataclasis, the crystals having highly sutured margins and showing marked strain extinction (Plate IV, 1). Biotite has a rich reddish-brown colour.

1793—1166—1168. These rocks come from the thrust zone in the lower Ulændedal on the east side of the valley.

1793. Partially granulitized injection granetiferous-schist. The garnets are well-rounded and up to 3 cm in diameter. Biotite flakes average 0.5 mm in length. Large segregations of pegmatite material, up to 2 cm in length, occur. Plagioclase occurs in porphyroclastic crystals up to 0.5 cm in lenght, which have their twin lamellae slightly bent; they have a composition An35 (n′g 1.553, n′p 1.545 for 001). Quartz and plagioclase in the partially granulitized groundmass average 0.2—0.4 mm in grain size. Although sillimanite does not occur in this rock section (1793) it is abundant within the schist group from which the rock was collected. It may be mentioned that this partially granulitized schist is identical in appearance to the 'mylonite-gneiss' figured by Kranck (1935, Fig. 5).

A further stage of granulitization of the above injection schist is seen in 1166. This rock shows moderately intense granulitization. Porphyroclasts of quartz and feldspar or aggregates of these minerals lie within a fine-grained matrix of biotite, muscovite, quartz, feldspar, and sillimanite. Garnet is poikiloblastic, occurring in rounded or slightly elongated crystals averaging 1 mm in length. Biotite flakes average 0.07—0.1 mm in length and show marked parallelism; they have a deep reddish-brown colour in thin section. Sillimanite is surrounded by aggregates of small muscovite flakes. A small amount of quartz and plagioclase in grains not exceeding 0.1 mm occur in the matrix of the rock.

Yet a further stage in the granulitization of the injection schist is seen in 1168 (Plate III, 2). Megascopically this rock resembles a fine-grained lava studded with small rounded garnets. The pink garnets are conspicuously rounded and rarely elongated. They average 1—2 mm in length and are always markedly poikiloblastic. Pegmatitic patches of quartz and oligoclase (An 26) up to 6 mm in length occur. The matrix of the rock consists of biotite, muscovite, quartz, feldspar, and sillimanite in grains averaging 0.05 mm in length.

1339. Partially granulitized biotite-schist from the Ulændedal (Plate III, 1). This rock shows good mortar structure with porphyroclasts of quartz, feldspar sillimanite, and garnet averaging 1—2 mm in length lying in a matrix of quartz, feldspar, biotite, chlorite, and epidote. The plagioclase porphyroclasts are of oligoclase which is intensely sericitized; the twin lamellae are bent. Quartz is abundant within the matrix of the rock in grains averaging 0.1—0.15 mm in diameter; it rarely forms porphyroclasts. Biotite flakes, which average 0.1 mm in length wrap round the feldspar porphyroclasts.

1799. Partially granulitized garnet-hornblende-biotite-granulite from the south-east side of the lower Ulændedal. Conspicuous banding is present within this calc-schist. Quartz forms about 75 $^0/_0$ of the rock occuring in much strained crystals ranging in size from 0.05 to 2 mm in length; their margins are sutured. Andesine-oligoclase is present in subordinate amount forming fresh slightly zoned crystals 0.2—0.4 mm in length. Garnet crystals are poikiloblastic and 1—3 mm in diameter. Hornblende forms xenoblastic crystals up to 2.5 mm in length. The texture of the rock is distinctive with large quartz, feldspar, hornblende crystals lying in a finer-grained groundmass of the same (Table 3, xi).

1792, 1318, and 1342 are representative types of partially and completely granulitized injection schists from the south side of the Svejstrups Dal to the N.W. of glacier S10. The injecting pegmatite in this area forms lit-par-lit bands up to 2 cm in width within muscovite-biotite schists. It consists largely of quartz and oligoclase, and a little microcline. During cataclasis this injection pegmatite is only partially broken down and forms beautiful mortar structure (Plate III, 3) with porphyroclasts of quartz and oligoclase lying in a finely granulitized matrix of biotite, quartz and feldspar. In 1792 some of the larger porphyroclasts are up to 1 cm in length. The twinning of the plagioclase porphyroclasts is frequently bent. Biotite has been largely pseudomorphed by chlorite. Veinlets of pure albite and epidote cut the rock and the latter are of frequent occurrence in the areas of shearing. Cataclasis is not always uniform in distribution but is most intense along curving fracture planes which impart to the rock a typical lenticular texture.

1318, 1342 (Plate III, 4) are more intensely granulitized than 1792. 1318 shows perfect mortar structure. The porphyroclasts may be composite consisting of both quartz and feldspar in aggregates up to 5 cm in length. The porphyroclasts are always wrapped round by foliae of biotite, muscovite, and chlorite. In 1342 cataclasis is most intense along curved fractures (Plate III,4).

c. Injection complex.

For the purposes of petrographic description the rocks of the injection complex can be divided into two main groups, namely (i) composite injection gneisses resulting from invasion of meta-sediments and orthogneisses and schists by granitic material, and (ii) transgressive pegmatites, aplites, and intrusions of granite.

1. Injection gneisses.

The injection gneisses may be classified according to the type of country rock affected.

Permeated and injected psammitic schists.

The psammitic schists within the injection complex are usually partially or thoroughly permeated by granitic material. The grey coloured unaffected schists become pink in colour and in thin section more feldspathic. A few typical examples of permeated granulites will be described.

1817. This rock comes from near the summit of Bavnen, the western ridge of this peak being composed of permeated granulitic schists. In thin section it is impossible to distinguish the injection material from the original rock. Quartz occupies about 70 % of the rock in crystals 1—2 mm in diameter. Oligoclase is the only feldspar present. Both biotite and muscovite become porphyroblastic within areas of permeated rock. The introduced material must have been composed largely of oligoclase and probably quartz.

1791. Muscovite-biotite-granulitic from 800 m on the eastern shoulder of Gere. The original rock prior to invasion by granitic material consisted of quartz, plagioclase, a little potash feldspar, and biotite and muscovite in equal amount. During injection it was considerably enriched in feldspar, particularly oligoclase. The injection material is discrete forming thin discontinuous veinlets (Fig. 16a). Along some of these veinlets there are small augen of calcic oligoclase exceptionally up to 1 cm in length; one of these augen is shown in Fig. 17. These plagioclase augen are sometimes conspicuously antiperthitic. The augen always lie parallel to the planes of schistosity and foliation in the schists. Occasionally the augen are of orthoclase (Table 4, I).

1336 and 1834. In these granulitic schists from the central Svejstrups Dal (near S3 glacier) and from the valley N.E. of 1246 m peak respectively, the injection material occurs in well-defined bands parallel to the foliation. In 1336 the injecting granite consists of oligoclase (An20) and quartz occuring in crystals averaging 1 mm in length. Oligoclase is slightly in excess of quartz. A very small amount of biotite is also present. In 1834 the injection bands are composed of a granoblastic aggregate of quartz, acid oligoclase (An15), myr-

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Fig. 16. Lit-par-lit injected semi-pelitic and pelitic schists from the Svejstrups injection complex.

a. Thin lit-par-lit injection veins in semi-pelitic schist from 600 m on Gere. A small auge of plagioclase occurs near the centre of the drawing.
b. Intense lit-par-lit veining in semi-pelitic schist from the east side of Trinity Gletscher.
c. Discrete injection veins in garnetiferous sillimanite schist from the Westendspids.
d. Lit par lit veins in biotite schist from 600 m on Dombjerg.
e. Lit par lit veins in muscovite-biotite-schist near S 10 glacier, Svejstrups Dal.
f. Lit par lit injection in biotite-schist from the lower Tyrolerdal. The injection pegmatite is rich in oligoclase.
g. Injection veins in calc-schist, Ulændedal.
h. Lit par lit pegmatite in biotite-schist from the east slopes of peak 1,203 m Grandjeans area.

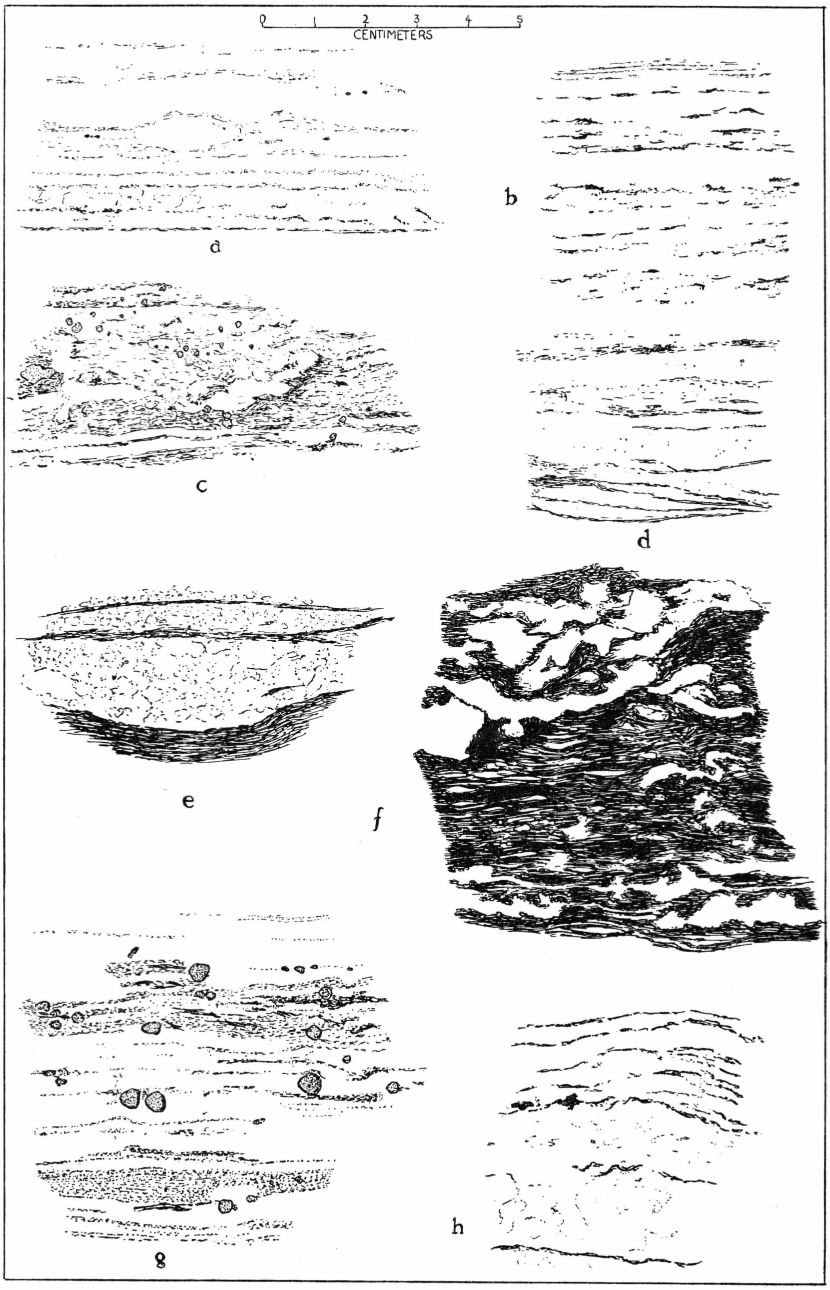

Fig 16.

mekite and microcline-microperthite. Plagioclase is slightly more abundant than potash feldspar. Biotite in the host rock is extensively chloritized and split by wedges of prehnite 0.5—1 mm in length.

1844. This is a coarse-grained garnet granulite from the Basement Series on the south slope of the Orienteringsspids, Zackenberg. These coarse granulites are the most abundant type of meta-sediment within the Basement Series of this area. The rocks have been permeated by granitic material. This material

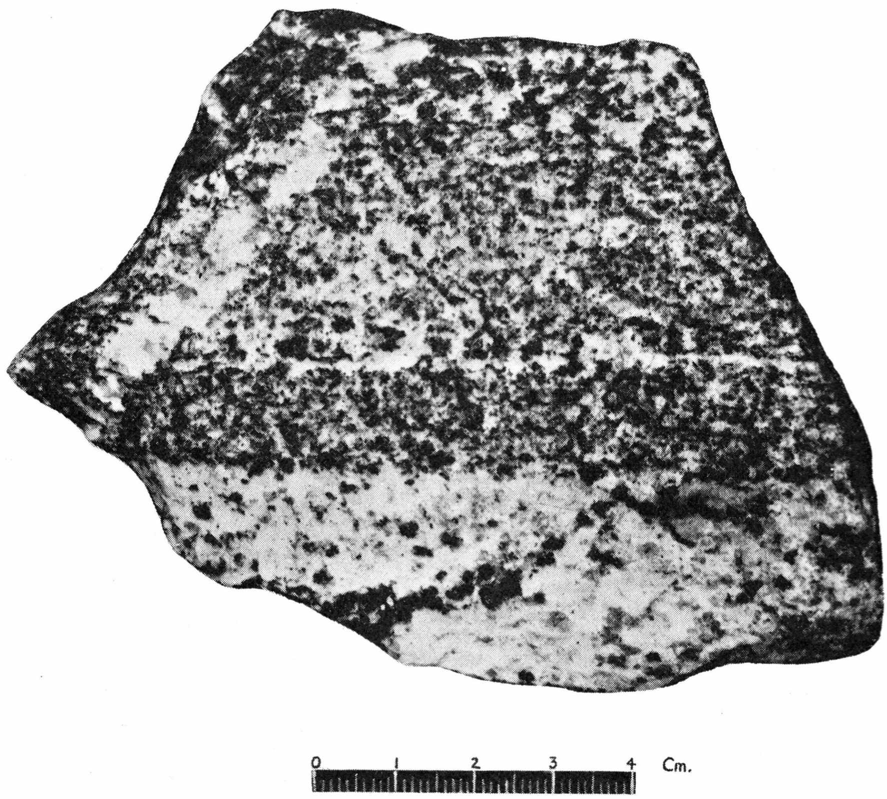

Fig. 17. Discordant and concordant veins of granite in garnetiferous semi pelitic schist from Lerbugt, Young Sund.

consists of quartz, potash feldspar, and oligoclase. Biotite in the host rock has X colourless, Y and Z deep reddish-brown. This pleochroism is typical of biotite in many parts of the injection complex and resembles that of hornfels biotite. Plagioclase forms about $25\,^0/_0$ of the rock; it is a calcic oligoclase (An 26) and is slightly antiperthitic; it becomes myrmekitic at its contact with potash feldspar. Perthitic orthoclase is present in about equal amount to plagioclase. Allanite is a very abundant accessory mineral occuring in well-formed crystals up to 0.5 mm in length which show simple twinning and a pleochroism from pale to deep brown.

Injected semi-pelitic and pelitic schists.

Semi-pelitic and pelitic schists owing to their well-defined schistosity were the most easily injected rocks of the complex. Composite injection gneisses resulting from injection of these schists are shown in the following thin sections: 1170, 1327, 1333, 1347—48, 1785, 1787—88, 1790, 1793—94, 1798, 1801—02, 1816, 1822, 1825—28, 1831, 1845.

The injection pegmatite and granite within these rocks consists predominantly of quartz and oligoclase (An 15—30, average An 26), the

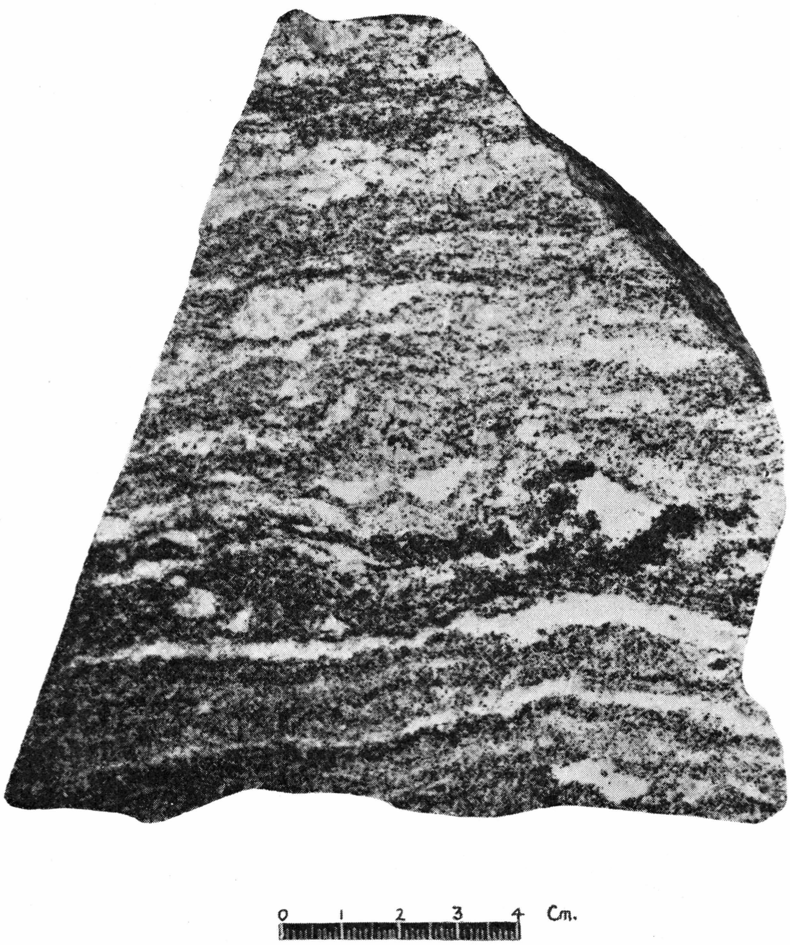

Fig. 18. Lit-par-lit injection veins in semi-pelitic schist from Odins Dal near the Svejstrups Dal.

latter being frequently antiperthitic. Occasionally potash feldspar, which is usually microcline, may be present in equal or slightly greater amount than plagioclase but in the more general case is entirely absent.

Sillimanite is common throughout the injection complex within semi-pelitic and pelitic schists. It is particularly abundant within the schists of the Tyrolerdal Banded and Westendspids Groups.

Biotite and muscovite in injection gneisses frequently becomes porphyroblastic. The former has invariably a reddish colour in thin section and in some cases the 'foxy' red colour is very pronounced.

The injection pegmatite and granite in the schists always follows the planes of schistosity forming either thin and discontinuous discrete veins or prominent bands up to several centimetres in width (Figs. 16, a—h, 17, 18). There are all transitions within injected schists from thin discrete veins to large veins which are separated by only thin foliae of mica (c. f. c with h of Fig. 16). Augen structure due to pinching and swelling of the injection bands is a common feature. A distinctive type of rock within the injection complex may be termed an oligoclase-biotite-gneiss (after Read, 1927 pp. 326—30). These rocks consist of abundant, somewhat rounded, crystals of oligoclase averaging 2—5 mm in diameter lying in a base rich in biotite (see 1822).

Examples of injected semi-pelitic and pelitic schists are described below.

1170. Injected semi-pelitic schist from the Odins Dal near pt. 407 m. The host rock is a semi-pelitic schist with well-defined schistosity. The injecting granite lies along the planes of schistosity. Biotite of the schist occurs in flakes 0.2—0.4 mm in length; it shows alteration to chlorite, hematite, magnetite and prehnite. The latter occurs in wedge-shaped crystals along cleavage cracks. It is a characteristic alteration product of biotite within the injection complex. The injecting granite consists of quartz, orthoclase, and plagioclase in equigranular aggregate. Strained quartz crystals average 0.4 mm in diameter. Potash feldspar is slightly more abundant than plagioclase (An 28). The latter are extensively sericitized and in some cases blotched by irregular grains of orthoclase forming a type of antiperthite. A small amount of pure albite is present in the rock (Table 4, ii).

1348. Sillimanite-schist from the Tyrolerdal Banded Group on the north shoulder of Munin. Original minerals of the schist include garnet, which has been partially chloritized; biotite, with a distinct foxy-red colour, and a little muscovite. The injection granite consists of quartz and plagioclase. The former occurs in long elongated crystals which are intensely strained. Plagioclase crystals average 1—2 mm in length and are clouded by sericite and calcite. Sillimanite of greenish-yellow colour occurs in fibrous aggregates of crystals up to 3 mm in length which generally border the injection bands. Pure albite crystals up to 0.6 mm in length are present and appear to be replacing quartz; they show vague lamellar twinning (Table 4, iii).

1785. Sillimanite-schist from upper Blaabærdalen. The host rock is a garnetiferous muscovite-biotite-schist. Poikiloblastic garnets are up to 1 cm in length and are elongated parallel to the schistosity. Biotite has a distinctive red colour in section. The injection material consists of quartz, plagioclase, and microcline. Quartz crystals which are frequently markedly elongated are up to 7 mm in length. Microline-microperthite forms augen up to 1 cm in length. Non-perthitic microcline and orthoclase occur throughout the groundmass of the rock. Plagioclase (An 20) crystals average 0.5 mm in length and are usually markedly antiperthitic; they are much sericitized. Sillimanite occurs in fibrous crystals which are generally aggregated into clusters up to 6 mm in length (similar to that in sections 1764, 1802, Plate V) (Table 4, iv).

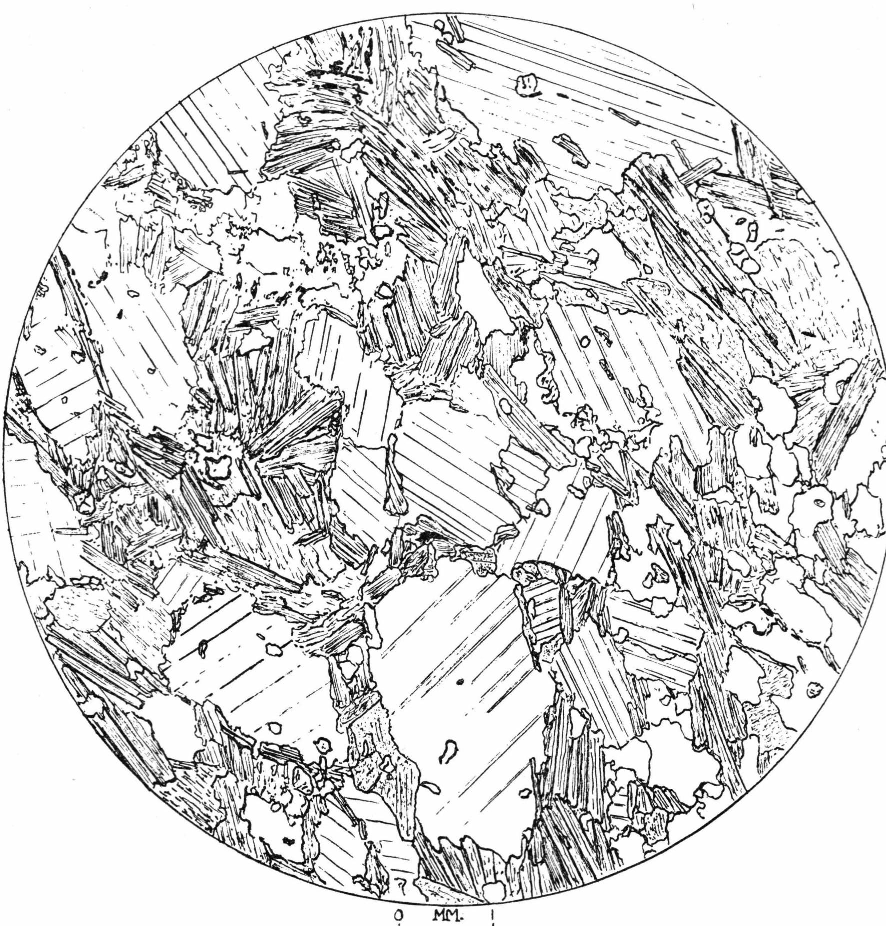

Fig. 19. Oligoclase-biotite-gneiss (1322) from the lower Tyrolerdal.

1787. Sillimanite-schist from 650 m on Gere. The injection material is very discrete forming thin lit-par-lit veins never greater than 3 mm in width. It is composed of quartz, plagioclase, and potash feldspar. Plagioclase (An 26) builds small augen up to 1 cm in length which lie along the planes of schistosity; they show myrmekitic margins against potash feldspar. Orthoclase also forms augen averaging 0.5—1 cm in length. The augen and injection veins are frequently mantled by trails of sillimanite intimately associated with muscovite (Table 4, v).

1794. Sillimanite-schist from the summit of the Westendspids. This rock is a garnetiferous muscovite-biotite-schist showing discrete injection by quartz/plagioclase granite. Plagioclase forms small sericitized crystals of composition An 25 (n'g 1.548, n'p 1.540 for 001). Strained quartz crystals are up to 6 mm in length. Sillimanite forms fibrous crystals up to 2 mm in length.

1798. The injection granite in this schist from near glacier S8 consists of quartz and plagioclase (An 28) (Table 4, vi).

1801. Sillimanite-schist from the 'col' between the Odins Dal and Blaabærdalen. This rock has been partially sheared. The injection material forms conspicuous composite augen of plagioclase (An 27) and quartz. Fibrous sillimanite has been formed at the expense of muscovite; it occurs in fine needle-like crystals averaging 0.3 mm in length which are sometimes enclosed within quartz.

1822. Oligoclase-biotite-gneiss from the lower Tyrolerdal. The host rock is a garnetiferous biotite-schist. The biotite flakes average 1—2 mm in length and sometimes enclose garnet; they have X colourless, Y and Z reddish brown. The rock is studded by somewhat rounded crystals of oligoclase (An 28, n'g 1.549, n'p 1.542) (Fig. 19) and there is a small amount of quartz present in crystals up to 5 mm in diameter. Although the injection pegmatite usually occurs in the form of isolated crystals of plagioclase and more rarely quartz it also forms lit-par-lit veins showing pinching and swelling (Table 4, vii).

1845. Injected semi-pelitic schist 4 km N. of Bavnen. The injection material is rich in potash feldspar, which exceeds plagioclase in amount. Both microcline and orthoclase are present though the former is much predominant. Biotite of the schist is chloritized and prehnitized (Table 4, viii).

Injected hornblende and hornblende-biotite orthogneisses.

These gneisses show veining of a concordant or discordant nature by granite and pegmatite, or in some cases, where injection processes have been intense, intimate admixture with granitic material. The concordant and discordant veins in these gneisses are usually well-defined; the two types are commonly connected, the discordant feeding concordant veins. Examples of composite gneisses resulting from injection of hornblendic gneisses are shown in Figs. 20, 21. Isolation of hornblende and hornblende-biotite layers and of individual crystals or small aggregates is not uncommon. The hornblende adjacent to, or isolated within the injection bands is invariably more coarsely-grained than that in the main mass of the rock. A few typical examples of composite hornblendic gneisses are described below.

1328. Hornblende-biotite-gneiss from the lower Ulændedal. The host rock is a hornblende-plagioclase-quartz-gneiss. Hornblende occurs in crystals up to 1.5 mm in length which are altered to chlorite, epidote, magnetite and sphene. A little biotite is present. The injecting granite occurs in concirdant veins and consists of sericitized, antiperthitic oligoclase (An 28, n'g 1.550, n'p 1.544 for 001) and quartz in crystals averaging 0.5 mm in length.

1343. Garnet-hornblende-biotite-gneiss from the head of Blaabærdalen. This rock is shown in Fig. 20a. It consists of concordant and discordant injection material banded with hornblende and hornblende-biotite leyers. It is impossible to discriminate between the injection material and the original leucocratic constituents of the rock. In thin section quartz and oligoclase are present in approximately equal amounts; the latter is partially sericitized. The rock is cut by veins of epidote (Table 4, ix).

1797. Hornblende-biotite-pyroxene-gneiss. The white injecting pegmatite forms concordant bands up to 1.5 cm in width. The hornblende of the gneiss

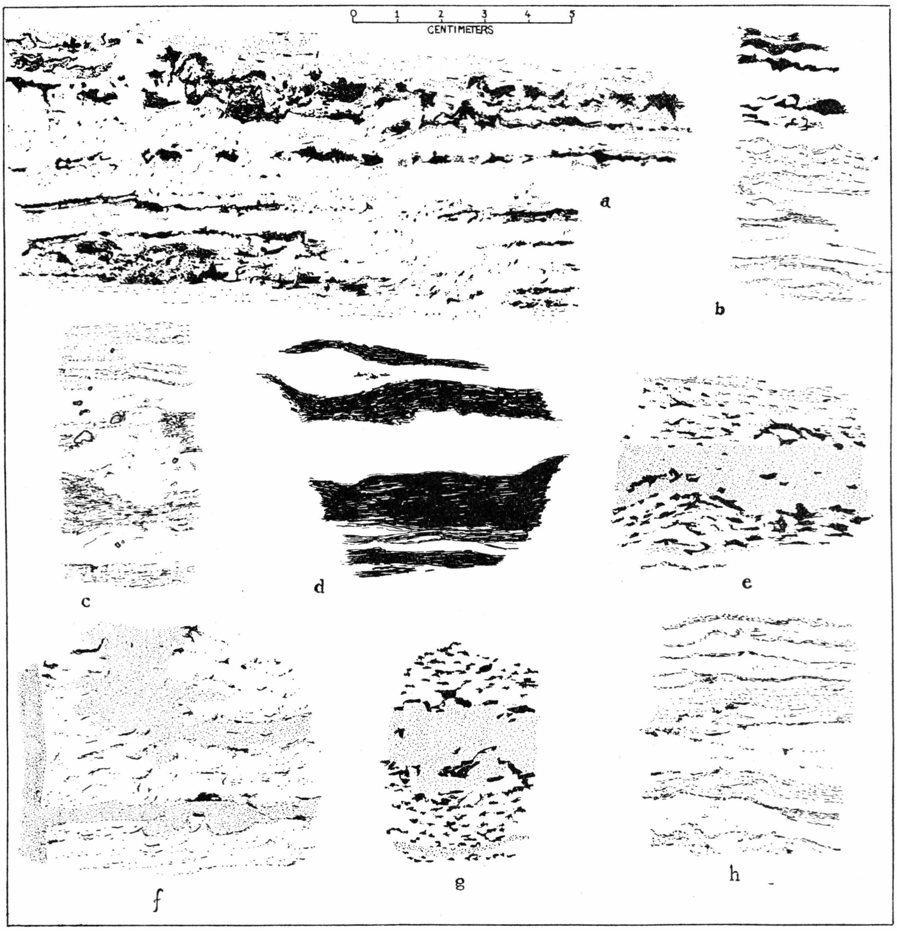

Fig. 20. Composite hornblende, hornblende-biotite, and biotite orthogneisses within the Svejstrups injection complex.

a. Concordant and discordant veins in hornblende-biotite-gneiss from upper Blaabærdalen.
b. Concordant veins in hornblende-biotite-gneiss from Ulændedal.
c. Concordant injection veins biotite-hornblende-gneiss from upper Blaabærdalen.
d. Concordant veins of pegmatite in amphibolite from near peak 1,104 m in the central Svejstrups Dal.
e. Concordant pegmatite vein in hornblende-gneiss from the lower Svejstrups Dal near the head of Lindemans Fjord. Hornblende has been isolated within the vein and is coarser-grained within and adjacent to it. Injection vein is stippled.
f. Concordant and discordant veins in biotite-gneiss from the south slope of the Orienteringsspids, Zackenberg. Injection is stippled.
g. Concordant veins in hornblende-gneiss from the upper Svejstrup Dal. Veins are stippled.
h. Concordant veins in biotite-hornblende-gneiss from 900 m on the east slope of Svejstrups Bjerg.

occurs in poikiloblastic crystals up to 4 mm in length. Biotite and pyroxene are subordinate to hornblende. The white pegmatite is composed of quartz and plagioclase in crystals averaging 3 mm in length; the latter is andesine-oligoclase (An30, n′g 1.550, n′p 1.542 for 001) and is slightly antiperthitic.

1829. Hornblende-biotite-gneiss from 600 m on the east slopes of 1,203 m peak, Grandjeans area. The injection material and gneiss are intimately mixed.

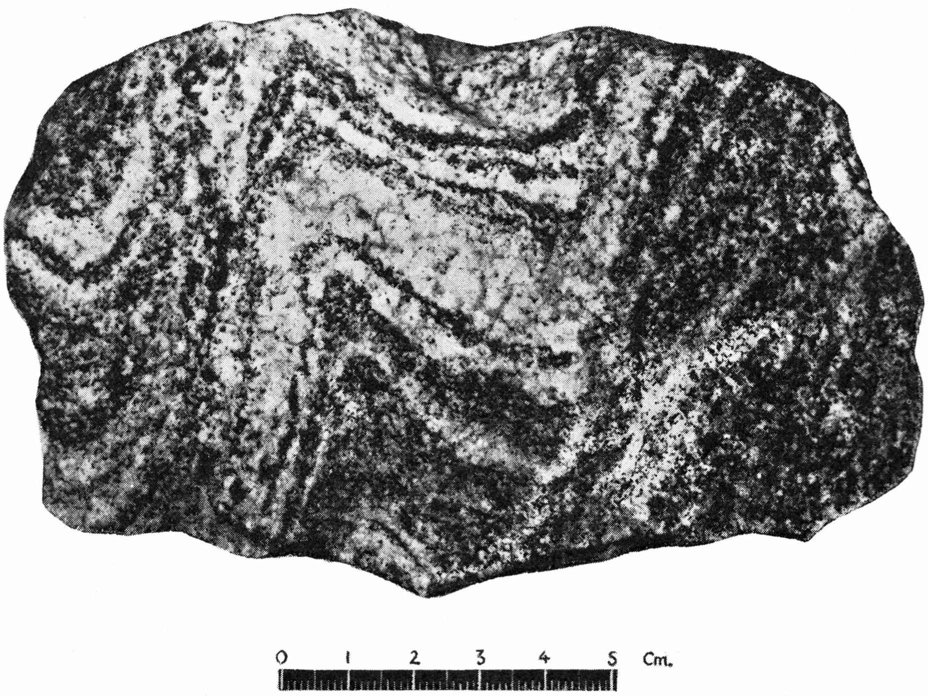

Fig. 21. Concordant granite veins in hornblende-biotite-gneiss from the south face of Gere. Intense small-scale folding has accompanied the injection.

The former consists of quartz (30—40 %) and oligoclase (40—50 %) and probably a little biotite.

1830. Hornblende-biotite-gneiss near S9 glacier, Svejstrups Dal. The host rock is a coarse-grained hornblende-biotite-plagioclase-gneiss. Thin concordant injection veins consist of oligoclase (about 60 %) and quartz (about 40 %) (Table 4, x).

Injected amphibolites and hornblende schists.

In general these rocks are resistant to injection processes in all but the most intensely injected areas. In the earliest stages of injection they are veined, generally in a concordant manner. As the veining becomes progressively more intense the amphibolites begin to lose their identity and ultimately, but only very rarely, pass into hornblende and hornblende-biotite gneisses of quartz-dioritic composition. Typical injected amphibolites are described below.

1335. Garnet-amphibolite south-west of peak 1,104 m in the central Svejstrups Dal. The white injecting material occurs in well-defined concordant bands up to 2 cm in width (Fig. 20 d). The amphibolite consists of hornblende and plagioclase and small amounts of biotite, garnet, magnetite, and accessory minerals sphene and apatite. Plagioclase has been extensively replaced by epidote. The injecting pegmatite is rich in oligoclase occurring in crystals up to 1.5 cm in length; quartz forms about 20—30 % of the pegmatite.

1167. Hornblende-epidote-amphibolite from the Tyrolerdal opposite Copeland Gletscher. The principal constituent of the rock is hornblende which forms markedly poikiloblastic crystals up to 1 cm in length which enclose quartz, epidote, and feldspar. In certain parts of the section the hornblende shows alteration to actinolitic amphibole with a pale green pleochroism. Epidote occurs in well-formed crystals 0.2—0.4 mm in length showing simple 100 twinning. Plagioclase (An 50) is present in small amount as a primary constituent of the rock. Accessory minerals are sphene and apatite. The introduced material consists largely of quartz, orthoclase and a little plagioclase and occurs disseminated throughout the rock.

Feldspar porphyroblasts and augen within the injection complex.

It is necessary at the outset to define the terms 'augen' and 'porphyroblast as used in this account. Feldspar augen are large crystals of potash feldspar or plagioclase formed by injection processes and which are lenticular in shape, and lie along the planes of foliation or schistosity of the gneisses and schists. The augen may be connected node to node by thin veins of aplite or granite or may be entirely isolated within the host rock. Examples of feldspar augen are shown in Fig. 22 b, c.

Large crystals of microcline designated porphyroblasts have the following characteristics: They show good crystal shape and cut across the planes of foliation and schistosity; sometimes enclose biotite and hornblende of the host rock; are commonly isolated within the host rock; show all stages of development from small incipient crystals (Fig. 23) to large porphyroblasts up to 10 cm in length; frequently show simple Carlsbad twinning; sometimes mantled by plagioclase. The above characteristics of the porphyroblasts are shown in Fig. 22 a, c, e, f; 23.

There are two possible modes of origin for the augen and porphyroblasts. They may have been formed by crystallization from magma injected along the planes of foliation and schistosity, or they may have been formed metasomatically by introduction of solutions and selective replacement of the invaded rock. In general the characteristics of the feldspar augen indicate that they originated by the former process; their lenticular shape may be due to the fact that they grew under conditions of moderate stress. The pushing aside of the mica foliae round the augen

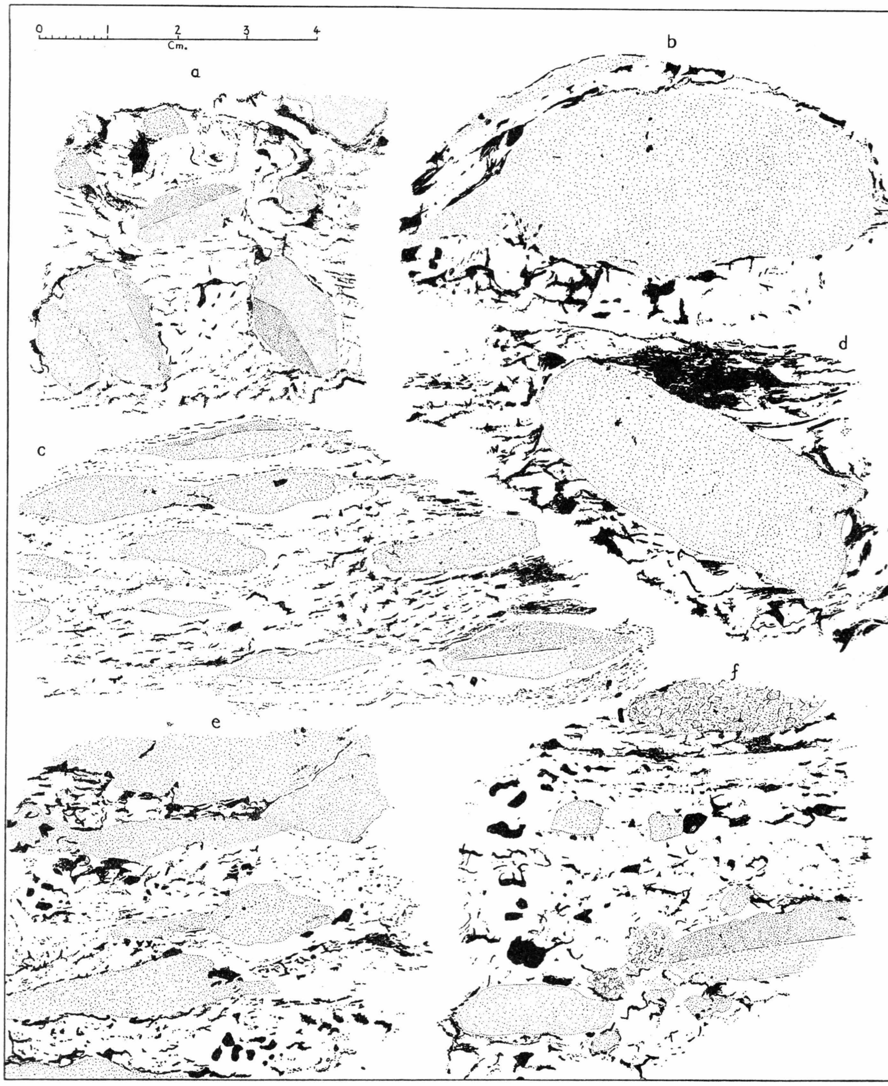

Fig. 22. Potash feldspar porphyroblasts and augen in hornblende and hornblende-biotite gneisses of the regional injection complex.

a. Well-formed porphyroblasts of microcline in hornblende-gneiss from the lower Svejstrups Dal.
b. Large augen of microcline in hornblende-biotite gneiss from the central Svejstrups Dal. The auge is fed by veins at its two ends.
c. Augen of microcline in biotite-gneiss from the lower Svejstrups Dal.
d. Porphyroblast of microcline in hornblende-biotite-gneiss from the east side of Trinity Gletscher. This porphyroblast cuts markedly across the planes of foliation.
e. Microline augen in hornblende-biotite-gneiss from the lower Svejstrups Dal; they lie along the planes of foliation.
f. Small and large porphyroblasts of microcline in hornblende-biotite-gneiss from the lower Svejstrups Dal.

In figs. a—f potash feldspar crystals are stippled and density of stippling indicates Carlsbad twinning. Hornblende and/or biotite are black.

is clearly indicative of a force of crystallization. The general characteristics of the microcline phenocrysts designated porphyroblasts suggests that they originated by metasomatic processes involving introduction of potassic solutions and partial replacement of the host rock to obtain the necessary alumina and silica. The good crystal shape shown by many of

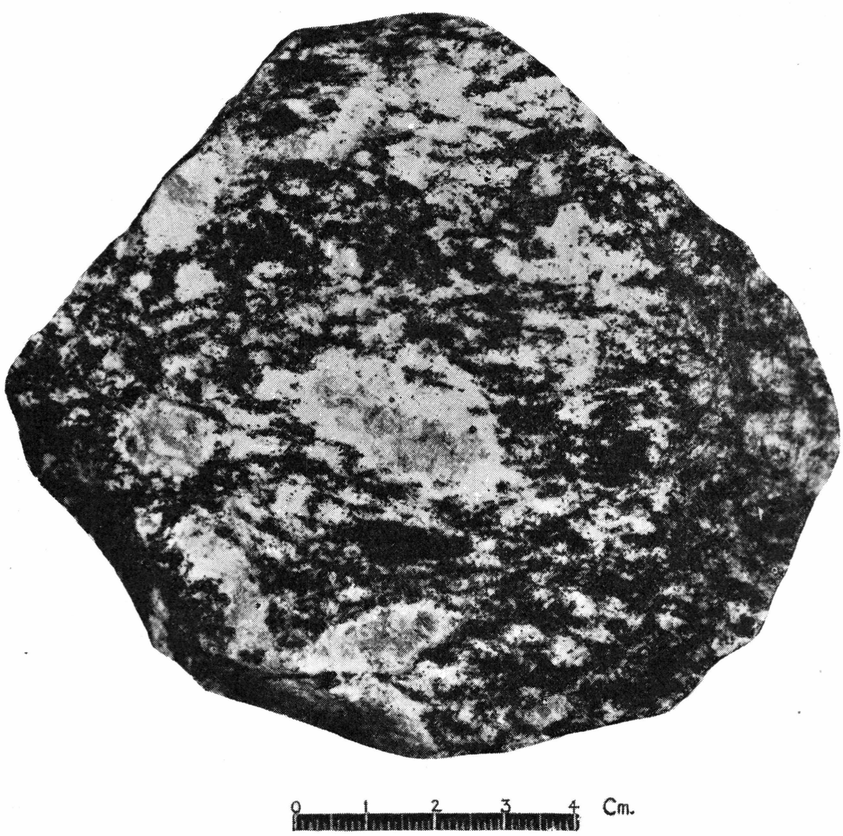

Fig. 23. Porphyroblast-gneiss from the lower Svejstrups Dal. Porphyroblasts of microcline in hornblende-biotite-gneiss. The porphyroblast seen in the centre of the photograph is mantled by plagioclase.

the porphyroblasts and the fact that they cut across planes of foliation and schistosity suggests that they grew largely after stress had ceased. A typical porphyroblast-gneiss is described below.

1341. Biotite-hornblende-porphyroblast-gneiss from the east slopes of peak 1,075 m in the lower Svejstrups Dal. The host rock is a well-foliated gneiss of quartz-dioritic composition. Oligoclase is extensively sericitized and sieved with numerous small crystals of quartz. Biotite flakes up to 3 mm in length have been entirely pseudomorphed by chlorite; pleochroic haloes occur round inclusions probably of sphene. Hornblende forms xenoblastic crystals up to 1.5 mm in length, partially altered to actinolitic amphibole. Accessory minerals are garnet, sphene, apatite, and pyrite and secondary minerals are calcite, sericite, and epidote. The gneiss contains numerous small elliptical or somewhat rounded crystals of microcline-microperthite up to 1.5 cm in length; some of them have their maximum length normal to the foliation and all of them show random orientation. The plagioclase in the microcline occurs in the form of strings (Alling, 1938, pp. 143—47) and two sets are generally present.

The development of porphyroblasts and augen of feldspar within injection complexes or in granitic terranes has been frequently described and it is only necessary to quote a few of the more important examples which appear to be closely comparable to the Svejstrups phenomena. In Greenland the development of large potash feldspar crystals by metasomatic processes has been described by Kranck (1935, p. 75), Wegmann (1938, pp. 106—15) and Huber (1590, pp. 66—69). In the Rogart granodiorite injection-complex (Read, 1925, pp. 37—38) feldspar augen often showing euhedral shape have been developed along and sometimes across the foliation of schists. In Idaho Anderson (1934, p. 390) and Anderson and Hammerand (1940, p. 588) have described microcline porphyroblasts developed by potash rich emanations permeating granite and gneiss. A similar metasomatic origin for potash feldspar phenocrysts in the Cape Town granite and migmatites is held by Walker and Mathias (1947) pp. 514—15). The large ovoids of potash feldspar in the Rapakiwi, granites of Fennoscandia are considered by Backlund (1938, p. 391) to be of metasomatic origin. Goodspeed (1937) has described the development of plagioclase porphyroblasts in the metamorphic rocks of the Wallowa Mountains of Northeastern Oregon.

2. Pegmatites and aplites.

The dominant type of pegmatite in the Svejstrups injection complex is a white-coloured biotite and/or muscovite-quartz-plagioclase type. Garnet is a common accessory mineral. Microcline-rich pegmatites are of much less widespread occurrence. The aplites can be divided into two distinct types namely oligioclase rich and potash feldspar rich. The latter are generally pink in colour and orthoclase or microcline is dominant over plagioclase. The potash-aplites are particularly common in areas of microcline porphyroblastesis and more potassic injection. Quartz pegmatite veins and dykes are of ubiquitous occurrence.

1796. Oligoclase pegmatite near glacier S3 in the Svejstrups Dal. Quartz is the principal constituent occurring in crystals up to 1 cm in length and averaging 2—3 mm; they are highly strained and sutured. Plagioclase (An 28, n′g 1.550, n′p 1.543 for 001) crystals are up to 2 cm in length and are slightly sericitized. A small amount of chlorite secondary after biotite is present (Table 4, xi).

1338. Oligoclase aplite from the lower Tyrolerdal. The texture is granoblastic and the average grain size 1 mm. Oligoclase forms about half of the rock and potash feldspar, both orthoclase and microcline, about 10 %. The orthoclase is perthitic. A very small amount of biotite is present. Accessory minerals are garnet, in small pink crystals exceptionally up to 0.5 mm in diameter, zircon and apatite (Table 4, xii).

1323. Oligoclase-orthoclase pegmatite from the upper Svejstrups Dal near glacier S3. The pegmatite is composed of quartz, oligoclase, orthoclase, myrmekite, and biotite. Quartz is much strained and shows undulose extinction. Plagioclase exhibits mymekitic margins against potash feldspar; myrmekite also occurs in separate grains up to 0.5 mm in diameter. Perthitic orthoclase shows replacement relations towards plagioclase. Biotite is reddish-brown and is partly altered to rutile, magnetite, and chlorite (Table 4, xiii).

1833. Microcline pegmatite from Lerbugt, Tyrolerfjord. This is a typical potassic pegmatite. Quartz forms strained crystals averaging 4 mm in length. Microcline-microperthite crystals are up to 2 cm in length. Plagioclase is albite-oligoclase and is much subordinate in amount to microcline. Both muscovite and biotite occur, the former being sieved with quartz inclusions. A little garnet is present (Table 4, xiv).

1347. Microcline-oligoclase pegmatite from upper Blaabærdalen. This pegmatite has been partially granulitized. Porphyroclasts of quartz, plagioclase, and orthoclase lie within a fine-grained matrix of the same minerals. Microcline crystals are up to 1 cm in length and are sometimes intergrown with quartz. Plagioclase is a sodic oligoclase. Muscovite is the only mica present. Garnet occurs as an accessory mineral (Table 4, xv).

3. Antiperthite feldspar.

Antiperthitic plagioclase is a characteristic feature of the Svejstrups injection complex. The plagioclase forms part of the injecting pegmatite within schists and to a lesser extent hornblende gneisses.

Nature of the antiperthite.

The injection antiperthite plagioclase occurs in two main ways, namely as large augen up to 1 cm in length (Fig. 24, A) or in smaller crystals averaging 0.3—1 mm in length (Fig. 24, B). The plagioclase crystals never show well-formed faces. Twinning on the albite, pericline, and Carlsbad Laws is present. The potash feldspar within the plagioclase occurs as stringlets, strings, rods, beads (Alling, 1938, p. 145) and in more irregular forms. The most frequent type of blebs are the rods; the largest of these are over 1 mm in length whilst the average length is 0.1—0.5 mm.

Textural relations.

In the large antiperthites the blebs are very numerous and regular in distribution and orientation (Fig. 24, A; Plate IV, 2, 3). They are generally absent or sparse round the margins of the plagioclase host;

also round inclusions of quartz. An interesting feature of one of the antiperthites is the radiating character of the blebs in an area where albite twinning is absent (Fig. 24, A). In one crystal the blebs are small and rounded on its margins where albite twinning is very frequent and occur as long fine strings and rods at its centre where there is little twinning. In the small antiperthite feldspars the blebs are never very abundant and are usually somewhat irregular (Fig. 24, B; Plate IV, 4). In some cases only one or two blebs may be present.

Orientation of the blebs.

In the large antiperthites the rods of potash feldspar are frequently parallel to 010 and lie along the albite twin planes. In some crystals there are two distinct sets of rods inclined to one another at a small angle (Plate IV, 2). Where microcline cross-hatch twinning is developed in the blebs the albite twin lamellae of the potash feldspar are parallel to those of the plagioclase host.

Composition.

The antiperthitic plagioclase ranges in composition from An 20 to An 30 and averages An 26 (n'g 1,548, n'p 1,540 on 001 cleavage faces). Many of the blebs of potash feldspar show the vague cross-hatch twinning typical of microcline but only rarely is it well-pronounced.

The amount of potash feldspar within the antiperthites ranges from a few per cent to probably about 35 $^0/_0$. Two antiperthites were measured on an integrating stage and showed 68 $^0/_0$ and 78 $^0/_0$ of plagioclase respectively, the remainder being largely potash feldspar. Both these examples are of large crystals containing numerous blebs.

Occurrence.

Antiperthite feldspars similar to those described above are of much less frequent occurrence than normal perthites. They were first described by Suess (1904, p. 419). Since the Greenland antiperthites occur within a Caledonian injection complex it is of interest to see to what extent antiperthite is characteristic of other complexes of similar age. Read

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Fig. 24. Antiperthite plagioclase crystals forming part of injection material within schists and gneisses.

A. Plagioclase crystals in schist from near the summit of Gere (902 m). The blebs of potash feldspar are generally aligned parallel to the albite twin lamellae. On the lower left-hand side of the crystal the antiperthite resembles a micrographic intergowth of quartz and feldspar. In this part of the plagioclase crystal twinning is absent. The albite twin lamellae are shown by ruled lines (diagrammatic). The inclusions within the plagioclase are of quartz.

B. Typical small antiperthite crystals.

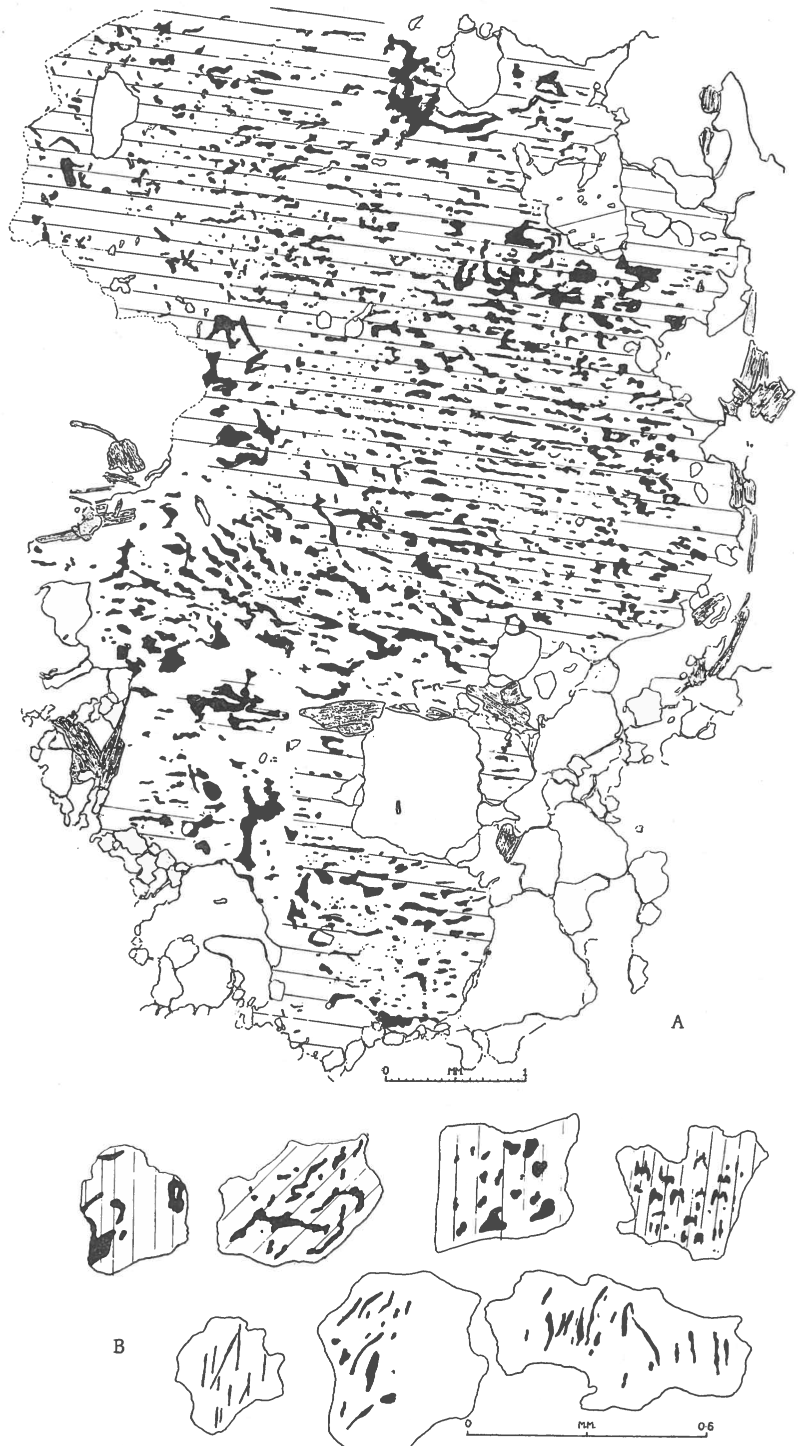

Fig. 24.

(1931, p. 117) mentions the occurrence of augen of antiperthite in the Loch Choire complex, Scotland but they do not appear to be characteristic. Antiperthite is present in the migmatites around Bettyhill, Sutherland (Yu-Chi Cheng, 1944, p. 41). In Inverness-shire antiperthite feldspar occurs in an intrusion of orthogneiss of Caledonian age but it does not appear to be characteristic of the regional injection complex of this area.

Antiperthite is not uncommon in metamorphic rocks (other than composite gneisses). It occurs in a few of the hornblende gneisses of the Svejstrups area and in pyroxene gneisses of Liverpool Land (Kranck, 1935, p. 36). It is of frequent occurrence in rocks of the 'granulite' facies (Groves, 1935, p. 54 and others).

Antiperthite is not common in igneous rocks with the exception of alkaline types (Quensel, 1914, p. 143, 166; Phemister, 1926, p. 25 and others). Examples of antiperthite in pegmatites have been described by Anderson (1928) and Buntin (1937), and in granitic rocks by Tschirwinsky (1929) Goldschmidt (1916, p. 39), Read (1931, p. 144; 1926, p. 154); Chudoba (1930) and others. The antiperthite described and figured in detail by Anderson is closely comparable to that of the Svejstrups injection complex. The following points of comparison may be briefly noted: the blebs frequently occur along twin boundaries; two sets of blebs with distinct orientations are present in many cases; and the albite twin lamellae of the microcline inclusions are coincident with those of the plagioclase.

Origin.

There is a very close similarity between the form and arrangement of blebs in entiperthite and perthite. This similarity indicates quite definitely a common mode of origin for both.

There are three possible processes which may be invoked to explain perthites and antiperthites: (1) by replacement, (2) by simultaneous crystallization, and (3) by exsolution. For the following reasons an origin of the Svejstrups antiperthite by replacement processes appears improbable: (1) abundance, regularity of distribution, and constancy of orientation of the blebs throughout the antiperthite, (2) absence of blebs from the margins of the plagioclase crystals, (3) sharply defined borders of the blebs and absence of any veinlike blebs or veins connecting blebs.

The theory for the origin of perthite and antiperthite by simultaneous crystallization has been upheld more particularly by Anderson (1928). It is possible that during growth of plagioclase potash feldspar may have been deposited on certain faces of the plagioclase or become trapped within cleavage cracks. If this process has occurred in the Svejstrups antiperthites it would seem that the 010 faces are preferentially incrustated by potash feldspar since in many of the antiperthites the blebs are parallel to 010. Such selective incrustation is a well-known feature (FRONDEL, 1934; other references quoted). If however some form of selective incrustation had occurred this should show itself in the pattern of the blebs. In the larger antiperthites however the blebs are of uniform distribution there is no 'hour-glass' zoning or zoning indicative of growth on two or more faces of the plagioclase.

Whilst the possibility of a process of simultaneous crystallization to explain the origin of antiperthite cannot be entirely ruled out it appears that an origin by exsolution is much more probable. The origin of microperthite by exsolution processes is now generally accepted. Experimental evidence (SPENCER, 1930, 1937; BOWEN and TUTTLE, 1950) supports this view. It may be noted that there is a close resemblence between the pattern of the blebs in the Greenland antiperthites and the textures seen in ore mineral pairs considered to have been formed by exsolution (SCHWARTZ, 1931; 1942 and references).

4. Summary.

The regional injection took place during a late stage of the main period of Caledonian folding and before the complete cessation of stress. The early lit-par-lit material within the composite gneisses and schists is considered to be the result of injection by water-rich magma. Permeation by solutions is of subsidiary importance. This magma originated during the Caledonian orogeny by differential fusion (palingenesis or anatexis) of an acid crust at depth. In the main it was of trondhjemitic composition, being rich in oligoclase and quartz and poor in ferromagnesian minerals. The injection granite and pegmatite within the injection complex is generally made up of 40—45 % quartz, 55—60 % oligoclase and up to 2 % of mica. The oligoclase ranges in composition from An 15 to An 30 but is usually about An 26. Trondhjemitic injection magma appears to be characteristic of the Caledonides of Greenland, Britain (READ, 1927; 1931, p. 147; WILLIAMSON, 1935, pp. 387—98; unpublished investigations by the author in the West Highlands), and Scandinavia (GOLDSCHMIDT, 1920).

At a late stage of the injection period and probably when stress was very weak potassic solutions were active and porphyroblasts of microcline were formed.

Pegmatites, aplites, and granite occur as transgressive sheets, dykes, and veins throughout the complex. These intrusions are generally earlier than the latest Caledonian folding since they have been partly sheared. They post-date the lit-par-lit injection and permeation.

d. Tertiary basalt.

The summit of Dombjerg (1,444 m) is composed of a Tertiary basalt flow resting upon crystalline schists and showing crude columnar jointing.

1345. Megascopically the basalt is fine-grained, sub-basic and contains conspicuous phenocrysts of plagioclase averaging half a centimetre in length. These phenocrysts (An60) show normal-oscillatory zoning. Micro-phenocrysts of plagioclase, monoclinic pyroxene, and olivine, the latter largely pseudomorphed by chlorite, average 0.1—0.5 mm in length. The groundmass consists of plagioclase (An55), monoclinic pyroxene, and magnetite. The basalt has the following composition; plagioclase phenocrysts 24, groundmass plagioclase 35, monoclinic pyroxene phenocrysts 7, groundmass monoclinic pyroxene 24, chlorite 5, magnetite 5 (Plate V, 4).

Similar plagioclase basalts to the above have been described by Backlund and Malmqvist (1932, pp. 30—6) from Clavering Ø, Hudson Land, and elsewhere.

VI. METAMORPHISM

The metamorphism of the igneous rocks and sediments of the Svejstrups area occurred in two main phases, in part overlapping. Firstly they were folded and altered under strong shearing stress and at a moderately high temperature. During this period of metamorphism they were transformed into crystalline schists and gneisses with well-defined directional structures. The typical stress mineral formed was almandine garnet. Shortly after, or possibly partly contemporaneous with this early metamorphic period the schists and gneisses were invaded by granitic material of the regional injection complex. Wherever possible this material was injected along pre-existing planes of foliation and schistosity. With the onset of the regional injection there was a marked increase in the temperature and a corresponding decrease in the shearing stress. Within the injection complex additive or injection metamorphism took place with the formation of the sillimanite in the pelitic and semi-pelitic schists, and re-crystallization of pre-existing minerals particularly the micas. The development of sillimanite as a consequence of thermo-metamorphism induced by the intrusion of granitic material into orogenic zones was long ago described by Barrow (1893, p. 337; 1912) and his conclusions have since been amply confirmed by later studies (Read, 1927, pp. 323—28; 1931, p. 146; Sugi, 1935; Barth, 1936, pp. 778—79; Billings, 1937, pp. 557—59; Kennedy, 1949, p. 55; Misch, 1949).

Stated briefly the metamorphism in the Svejstrups area, and probably throughout much of the Caledonides of East Greenland, is the result of increase of temperature connected with the rise of granitic material and combined with mainly contemporaneous orogenic deformation.

According to the facies classification of Eskola (1920) the Svejstrups Dal gneisses and schists unaffected by regional injection belong to the amphibolite facies, typical assemblages being:

Pelitic and psammitic schists: muscovite-biotite-plagioclase-microcline-quartz-almandine.

Calc schists: quartz-biotite-plagioclase-hornblende-garnet.

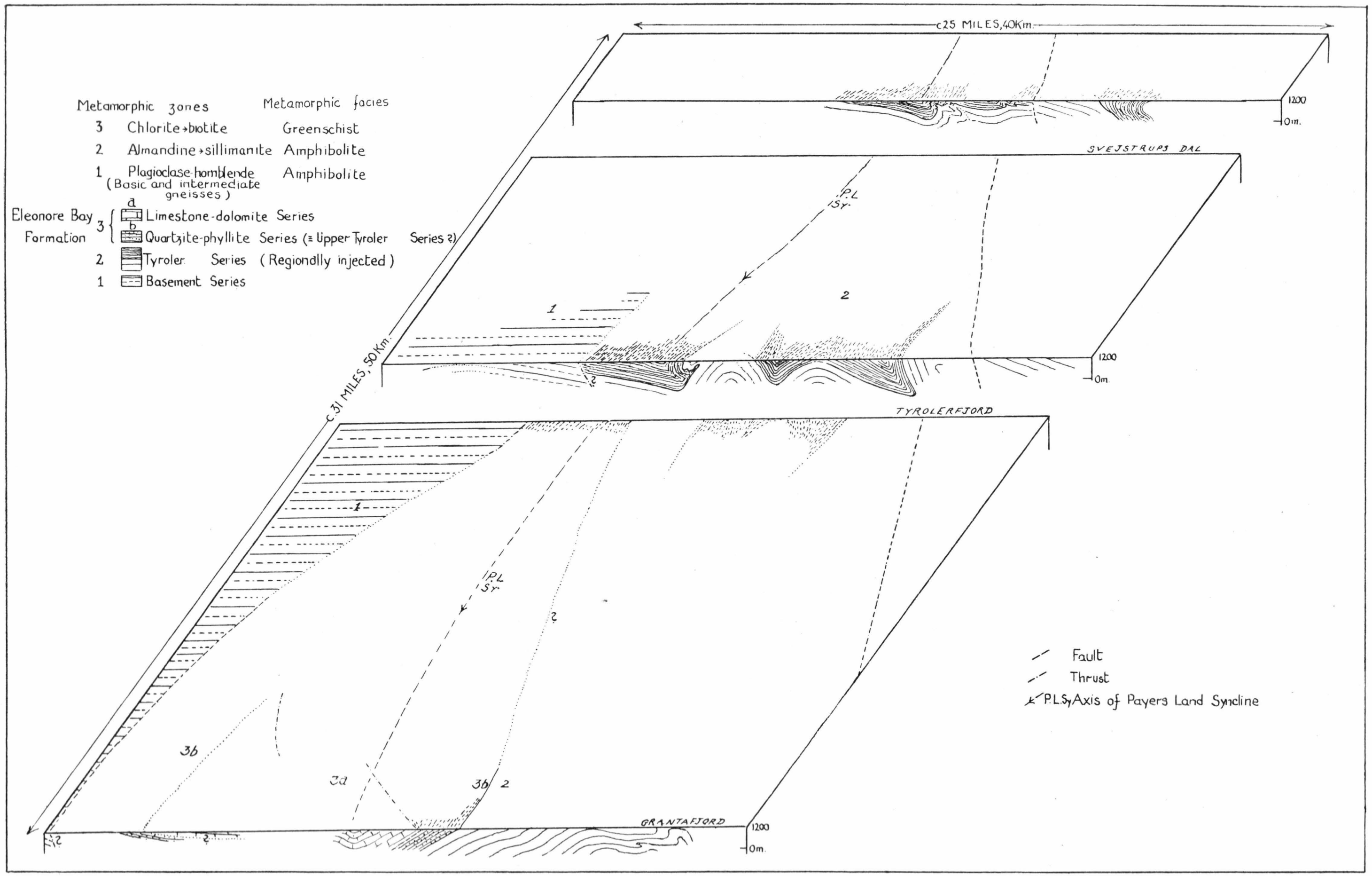

Fig. 25. Diagram showing the relationships of structure, metamorphism, and regional injection in Payers and A. P. Olsens Lands. Relationships in south Payers Land largely based in Mittelholzer (1941).

Intermediate and acid gneisses: biotite-quartz-potash-feldspar-plagioclase.

hornblende-biotite-quartz-plagioclase-almandine.

Amphibolites: hornblende-plagioclase-almandine,

hornblende-biotite-plagioclase-almandine.

The gneisses and schists of the injection complex belong to the amphibolite facies (sillimanite-almandine subfacies). Sillimanite and almandine are the characteristic minerals in pelitic and semi-pelitic schists.

The relationship between metamorphism and regional injection is clearly displayed in Payers Land; in this area the S.S.W. pitching Payers Land syncline exposes weakly metamorphosed uninjected rocks of the Eleonore Bay Formation in its trough and high-grade regionally injected gneisses on its two limbs (Fig. 25). From Mittelholzer's descriptions (1941) it appears that there is a decrease of metamorphic grade upwards from the injection gneisses into the Eleonore Bay Formation. The relationships are somewhat complicated by the fact that the upper part of the Eleonore Bay Formation is considered to be thrust over the lower part. It is quite clear however that in Payers Land, structure, injection, and metamorphism are all related, the injection dying out upwards in the Tyroler Series and lower part of the Eleonore Bay Formation and metamorphism showing corresponding progressive upward decrease. Owing to the S.S.W. pitch of the Payers Land Syncline high-grade regionally injected rocks appear in the Tyrolerdal and Tyrolerfjord areas to the north. A similar progressive upwards decrease in metamorphic grade has been described by Odell (1944, pp. 241—3) from the Kejser Franz Josephs Fjord area.

Retrogressive metamorphism.

Retrogressive metamorphism or diapthoresis accompanying post-crystalline thrust movements is of widespread occurrence in the Svejstrups area. New minerals were formed under conditions of low temperature and strong shearing stress. Some rocks within the thrust zones suffer only change of fabric unaccompanied by mineralogical reconstitution, but in the general case a certain amount of diapthoresis has occurred. Minerals susceptible to diapthoritic change are biotite, garnet, and hornblende. Garnetiferous biotite-muscovite-granulites are replaced by granulitized chlorite-schists; garnet-biotite-schists by granulitized garnet-chlorite-muscovite-biotite schists; hornblende gneisses and amphibolites by epidote-chlorite-plagioclase, epidote-actinolite-chlorite-plagioclase, assemblages etc.

Table 2.

	I	II	III	IV	V	VI	VII	VIII	IX
Quartz	×	16.2	22.6	34	3.2	24	..	..	43.8
Plagioclase	66.4	59.2	52.9	23	51.4	59	24.2	28	..
Orthoclase	..	..	..	33	..	2	..	..	39.1
Microcline	..	..	×	9	..	..	..	..	16.8
Hornblende	26.7	13.6	14.8	..	39.2	14	66.9	65.7	0.1
Biotite	2.5	10.5	9.0	1	..	..	5.1	6.3	0.2
Augite	..	..	..	..	5.8	..	..	..	..
Enstatite	..	..	..	..	..	..	..	..	..
Olivine	..	..	..	..	..	..	..	..	..
Sphene	..	..	..	..	0.4	..	0.5	..	×
Pyrite	×	×	×	..	..	..	..	..	..
Epidote	..	..	..	..	..	..	3.0	..	..
Prehnite	..	..	..	..	..	..	..	..	..
Spinel	..	..	..	..	..	..	..	..	..
Apatite	2.7	0.5	×	..	..	×	0.3	..	×
Magnetite	×	×	×	×	..	×	..	..	..
Garnet	..	..	..	..	..	..	..	..	..
Zircon	..	..	..	..	×	..	..	..	×
Allanite	..	..	..	..	..	×	..	..	..
Combined accessories	1.7	..	0.7	..	..	1	..	..	..

XII a. "Plagioclase-granite", Long Bay, Virgin Gorda, West Indies (JOHANNSEN, 1932, p. 382).
XIII a. Tonalite, Port Lochroy, Antarctica (JOHANNSEN, p. 384).
XVI a. Quartz-diorite, La Sarre Township, Quebec (JOHANNSEN, p. 389).

Table 3.

	I	II	III	IV	V	VI	VII	VIII	IX	X
Quartz	84.1	88.6	65.3	62.3	31.4	65.0	54.6	52.0	29.1	17.3
Plagioclase	11.8	9.3	17.6	14.5	20.6	26.5	34.3	33.5	31.2	41.5
Orthoclase	×	×	..	×	..	..	..	..	..	..
Microcline	..	..	6.9	..	..	..	..	..	..	..
Hornblende	..	..	..	..	8.3	4.8	2.8	4.5	16.9	31.7
Biotite	1.5	1.8	1.5	8.7	25.4	0.6	5.7	4.0	3.8	0.8
Muscovite	2.4	..	8.5	..	..	..	..	..	..	..
Garnet	..	..	..	9.5	14.0	2.6	2.5	4.5	18.5	5.2
Magnetite	..	0.3	..	×	..	×	..	×	×	×
Sphene	..	..	×	..	..	×	..	..	×	×
Hematite	..	..	..	..	..	..	..	..	×	..
Apatite	..	..	..	..	..	..	..	..	..	×
Zircon	..	..	×	..	0.3	..	0.1	×	..	..
Pyrite	..	..	..	..	..	..	..	..	..	..
Chlorite	..	..	..	4.5	..	..	..	..	..	..
Epidote	..	..	..	×	..	×	..	..	..	..
Combined accessories	0.2	..	0.2	0.5	..	0.5	..	1.5	0.5	..

	X	XI	XII	XII a	XIII	XIII a	XIV	XV	XVI	XVI a	XVII	XVIII	XIX	XX	XXI	XXII
	24.9	25	40.0	38	36.0	29.0	35	22.1	22.5	15	17	5.9	..	..	31	..
	39.3	57	48.6	53	38.7	45.7	42	61.0	29.7	25	29	52.6	56.5	42	2	1.5
	28.6	..	..	..	..	2.3	1	..	..	..	..	..	21.4	..	..	..
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	..	..	6.9	6.0	8.3	6.3	18	15.1	46.3	60	53	38.0	18.6	58	15	..
	6.0	18	3.4	×	15.5	10.4	2	..	..	..	..	2.2	0.9	..	..	..
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	44.4
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	21.0
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	31.8
	×	..	×	..	×	..	×	..	1.0	..	×	1.0	1.7	..	4	..
	..	..	..	..	..	6.3	..	1.0	..	..	..	..	..	..	..	..
	..	..	×	..	..	..	..	×	..	..	..	..	..	..	..	..
	..	..	..	..	0.8	..	..	..	..	..	..	..	..	..	..	..
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0.7
	×	×	..	..	×	..	×	..	..	..	..	×	×	×	..	..
	..	..	..	..	×	..	×	×	0.5	..	×	..	×	×	..	0.6
	..	..	0.3	..	..	..	..	..	..	..	..	..	..	..	48	..
	×	×	..	..	..	..	×	..	..	..	..	..	×	..	..	..
	..	..	..	..	..	..	..	..	..	..	×	..	×	..	..	..
	1.2	..	0.8	2.0	0.7	..	2	0.8	..	..	1	0.3	0.9	..	..	..

Table 4.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
Quartz	38	37	39	31.6	33	56.2	46	30	41.3	10	63	38	35.6	30	29.6
Plagioclase	17	22	57	23.7	44	22.5	54	24	46.0	62	34	47	33.9	20	26.0
Pure albite	..	..	×	..	..	..	..		..	..	..			..	..
Orthoclase	..	33	..	..	23	..	..	41	..	..	..	13	27	..	..
Microline	35	..	..	16.4	..	..	..		..	..	..			45	39.4
Hornblende	..	..	2	..	..	..	..	..	9.9	16	..	..	..	..	..
Biotite	4	8	..	19.9	..	8.6	..	5	2.1	11	..	1	1.5	×	×
Muscovite	4	..	..	2.3	..	11.7	..	..	..	..	..	..	..	×	4.5
Garnet	2	..	×	5.1	..	×	..	..	0.5	..	..	×	..	..	0.4
Magnetite	..	..	..	×	..	..	..	..	..	×	..	..	..	..	..
Sillimanite	..	..	×	0.8	..	..	..	..	..	..	..	..	..	..	..
Sphene	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..
Apatite	..	..	×	..	..	×	..	×	..	×	..	×	..	..	..
Zircon	×	..	×	×	×	..	..	..	..	..	..	×	..	..	..
Chlorite	×	×	×	×	×	×	..	×	×	×	3	..	..	..	..
Epidote	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..
Myrmekite	×	×	×	×	×	×	..	×	..	..	..	..	2.0	×	×
Combined access.	..	..	2	0.2	..	1.0	..	..	0.2	1	..	1	..	5	0.1

VII. SUMMARY

Morphologically the Svejstrups area consists of two well-defined units, namely a peneplain surface at an altitude of from 1,000 to 1,500 m, and a system of fjords and related valleys. The peneplain slopes gently eastwards and is terminated in the coastal area by a series of north-south trending faults sometimes marked by prominent scarps. The fjords originated by glacial erosion along pre-existing river valleys; their formation cannot be ascribed to any direct tectonic causes.

The peneplain surface is covered by small ice-caps, remnants of a once continuous ice-sheet. The glaciers descending from these ice-caps are all retreating as is shown by abandoned moraine and other phenomena. The amount of regression from the maximum advance position in post-glacial times (probably late 18th. or early 19th. century) varies from 200 to 1200 m with an average of 700 m.

Crystalline rocks in this part of North-East Greenland occupy much of the country extending from the coast westwards to the inland-ice. Mesozoic sediments and Tertiary volcanics veneer the crystalline rocks of Clavering, Sabine, Pendulum, and Kuhn islands, and on Wollaston Forland.

Three main series of crystalline rocks are distinguished, namely the Basement Series, Tyroler Series, and the Eleonore Bay Formation (youngest). In the Kejser Franz Josephs Fjord region the Eleonore Bay Formation underlies fossiliferous Cambrian beds and has generally been accepted as of young Pre-Cambrian age. The sediments (now meta-sediments) of the Tyroler Series may also be of young Pre-Cambrian age.

The Basement Series consists predominantly of hornblende and hornblende-biotite orthogneisses and amphibolites. Meta-sediments are of subordinate occurrence. The Tyroler Series consists of psammitic and pelitic schists, subordinate calc-schists and limestones, and orthogneisses and schists. The Tyroler Series seems to show lithological equivalence to the Gregory Series of the Kejser Franz Josephs Fjord. The orthogneisses of the Svenstrups area can be closely matched by Scottish Lewisian types, the meta-sediments by rocks of the Moine Series.

The gneisses and schists of the Tyroler Series were formed during the Caledonian orogeny. The Basement gneisses were probably formed in Pre-Cambrian times and later affected by Caledonian folding.

The Caledonian movement was towards the west and overfolding occurs in this direction. In the Tyrolerdal and central Svejstrups Dal the gneisses and schists are disposed in a series of major open folds, the average distance between the fold-axes being 3—5 km. The fold-axes trend between N.E. and N.N.E. and pitch at angles of 5° to 30°. The dominant feature of the structure is the Payers Land syncline which extends from south Payers Land to at least as far as the Svejstrups Dal. The western limb of the syncline dips gently eastwards; the eastern limb is overturned. The syncline pitches gently towards the S.S.W. and brings in the Eleonore Bay Formation in south Payers Land and Stenos Land.

Post-crystalline thrust movements, of late Caledonian age, have occurred in the Svejstrups area and throughout the Caledonides of East Greenland. Post-Devonian normal faults with a general N.—S. trend intersect the crystalline block dropping it down towards the east. These faults are often marked by scarps.

The crystalline rocks of the Svejstrups area lie within a regional injection complex of Caledonian age. Within the complex the schists and gneisses have been soaked and injected by granitic material and pass into coarsely crystalline composite or migmatitic gneisses. Transgressive intrusions of pegmatite, aplite, and granite are of widespread occurrence. The regional injection took place in part contemporaneous with the Caledonian folding and before stress had ceased.

Metamorphism in the Svejstrups area is the result of increase of temperature, connected with the rise of granitic material, combined with contemporaneous Caledonian orogenic deformation. In the schists outside the injection complex almandine garnet is the characteristic mineral, and within it, sillimanite. Injection and metamorphism increase downwards. Uninjected phyllites, limestones and other weakly metamorphosed rocks of the Eleonore Bay Formation grade downwards into sillimanite gneisses and schists and other high grade regionally injected rocks of the Tyroler Series.

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Færdig fra trykkeriet den 9. februar 1952.

PLATES

Plate I.

Geological map of the crystalline rocks of North-East Greenland between latitudes 74°30′ and 75° N. Geology of parts of the Tyrolerfjord, Clavering Ø and the Pasterze based upon maps by MITTELHOLZER (1941) and VISCHER (1943).

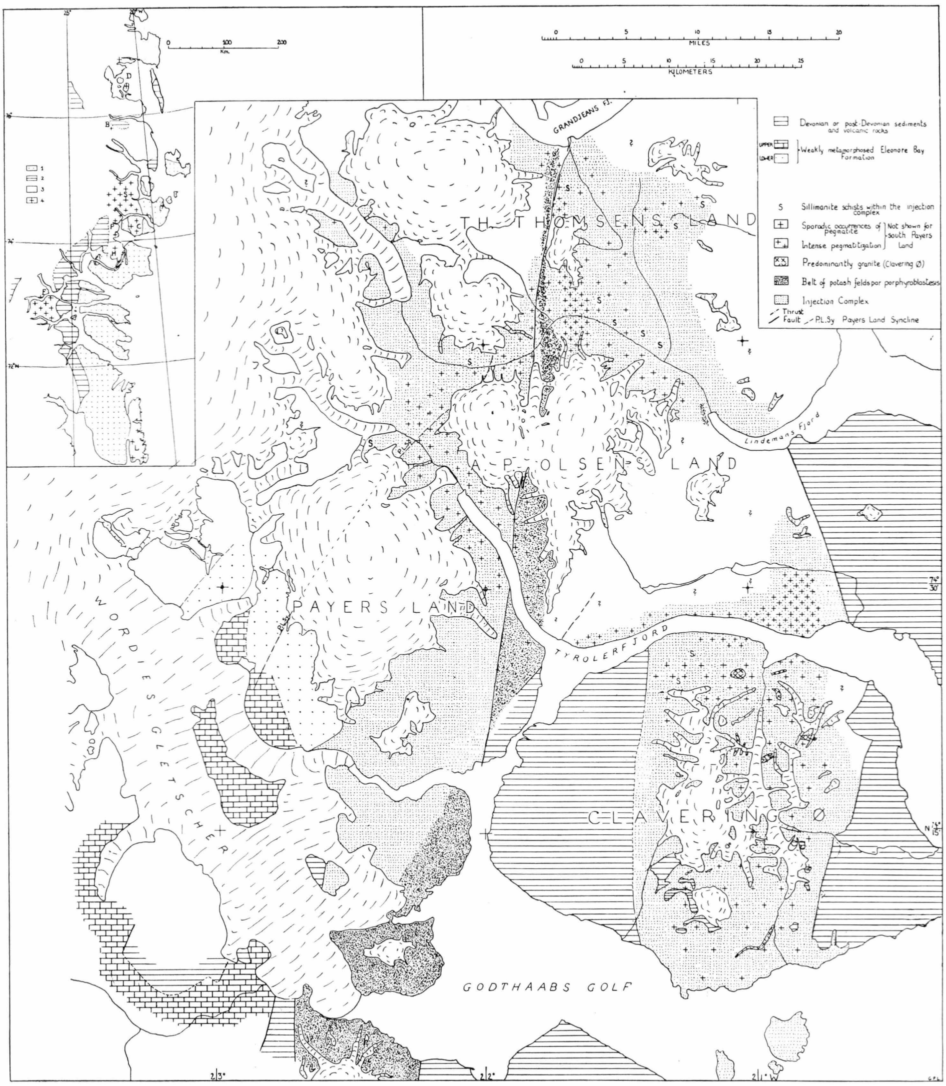

MILES
KILOMETERS
Km.
Devonian or post-Devonian sediments and volcanic rocks
UPPER
LOWER
Weakly metamorphosed Eleonore Bay Formation
S Sillimanite schists within the injection complex
Sporadic occurrences of pegmatite
Intense pegmatitization
Not shown for south Payers Land
Predominantly granite (Clavering Ø)
Belt of potash feldspar porphyroblastesis
Injection Complex
Thrust
Fault
P.L.Sy Payers Land Syncline
GRANDJEANS FJ.
TH. THOMSENS LAND
A. P. OLSENS LAND
Lindemans Fjord
PAYERS LAND
WORDIES GLETSCHER
TYROLERFJORD
CLAVERING Ø
GODTHAABS GOLF
74° 30'
23°
22°
21°

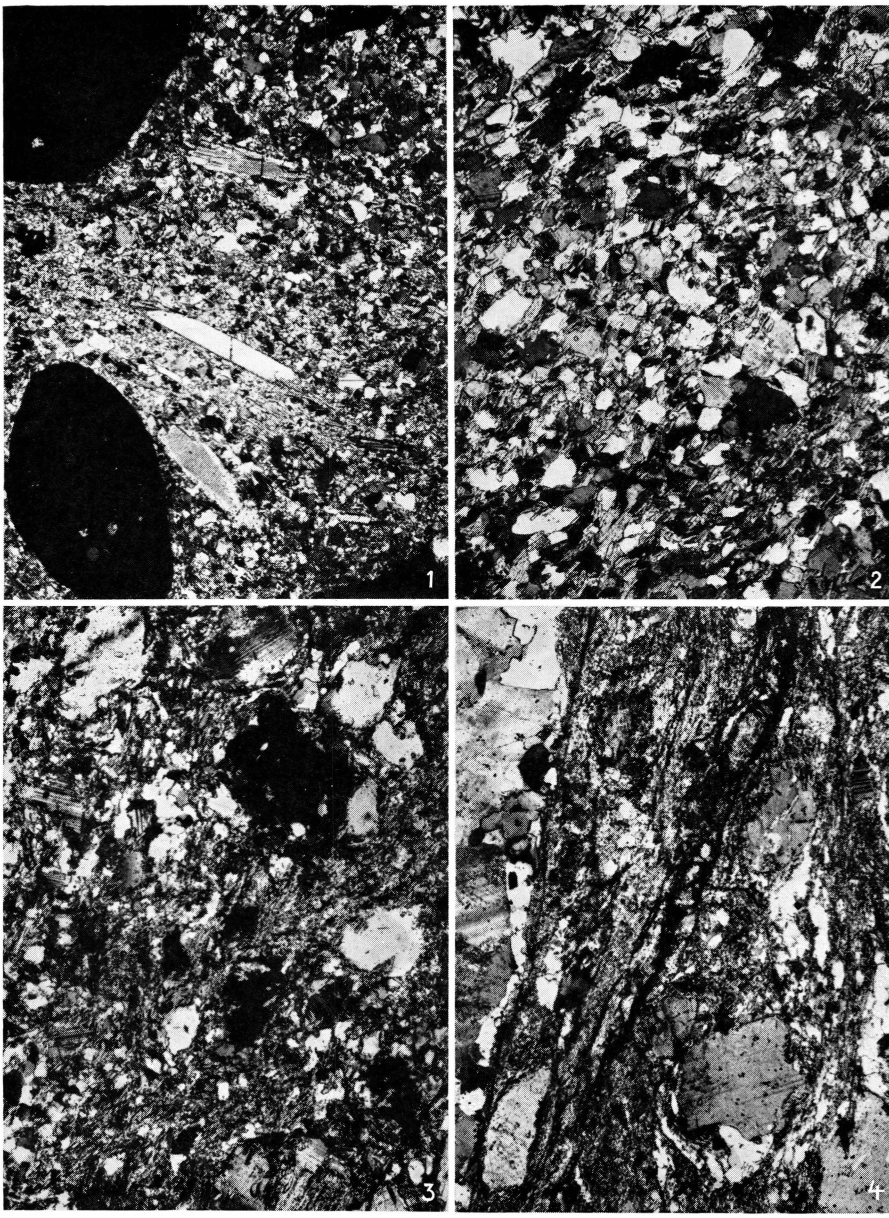
Plate II.

The regional injection complex in North-East Greenland between latitudes 74° and 75° N.

Occurrence of regional injection in East Greenland.

1. Devonian and post-Devonian.
2. Eleonore Bay Formation and Petermann Series.
3. High-grade gneisses and schists.
4. Known areas of regional injection within 3.

D. Dove Bugt. Injection gneisses described by MITTELHOLZER (1941).
B. Bessels Fjord—Ardencaple Fjord. Injection described by TEICHERT (1933). Probably much of this area forms the northern continuation of the Svejstrups complex.
S. Svejstrups injection complex.
C. Clavering Ø. Injection described by MITTELHOLZER (1941) and BACKLUND (1930; 1932).
P. Payers Land. Injection described by MITTELHOLZER, BACKLUND, and TEICHERT.
H. Hudson Land. Injection described by BACKLUND.
F. Kejser Franz Josephs Fjord. Widespread injection (WEGMANN, 1935; ODELL 1944; BACKLUND, 1930; HUBER, 1950).
L. Liverpool Land. Widespread migmatization described by KRANCK (1935).



1
2
3
4

Plate IV.

1. 1343. Psammitic schist from 1,000 m on the south-east shoulder of the Gross Glockner showing incipient granulitization. Quartz is partly sutured and shows intense straining. A fine-grained matrix is partly developed. Crossed nicols, × 65.

2. 1816. Antiperthite injection feldspar. The rods of potash feldspar within the plagioclase host (An_{25}) show two distinct trends. The plagioclase is clouded by sericite and opaque material probably iron ore. Crossed nicols, × 120.

3. 1791. Antiperthite feldspar in injection schist from 800 m on the east shoulder of Gere in the lower Svejstrups Dal. The rods are here aligned parallel to the 010 twinning of the plagioclase host. Crossed nicols, × 135.

4. 1328. Small antiperthite feldspars in an injected hornblende-gneiss. Each plagio. clase crystal contains a few unorientated rods of potash feldspar. Crossed nicols, × 60.

Plate IV.

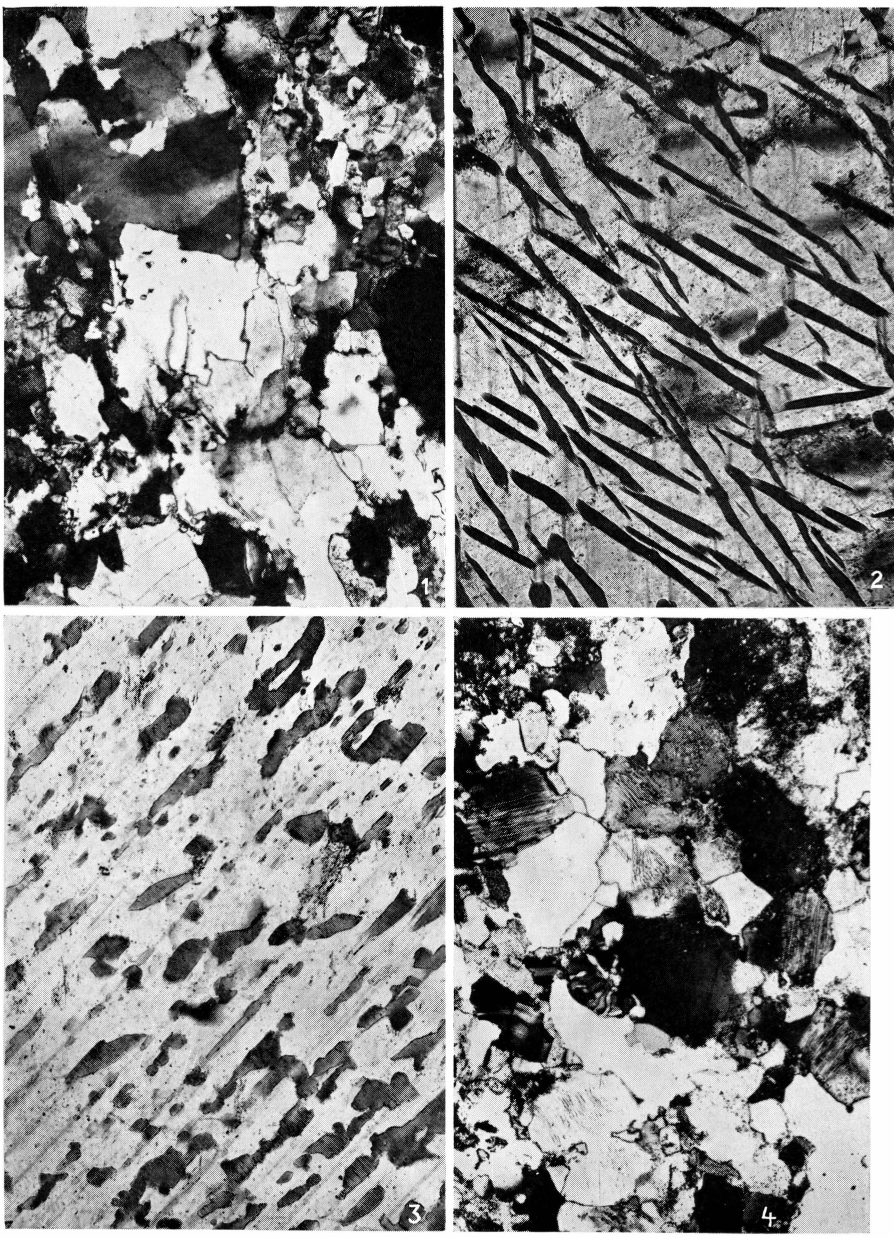


Plate V.

1. 1802. Sillimanite in injected schist from 650 m on the east shoulder of Gere. Crossed nicols, $\times$ 75.

2. 1764. Sillimanite in injected schist from the summit of the Westendspids (1,404 m). Crossed nicols, $\times$ 65.

3. 1320. Augite-olivine-enstatite rock from peak 1,246 m in the central Svejstrups Dal. A large crystal of enstatite occurs on the left-hand side of the photograph. Small rounded olivine crystals are enclosed within augite. Crossed nicols, $\times$ 75.

4. 1345. Plagioclase-basalt from the summit of Dombjerg (1,444 m). Phenocrysts of labradorite and microphenocrysts of augite lie in a groundmass of plagioclase, augite and magnetite. A few small phenocrysts of olivine also occur within this rock. Crossed nicols, $\times$ 75.

PLATE V.