THE GEOLOGY OF THE MARAN AREA, DONEGAL, IRELAND.

THESIS

submitted for the

Degree of Ph.D. of the

University of London.

by

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Dept. of Geology,
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London, 1954.

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" No.4.	Northern Aureole of the Ardara Pluton, scale 3 inches = 1 mile (approx).	Opposite p.228.

A B S T R A C T.

A thick series of Dalradian sediments with minor doleritic intrusions was subjected to orogenic movements from the south accompanied by a regional metamorphism up to the 'garnet grade'. Immediately following this episode, the intrusion of a suite of lamprophyre-felsite dykes marked the opening phase of a lengthy igneous period. Next, minor bodies of granodiorite were emplaced, followed by a swarm of basic lamprophyre dykes. Later movements from the south-east gave rise to major thrusts in the south trending N.E.-S.W., one of which was occupied by the Carbane sheet of migmatitic tonalite. These movements caused a regional retrograde metamorphism converting garnet to chlorite.

The Ardara Granitic Pluton now came into position as a diapir forcibly displacing the country rocks, the magma having originally ascended along a major dislocation trending N.E.- S.W. The Pluton, 5 miles in diameter, consists of a core of granodiorite and an outer mantle of tonalite. The granodiorite core is a member of the Donegal Granite Series, and has an outer part which has acquired the composition of a quartz-diorite by interaction with rocks of the Amphibolitic Complex of Meenalargan; its central portion of biotite-granodiorite was emplaced as a second upwelling of magma. The outer tonalite is a mobilised derivative of the Meenalargan Complex, and is strongly foliated parallel to the confining envelope. A thermal metamorphism was superimposed upon the country rocks, and in the northern side, a zoned aureole consists of an inner sillimanite zone followed by an outer andalusite zone; in this aureole, the intrusion-history of the pluton is recorded mineralogically, structurally and texturally.

Post-granite tectonics have converted the tonalite sheet into mylonitic gneiss and have caused the progressive destruction of the southern aureole. Later movements have impressed secondary structures upon the 'neck' of the pluton. These were contemporaneous with the emplacement of another member of the Granite Series across the 'neck', with the development of staurolite and garnet in adjacent pelites. Finally, sheets and dykes of microgranodiorite were intruded and were followed by a set of porphyry dykes.

Chapter ONE. INTRODUCTION.

I. Delimitation of the Area.

The area which forms the subject of the present study covers about 40 sq. miles lying within the latitudes 54° 44' 20" - 54° 51' 20" and longitudes 8° 15' 20" - 8° 26' 30", in the centre of the western part of County Donegal in the Republic of Ireland. It is included in Sheets 64, 65, 73, 74, 82 and 84 of the Ordnance Survey Maps of Ireland on the scale of 6" to the mile. The geology of the area is represented on the One-Inch Geological Survey Maps No.15 (Dunglow) and 23 (Glenties) published in 1890.

The area is bounded on its northern side by Gweebarra Bay and is situated between the towns of Ardara and Glenties to the south-west and south-east, Maas and Clooney on its north-eastern side and Narin to the north-west. The area investigated also includes the island of Inishkeel lying about ½ mile off the coast of Portnoo, as well as several isolated rocks and small islands along the southern shores of Gweebarra Bay. On the western side, the area is bounded by the Narin Ardara road and on the southern side by a range of hills trending in the north-eastern direction from the Slieve League peninsula towards Fintown. The north-eastern boundary of the area is a line running roughly from Meenalargan village to Letterilly and thence along the main road to Maas.

II. Physical Features.

The physical features of Western Ireland have been described in the Geological Survey Memoirs published in 1891. The present area is mainly lowland usually about 100ft. above sea level and rarely reaching 200ft. in height. The range of high hills bounding the area from the south and south-east stands in bold contrast to the low ground to the north. This range includes the following peaks, Mogumna Hill 583ft., Ardvally 1042ft., Crockbrack 809ft. and Drumnasilla Hill 746ft., and is intersected by valleys as low as 100 and 200ft. above sea level. In the northern part of the area, the elevated ground constituting Clooney and Cashelgolan Hills reaches a height of 304ft.

The area is strewn with lakes of different sizes, ranging from the small swamp about 50yds. across to larger lakes about more than ¼ mile in length. Among the larger lakes occuring in the central part of the area are Lough Derryduff, Lough Adenny, Lough Mc.Hugh, Lough Ananima and Lough Fad. Lough Fad together with a series of smaller Loughs fall along one arcuate line and afford an excellent example of lakes controlled by late faulting. Clooney Lough, on the other hand, represents a lake produced mainly by the dissolution of limestone.

The minor rivers and streams run westerly towards the sea. The two largest, the Owenea and the Owentocker, in

the southern part of the area, flow in a westerly direction into Loughros More Bay. Stracashel river passing through Glenties, joins the Owenea river to the south-west of that town.

III. Scope of the Present Work.

The detailed mapping of the area forming the subject of the present study was carried out during two field seasons in 1951 and 1952, representing about 35 weeks field work. The method of outcrop mapping was employed on the six-inch scale, using the Ordnance Survey Six-Inch Sheets as a base. The group of islands and isolated rocks along the southern shores of Gweebarra Bay have all been mapped on the scale of 13" to the mile. The writer's maps of these islands and isolated rocks are somewhat different from the Ordnance Survey 6" Sheets, as the latter have been found now to be inaccurate. These maps of the islands and isolated rocks represent the geology as seen at low tide, since extensive exposures of rocks exhibiting important structures are only then visible.

About 1090 rock specimens were collected and from these about 360 thin sections were prepared. A number of rock specimens were cut andpolished. Over 100 field photographs, mainly showing small structures, were taken.

For the statistical study of small scale structural elements, a great number of bearings of structures such as lineations, fold axes, fracture cleavage, joints, veins of

aplite and pegmatite have been noted. Out of about 5000 such observations in all, 4179 readings were plotted on 27 stereographic projections and contoured diagrams were subsequently prepared. These diagrams represent different structural elements in separate localities, plotted on the lower hemisphere of an equal area net.

During the course of the field work, detailed information has been collected, together with sets of specimens and field photographs etc., of certain additional points of geological interest in the area. These will not be dealt with in this thesis, but will be the subject of separate studies.

IV. Previous Literature.

The area was surveyed by members of the Irish Branch of the Geological Survey of the United Kingdom under the directorship of Sir Edward Hull between the years 1881 and 1884. Sheets 15 and 23 of the One-Inch Geological Survey Maps were published in 1890 and the memoirs covering the two sheets were published in 1891. The previous literature on N.W. Donegal, which dates as far back as 1934, can be divided among three topics, first the determination of the age of the metamorphosed country rocks, secondly the establishment of a succession and thirdly- the most controversial- the origin of the granitic and gneissic rocks of Donegal.

As regards the Age of the Country Rocks, several views

have been expressed, the most important being as follows:-

Harkness (1860) considered the metamorphosed country rocks to be the Irish representations of the Grampian strata i.e. equivalent to the Lower Silurian.

Hunt (1863) stated that they were identical with the Laurentian of Canada.

Kinahan (1881) held that they were more probably Huronian than Laurentian.

Geikie (1891) and Cole (1900) grouped them as Dalradian.

Anderson (1948 and 1952) assigned a Moine age to the Lower members of the series and Dalradian for the upper parts of the metasediments which have been so far investigated by the Imperial College Donegal Research Team. It is the immediate object of this Research Team - the present work forming part of it - on the one hand to dissect, in the greatest possible detail, the Donegal Granite Series into its different members, and on the other hand to establish a sound succession. It is by no means the object of the present work to assign an age to the country rocks in the area. It seems that the final decision regarding such problems as the precise age of the rocks grouped under the term Dalradian may be the result of sorting out the 'Scottish Dalradian' in the light of the results achieved in N.W. Ireland.

Harkness (1860), Blake (1861), Calloway (1885) and Kilroe (1891) have all made attempts to Establish a Succession of the metamorphosed country rocks; at present,

appear to be very preliminary. Recent work by McCall 1951, Mithal (1952) and particularly by Iyengar, Pitcher and Read (1953) has done a great deal towards establishing a correct and detailed succession of the metasediments, as will be considered in detail in the next chapter of this work.

In addition, Anderson 1952 has produced a succession for the rocks of the Slieve League promontory immediately to the south-west of the writer's area. This will also be considered in the next chapter.

Since 1834, there has been wide diversity in opinion as regards the Origin of the Granitic and Gneissose Rocks of Donegal. These opinions have been reviewed by other workers of the Research Team particularly Iyengar (1949), Gindy (1950) and Mithal (1952). Only a selected bibliography of this early literature is given in this thesis.

V. Summary of Geological History.

Subsequent to the sedimentation of a thick series of clays, silts, varved mudstones, limestones, marls and sandstones under shallow water conditions, probably in a deltaic environment, there occurred the emplacement of transgressive sill-like bodies and thick lenticular masses of dolerite. Sometimes these early dolerites were in the form of steep dykes. The rocks appear to have been pyroxene - labradorite - dolerites with ophitic and sub-ophitic textures and the dolerite bodies possessed chilled margins. Contact effects

due to these intrusions were very localised.

The sediments with their early basic intrusions were then subjected to the main orogeny in the area, in which the rocks were folded along axes trending roughly east-west. The folds were assymetric and their axial planes dipped about 60° south; parallel to these planes a fracture-cleavage was developed. A large anticline, the Mulnamin anticline lying to the north-east of the present area was also formed during the main orogeny. With the orogeny was closely associated a regional metamorphism, the first metamorphism in the area. Pelitic and semi-pelitic rocks were converted into biotite-muscovite-garnet-schists, limestones were recrystallised as marbles, marls and calcareous silts passed into calcareous schists and calc-granulites and sandstones into quartzites, quartz-granulites and siliceous flags. Early basic intrusions were converted to metadolerites.

Immediately following the final phases of the orogeny and regional metamorphism, the earliest members of an important suite of lamprophyre-felsite dykes were intruded. The dykes of this suite, which show a marked concentration in the north-western part of the area, appear to have been intruded over a prolonged period.

Subsequent to the intrusion of the earliest members of the lamprophyre-felsite suite of dykes, minor bodies of granodiorite were forcefully intruded into the rocks of the small islands along the southern shores of Gweebarra Bay.

These granodiorite intrusions show localised contact effects on the enveloping metasediments, and in one case a semi-pelitic schist is converted to andalusite hornfels.

A minor swarm of basic lamprophyre dykes and sheets was also intruded in the north-western part of the area, some of these entering along the main joints of one of the minor granite bodies.

At about this stage, post orogenic thrust movements from the south-east gave rise to considerable thrusts trending N.E.- S.W. in the southern part of the area. A thick belt of metasediments trending N.E.- S.W. was thrust against the southern flank of the Mulnamin anticline. This thrust - the Glenties Thrust - was responsible for the elimination of the higher lithological groups forming the anticline. The N.E.- S.W. trending belt itself consisted of a Quartzite Group thrust over part of a thick succession of pelites, semi-pelites and calc-silicate rocks here called the Glenties Series. A subsidiary dislocation in the Glenties Series moving parallel to the major thrusts, localised the intrusion of a migmatitic tonalite in the form of a sheet over 5 miles long. This tonalite sheet has affected its contact metasediments in a zone about 200yds. wide with the development of staurolite and garnet. During the thrust movements, a large low angle thrust slice, consisting mainly of psammitic rocks, emerged from beneath the Quartzite Group in the south-

western part of the area and lay unconformably over rocks of the Glenties Series. These post-orogenic thrust movements from the south-east were accompanied by a regional retrograde metamorphism. This second metamorphism was responsible for the conversion of the regional garnet into pseudomorphs of chlorite, and the development of porphyroblasts of chlorite. The latter were found in some places to possess a preferred orientation parallel to a lineation plunging moderately to the south-west and associated with the post orogenic movements.

The first stages in the emplacement of the Ardara Granitic Pluton was effected by the movement of biotite-granodiorite magma along the Glenties Thrust to come into contact with the Amphibolitic Complex of Meenalargan; this took place at a relatively deep level. Considerable interaction between the biotite-granodiorite magma and the amphibolitic rocks resulted in the former acquiring the composition of a quartz-diorite and becoming loaded with xenoliths of amphibolites in all stages of interaction and resorption. This contaminated xenolithic quartz-diorite on making its way up the major dislocation, pushed ahead of it a coarse tonalite in the form of a thick plastic mantle thought to be a mobilised deriative of the Meenalargan Complex. Not far from the present level, the magma began to accumulate along the southern flank of the Mulnamin Anticline, at a point where the Glenties Thrust and the axis

of the anticline diverge. With the incoming of contaminated magma, a circular body of granite developed with a protrusion or 'neck' marking the north-eastern trend of the Glenties Thrust. This pluton consisted of a central core of xenolithic quartz-diorite with an outer mantle of strongly foliated tonalite. Ultimately the contaminated quartz-diorite was exhausted and a small quantity of uncontaminated biotite-granodiorite, containing only occasional dark xenoliths, reached the present level. The outer margins cooled sufficiently to permit the formation of joint fractures some of which were occupied by pegmatite veins.

The forceful emplacement of the pluton resulted in pushing aside the country rocks especially towards the north, the shearing out of the higher lithological groups in the succession and the initiation of numerable structural dislocations of a complex nature. A thermal metamorphism - the third main metamorphism in the area - was superimposed upon the confining envelope of the pluton for a distance of up to 1½ miles. Pelites and minor semi-pelites bounding the pluton on the northern and north-eastern sides were converted into high grade hornfelses characterised mainly by andalusite, sillimanite, staurolite and garnet. The hornfelses are displayed in a zoned aureole consisting of an inner sillimanite zone and an outer and much wider andalusite zone.

At about this stage, a second upwelling of uncontaminated and xenolith-free biotite granodiorite was emplaced in the still uncongealed central part of the pluton. This second upwelling was accompanied by a considerable wave of heat. The direct effects of this event were first the further shouldering of the confining country rocks and, second, their further contact metamorphism in the inner part of the aureole, marked especially by a readjustment of mineral assemblage and a slight broadening of the sillimanite zone. As the outer periphery of the pluton cooled for the second time, radial joints were developed and some of these were occupied by aplitic and pegmatitic veins, these residual liquids marking the hydrothermal phase of the second upwelling of magma. After all these hydrothermal liquids were exhausted, circular joints were also formed in the circular body of the pluton. Joints equivalent to the radial system in the granite pluton were later formed in the hornfelses.

At this stage, the granite pluton, as a solid mass, moved vertically, impressing upon the hornfelses a steep shear parallel to its circular margins. Minor planes of dislocation were also formed. This movement has caused a local retrograde metamorphism accompanied by the hydrothermal introduction of potash. Crystals of andalusite and sillimanite were, in many places, altered to pseudomorphs of shimmer

aggregates, and large porphyroblasts of muscovite were formed along the sheer planes.

A set of porphyry dykes was then intruded in the northern part of the pluton traversing the granite and the well jointed hornfelses in a north-south direction.

On the southern side of the pluton, the Quartzite Group was further thrust upon the Glenties Series. The tonalite band, now lying at the foot of the Quartzite thrust blocks, became changed to a mylonitic gneiss. Meanwhile, the metasediments of the Glenties Series were strongly sheared thus causing the phyllonitisation of the southern aureole of the Ardara Pluton and the zone of contact-altered rocks adjacent to the tonalite sheet.

Late movements operating in the 'neck' of the pluton and the northern half of the Glenties Series, have impressed upon the xenolithic quartz-diorite of the 'neck' a secondary linear structure plunging gently to the south-west. After these movements had reached their climax, the pegmatitic fringe of another member of the Donegal Granite Series was intruded across the 'neck' of the pluton and also wedged between the outer tonalite and the Glenties Series. These movements were still in operation while the pegmatitic fringe of the granite was intruded, and porphyroblasts of staurolite formed in the contact metasediments of this

granite clearly indicate a rolling movement.

It is the purpose of the following pages to demonstrate the evidence on which the foregoing summary is based.

Chapter TWO. THE COUNTRY ROCKS.

I. Introduction.

The Ardara pluton was emplaced in a thick succession of Dalradian metasediments dipping to the south, and associated with bodies of metadolerite. These metasediments include pelites, semi-pelites, limestones, calc-silicate rocks and quartzites.

The metasediments bounding the pluton on the northern side are equivalent to part of the Maas Succession established by Iyengar, Pitcher and Read (1953), and form the continuation of the south-western limb of the Mulnamin anticline, located to the north-east of the pluton.

The metasediments found on the southern side of the pluton are mapped for the first time since the Geological Survey's work in the period 1881-1884. They were found to be different from the rocks in the Maas Succession, but may eventually prove to be still higher members of that succession These metasediments on the southern side of the pluton however, occur in a wide belt trending N.E.- S.W. which bears a thrust relationship to the Maas Succession of the Mulnamin anticline.

It is intended here to review the lithological groups of the present and neighbouring areas, and to give a brief description of the metasediments. The lithological details of these groups will be presented in the course of the work.

II. The Maas Succession and the Rosbeg Semi-Pelitic Group.

The metasediments occurring on the northern side of the Ardara pluton were originally the continuation of the southern limb of the Mulnamin anticline, Iyengar, Pitcher and Read (1953) have established the following Maas Succession of the Dalradian metasediments in this anticline:-

Cleengort Pelites	800-	ft.
Portnoo Limestone	500	ft.
Maas Semi-pelites	750	ft.
Mulnamin Calc-silicate Flags	800	ft.
Cor Quartzite.	250	ft.

R.S. Mithal (1952), working on the area to the west of the Ardara pluton, placed the pelitic and semi-pelitic rocks above the Portnoo Limestone in a broad lithological group, about 12,000 ft. in thickness and named it the Rosbeg-Semi-pelitic group. He further sub-divided this group into the following main members :-

(iii) Dawros - Rosbeg banded Semi-pelitic schists.
(ii) Aghros Hill - Eden House Semi-pelitic schists.
(i) Dunmore - Doon Lough Pelitic phyllites.

The lowermost member, the Dunmore-Doon Lough Pelitic phyllites is, no doubt, equivalent to the Cleengort Pelites and is the western continuation of that group, which, in the present area, is named the Clooney Pelitic group.

On the other hand, the rest of Mithal's Rosbeg group

can be placed in a separate group under the name of Rosbeg Semi-pelitic Group, and can be sub-divided into :-

(ii) Dawros Banded Semi-pelites.
(i) Aghros Semi-pelites.

The Dawros banded semi-pelites are thought to continue into the Loughros peninsula.

The following table gives the divisions adopted by the writer for the northern part of the area :-

Rosbeg Semi-pelitic group.
Clooney Pelitic group.
Portnoo Limestone group.
Maas Semi-pelitic group.

III. Metasediments North of the Ardara Pluton.

A. General Distribution of Lithological Groups.

The metasediments to the north of the Ardara pluton comprise the Clooney Pelitic Group (Cleengort Pelites), the Portnoo Limestone group and the Maas Semi-pelitic group. These lithological groups are 'right way up', 'younging' to the south, and are all separated from each other by structural breaks of a complex nature. The Clooney Pelitic group bounds the Ardara pluton on the north and partly overrides the main part of the Portnoo Limestone group. The Maas Semi-pelitic group is the lowest group in the present area, and occurs in the islands along the shores of Gweebarra Bay.

B. The Clooney Pelitic Group.

The Clooney Pelitic group, bounding the Ardara pluton

on the northern and north-eastern sides, is the highest lithological group among members of the Maas Succession in the present area. It consists of pelites with minor semi-pelites and thin calc-silicate bands. The pelites, which form the larger part of the group, show varved types of banding produced by alternating pelitic and semi-pelitic layers. Sometimes the rocks show graded bedding, but more often a rhythmic banding. The graded bedding, which is described in detail on p.240, shows the rocks of this group to be intricately folded. Some parts are 'right way up', 'younging' to the south, while other parts are inverted. The thickness of the individual alternating bands varies considerably.

Generally, the upper part of this group is less pelitic than the lower part, and lacks the banded nature. This part seems to form a transition towards the Aghros Semi-pelites of the Rosbeg Semi-pelitic group.

The rocks of the Clooney Pelitic group have been altered to high grade hornfelses by the contact effect of the Ardara pluton; sillimanite and andalusite hornfelses occur in a thick belt on the northern side of the pluton and are referred to as the Clooney Hornfelses, the sillimanite hornfelses in contact with the pluton from Ballyiniston towards Letterilly being called the Maas Hornfelses.

C. The Portnoo Limestone Group.

1. Subdivision.

In the present area, the Portnoo Limestone group is subdivided into two distinct parts which also occur in two separate structural units. The lower part of the group consists of a thick limestone, named the Lower Portnoo Limestone, while the upper part is called the Upper Portnoo Limestone and comprises limestones, pelitic and semi-pelitic bands, graphitic flags and phyllites.

2. The Upper Portnoo Limestone.

The Clooney hornfelses end abruptly at Ardlougher against a major dislocation - the Ardlougher Thrust. The latter brings the Clooney Pelitic group structurally against the Upper Portnoo Limestone. The latter consists of limestones, pelites and semi-pelites, graphitic flags and phyllites. The succession strikes N W. - S.E. parallel to the major dislocation. Along the dislocation, the beds stand vertical, but the dip decreases down to 70° S.W. in the north-eastern part of the area. The rocks are partly covered on the mainland, but excellent and continuous exposures are found along the rocky beach from north-eastern Cashelgolan to Drumshantony.

The thickness of the Upper Portnoo Limestone is exagerated by folding, but the following subdivisions can be established :-

---------- Ardlougher Thrust.

(youngest) Upper Pelite.
Upper Banded Calc-phyllite.
Upper Limestone.
Interbanded Limestone and Flags.
Middle Pelite.
Banded Semi-pelite.
Middle Limestone.
(oldest) Lower Banded Limestone.

The rocks of some of these members of the Upper Portnoo Limestone are of great interest with regard to the contact effect of the granite pluton, and will be treated in detail (p.261). It is intended at present to describe the metasediments briefly with special emphasis on their sedimentary structures.

(a) The Upper Pelite is a band of silvery grey pelite about 40ft. thick and stands vertical trending N.W. - S.E. alongside the Ardlougher Thrust. The rocks are tightly folded. Several thin bands of calc-silicate form intercalations; these are greyish green with a greasy lustre. The Upper Pelite is considered in detail on p.262.

(b) The Upper Banded Calc-phyllite is rhythmically banded and consists of dark grey and dense phyllitic bands, from ½" to 3" thick, alternating with bands of brownish micaceous limestone of approximately the same thickness. The latter bands weather out and present a strong contrast to the black flaggy bands. The phyllitic bands consist of biotite, clinozoisite - epidote, calcite and graphite with subordinate tremolite. The alternating bands of limestone consist

of calcite, tremolite, zoisite, biotite and quartz with subsidiary plagioclase and potash felspar. Sphene and rutile are accessory. These rocks are best seen in the quarry at Ardlougher, where the vertical phyllites show very tight isoclinal folding. The thickness of this member is greatly exaggerated by this folding.

(c) The Upper Limestone is about 80ft. thick and is exposed in several places to the north-east of the Ardlougher quarry. It is also well exposed along the rocky coast. The limestone is grey and massive, with a sugary appearance and shows a notable elongation of the crystals of calcite. Thin micaceous and graphitic partings reveal minor folds in the massive marble. The upper part of the limestone is very thinly and closely banded with micaceous partings, the rock resembling a highly weathered pelite.

(d) The Interbanded Flags and Limestone consist of a series of alternately banded graphitic flags and limestone, about 25ft. thick. It is very well exposed along the rocky coast where it appears below the limestone. These banded flags dip very steeply towards the south-west, and are sometimes almost vertical (Plate 3C). They consist of bands of black graphitic flags about 1" to 2½" thick alternating with bands of limestone about 2" thick, buff to fawn in colour. In addition to this rhythmic banding, the alternating limestone bands show current bedding.

The flaggy bands are fine-grained and consist of biotite, calcite, clinozoisite - epidote and graphite. The limestone bands consist of calcite, quartz and biotite with subordinate sphene, iron oxide, apatite, rutile and zircon. Calcite constitutes about 60% of these bands.

(e) The Middle Pelite is an andalusite hornfels resembling in every respect the Clooney hornfelses. It is about 80 to 100ft. thick and dips steeply to the south-west. Andalusite crystals are concentrated in bands from 2" to 12" thick. At its base occurs a thin band of dark silvery schist, with slight knotting on the bedding place. This is a muscovite - garnet - plagioclase - schist with a few pseudomorphs of schimmer aggregates after andalusite and subordinate quartz and biotite.

(f) The Banded Semi-pelite is a closely folded and banded member consisting of bands of medium grey micaceous schist 1" to 1½" thick alternating with slightly thicker bands rich in porphyroblasts of plagioclase. These plagioclase-rich bands tend to weather out more readily than the more schistose bands, and the distribution of these plagioclase crystals relative to the units of these bands suggests a certain degree of graded bedding. An important point about this phenomenon lies in that it affords further confirmation of the sedimentary origin of the so called 'igneous looking' bands reported by other members of the Donegal Research Team.

The rocks of this member are of great interest with regard to the thermal effect of the granite pluton, and a detailed petrographic description of these rocks will be found on p.264.

(g) The Middle Limestone follows directly below the Banded Semi-pelite and is about 25ft. thick. It is well exposed along the rocky coast and is a fairly pure marble of a tan colour on the weathered surface. It consists of elongated crystals of calcite up to 1½mm. long with highly developed glide planes, quartz and subordinate muscovite and graphite.

In the middle of this limestone occurs a thin band of biotite-muscovite-plagioclase-clinozoisite-schist, simulating the pelites with the plagioclase porphyroblasts.

(h) The Lower Banded Limestone differs from that above it by containing abundant micaceous and dense graphitic bands, varying in thickness between a fraction of an inch to 3". The calcite grains in the limestone contain minute inclusions of graphite and epidote.

Several representative bands and partings in the limestone have been studied in thin section and have been grouped as follows :-

(i) Micaceous Graphitic bands composed of calcite, biotite, quartz, muscovite and graphite in their order of abundance.

(ii) Dense flaggy bands composed mainly of biotite, quartz, calcite, quartzite and epidote - clinozoisite.

(iii) Black basic bands running oblique to the original sedimentary bands over a distance of a few inches and thereafter resuming their parallelism to the bedding of the limestone; such bands thus become often undistinguishable from the sedimentary bands. In thin section, they resemble metadolerites and consist of actinolitic hornblende, biotite, epidote, acid plagioclase and minor quartz.

3. The Lower Portnoo Limestone.

The Lower Portnoo Limestone constitutes the main part of the Portnoo Limestone group, and in the writer's area, it consists of a thick marble about 750ft. thick. Its base is concealed under drifting sand; at its present top the limestone is overridden by the Clooney Hornfelses. The contact between the Clooney Pelitic group and the Lower Portnoo Limestone marks an important dislocation - the Cashelgolan Thrust- responsible for the shearing out of the Upper Portnoo Limestone in the area below the high ground of Clooney and Cashelgolan Hills.

In contrast to the Upper Portnoo Limestone, the Lower Portnoo Limestone is devoid of pelitic and semi-pelitic bands of any importance. The limestone is coarsely crystalline, with a greyish sugary appearance, and a marked elongation of the crystals of calcite is usually discernible in the hard

specimen. On the weathered surface, the colour varies with the relative abundance and thickness of micaceous partings. At the eastern part of Cashelgolan, the limestone shows current bedding only in one exposure; this being not so well developed as the current bedding at Portnoo. The petrography of the Lower Portnoo Limestone is given on page 268.

D. The Maas Semi-Pelitic Group.

The Maas Semi-pelitic Group is the lowest lithological group in the present area and occurs in the group of small islands in the northernmost part of the area along the shores of Gweebarra Bay. All these islands have been mapped on the scale of 18" to the mile.

The group consists mainly of banded semi-pelites with minor bands of limestone and is characterised by the predominance of alternately banded pelites and semi-pelites. In general, the lower part of this group consists of fine grained graphitic phyllites and quartz-mica-phyllites. The rocks of this group are 'right way up' as shown by frequent graded bedding in the upper horizons at Inishkeel. Graded bedding is also noted in the disrupted bands in the immediate neighbourhood of the minor granite body at Grabbindoo.

Approximately 400ft. of the Maas Semi-pelitic group are very well exposed on the barren shores of Inishkeel island, and the following succession was established for the rock of this island, beginning with the uppermost and youngest:

Horizon 13. Pelitic schist alternating with thin psammitic bands showing graded bedding (right way up). Only about 40ft. of this horizon is present, and occurs in the plateau-like western part of the island.

" 12. Calcareous schist, thinly banded and fissile about 4ft. thick.

" 11. Semi-pelitic schist, showing graded bedding (right way up) about 20ft.

" 10. Calcareous band ash-grey in colour, about 3ft.

" 9. Semi-pelitic banded schist with calcareous bands, about 25ft.

" 8. Limestone about 15ft.

" 7. Semi-pelitic banded schist with thin limestone partings about 20ft.

" 6. Muscovite-quartz-phyllite about 75ft. or more.

" 5. Quartz-graphite granulite about 3ft.

" 4. Limestone about 20ft.

" 3. Alternately banded pelitic and semi-pelitic schist resembling the schist at Molloys quarry, Maas, about 100ft. or more.

" 2. Black semi-pelitic schist with abundant graphite about 50ft.

" 1. Graphite phyllite, about 30ft. is exposed in the north-eastern corned of the island during low tide.

IV. Metasediments South of the Ardara Pluton.

A. General Statement.

The metasediments occurring on the southern side of the Ardara pluton are different from those on the northern side and, indeed, from other members of the succession so far established, including the Maas Succession and the Rosbeg Semi-pelitic Group.

The Ardara pluton is bounded on the South side by a thick series of pelites, semi-pelites and calc-silicate rocks with minor bands of limestone and quartzite - here named the Glenties Series. A thick succession of quartzites lying along the southern and south-eastern boundaries of the area are thrust against and override part of the Glenties Series. These thick quartzites, here referred to simply as the Quartzite Group, connects the Slieve Tooey Quartzites of the Slieve League promontory on the western side with the quartzites of Agla and Lough Finn in the north-east. A lithological group called the Strawoaghter Semi-pelitic group is apparently higher than the Glenties Series and is usually overridden by the Quartzite group. In the south-eastern part of the area, a large block of metasediments emerges from below the Quartzite group in the form of a low angle thrust slice. The metasediments of this exotic block, which are dominantly psammitic, have been grouped as the Monargan

Psammitic group. At present, the latter is taken to be stratigraphically higher than the Strawoaghter group, but may prove to be only the upper or middle part of this group. A boulder bed with a matrix of greenish granulites and associated with a limestone was found to occur along the northern margin of the thrust slice.

The lithological groups occurring to the south of the Ardara pluton can be placed in the following order; no continuity is suggested :-

(youngest) The Quartzite group.

---------- The Carbone Thrust.

The Monargan Psammitic group.

---------- The Monargan Thrust.

The Strawoaghber Semi-pelitic group.

---------- The Strawoaghter Thrust.

The Glenties Series.

---------- The Glenties Thrust.

Anderson (1952) proposed the following succession for the pre-Carboniferous rocks in the Slieve League promontory:-

Slieve Tooey Quartzitic Group

Boulder Bed

Ardara Limestone Group

Killybegs Pelitic and Calcareous Group

This proposition gives rise to certain points of interest which can be summarised as follows :-

(i) Anderson has chosen the locality south-east of Ardara as the type locality for his limestone group occurring below the boulder bed in other parts of the Slieve League promontory, and has given it the name 'Ardara Limestone Group'. The rocks in this locality were found, by the writer, to form the Moy-Monargan Thrust Slice emerging from below the Quartzitic group and resting structurally discordant on the rocks of the Glenties Series. The boundaries between the Quartzitic Group, the thrust slice and the Glenties Series are strictly structural and there is certainly no boulder bed occurring structurally between the Quartzite group and the exotic thrust slice. Moreover as already said (p.27) the rocks of the thrust slice are dominantly psammitic and the term 'Ardara Limestone Group' is certainly unjustified.

It must be admitted that contrary to his statement in the discussion following Anderson's paper (Proc.Geol.Soc. Lond. No.1491, p.iii.,1952) as regards the absence of a boulder bed in the area south-east of Ardara, the writer has, at a later date, found a boulder bed along the northern boundary of the thrust slice. This boulder bed is either the lowermost horizon present in the Monargan Psammitic group or forms a detached mass along the northern boundary of the thrust slice.

(ii) The Glenties Series in the present area presumably corresponds in structural position to Anderson's Killybegs Group. The writer cannot, as yet, equate on lithological characters the Glenties Series with the Killybegs group as seen at its type localities, particularly on the shores of Killybegs Lough. Nevertheless, the following points should be taken into consideration. First, the rocks of the Glenties Series occur in a great imbricate zone and the presence of all natural members and horizons in the original series cannot be assumed. Secondly, that while the rocks of the Killybegs group are mainly low-grade chlorite schists, less often in the 'biotite grade', the rocks of the Glenties Series have undergone two high grade metamorphisms each followed by a retrograde metamorphism; this would naturally make it more difficult to correlate the two groups.

Anderson has correlated the schist succession in S.W. Donegal with the Moinian and Dalradian of the Scottish Highlands and particularly with that of Islay. Were the Glenties Series equivalent to the Killybegs group, it would be taken by Anderson as of Moinian age.

B. The Glenties Series.

1. Subdivision of the Glenties Series.

The Glenties Series comprises a thick succession of pelites, semi-pelites and calc-silicate rocks with minor bands of limestone and quartzite, forming a wide belt between

the southern boundary of the Ardara pluton and the foot of the highground of the Quartzite group. This belt generally strikes N.E.- S.W., extending from near Ardara to the eastern boundary of the present area and further towards Fintown. This belt is a zone of considerable imbrication which has suffered several periods of drastic movement. Thus, the rocks of the Glenties Series do not occur as distinct horizons and members of groups, such as marker horizons of limestone and quartzite usually disappear abruptly or occur as isolated lenticles due to their having been sheared out. The mapping of innumerable minor strike dislocations showed that the reconstruction of a detailed stratigraphic succession was impossible. Nevertheless, it is held that the Glenties Series can be divided into two broad groups, the Glenties Pelitic and Semi-pelitic group and the Glenties Calc-group.

2. The Glenties Pelitic and Semi-pelitic group.

This group consists mainly of pelitic and semi-pelitic phyllonites with minor bands of limestone and quartzite. The presumed lower part of the group nearest to the granite pluton is generally more pelitic and, as these rocks are fairly distinct in the field, they can be referred to as the Glenties Pelites. The upper part of the group is decidedly semi-pelitic, and contains frequent thin ribs of quartzite and siliceous granulite. The Glenties Pelites also contain important bands of limestone and quartzite, the Glenties

Limestone and Glenties Quartzite respectively. There are several other bands of banded limestone and calcareous horizons.

3. The Glenties Calc-group.

The Glenties Calc-group forms the upper part of the Glenties Series and is very distinct from the lower part. It consists of a variety of rocks of calc-silicate origin including banded calc-silicate rocks, dark green amphibolitic types and minor calc-granulites. It also includes a limestone band over 500yds. long as well as subordinate semi-pelitic bands.

The distribution of the rocks of this group, as seen on the main map of the area, gives an idea of the manner in which they occur in this intricate zone. They tend to taper down and ultimately disappear as the result of shearing.

The Mylonitic Gneiss of Carbane is closely associated with the calc-silicate rocks of this group; the latter are considered in detail (pp.333 and 354).

C. The Strawoaghter Semi-pelitic Group.

The Strawoaghter Semi-pelitic group is a lithological group quite distinct from the Glenties Series, and appears to be stratigraphically as well as structurally above the latter. It is separated from the Glenties Series by the Strawoaghter Thrust running parallel to the strike of the

imbricate zone. From the map of the area, it is clearly seen that the Quartzite group overlies the Strawoaghter group except in the area between Tullyhonwar and Owenea Lough.

The rocks of this group are dominantly semi-pelitic and siliceous, and comprise siliceous granulites, banded semi-pelites with several minor quartzitic bands.

The lowermost beds of this group are mainly light green quartz granulites with occasional bands rich in pale green amphibole. These rocks are usually brecciated in a zone along the Strawoaghter Thrust. These quartz granulites also give rise to thick breccias to the north-east of Owenea Lough.

The granulites are succeeded by thinly banded semi-pelites which are fairly uniform in appearance, and contain occasional quartzitic horizons. The highest part of this group mapped by the writer consists of silvery phyllonites with characteristic dark chlorite pseudomorphs after garnet. These phyllonites are well exposed near Tullyhonwar bridge on the north-eastern side of the Owentocker river, and also along the southern shores of Owenea Lough.

D. The Monargan Psammitic Group.

The rocks of the Moy-Monargan Thrust Slice are dominantly psammitic, consisting mainly of siliceous granulites, quartz flags, and semi-pelites with some beds of quartzite and limestone.

The rocks in this group have the following presumably stratigraphical succession beginning with the highest member:-

(iii) The Ardlougher Semi-pelites and Pelites. 150ft
including two bands of limestone each about 20ft. thick.

(ii) The Moy Quartz Flags including a band of limestone and another of semi-pelite each about 30ft. thick. 400ft

(i) The Monargan Siliceous Granulites and Quartzites including a band of yellow limestone, and a boulder bed at its base. 500ft

The rocks of the Monargan Psammitic group will be considered in detail on p.96.

E. The Quartzite Group.

The Quartzite group is apparently the youngest lithological group in the present area and consists of a successio of quartzites well over 1000ft. thick. These quartzites mak a series of hills forming a high ridge along the south-

western, southern and south-eastern boundaries of the area. This high ridge forms a part of the larger chain of mountains extending from the mountain of Slieve League through the Slieve League Promontory to the present area and further to the north east to the quartzites of Agla and Lough Finn. Thus they are considered provisionally to be equivalent to the Slieve League Quartzitic Group of Anderson (1952).

The structure of the Quartzite Group in relation to the lower group of metasediments on the south side of the pluton is the subject of an important part of the present work, but the quartzite in the high ground has not been mapped in detail

V. Early Basic Intrusions.

The original sediments in the area have been intruded by dolerite and/or quartz-dolerite, either in the form of transgressive sill-like bodies or more frequently as short lenticular masses. These bodies usually seem to have been conformable with the bedding of the sediments; less often they now appear as elongated bodies running across the bedding. These early basic intrusions were subsequently metamorphosed to metadolerites and hornblende schists. This was accompanied by a certain degree of deformation. However, in two cases, there is evidence indicating that the metadolerite bodies have not been deformed at all. The first case is the presence of a perfectly normal dyke of metadolerite along the northern

coast of Auninish (p.237). Secondly, in the western part of Carrickfad which is lying flat, undistorted and apparently unmoved, metadolerite bodies occur as thick masses of oval outline and appear to have been originally intruded as such (p.47).

Chapter THREE.

EARLY OROGENIC MOVEMENTS AND REGIONAL METAMORPHISM.

I. Introduction.

Subsequent to the intrusion of the early basic dykes and sills in the sedimentary rocks, the latter were subjected to orogenic movements accompanied by regional metamorphism. The orogenic movements resulted in the folding of the rocks along axes roughly east-west, while the regional metamorphism has converted the pelitic sediments into schists of the 'garnet grade' and the early basic intrusions to metadolerites. These changes record the first main metamorphism in the area. The early basic intrusions had produced very localised thermal effects upon their sedimentary hosts, the altered rocks varying in width up to 2-3ft; this can hardly be considered as a separate metamorphism of regional value.

In the greater part of the area, the regional folding and metamorphism have been almost entirely obliterated or drastically altered by later events in the complicated history. The only localities within thewriter's area in which the early orogenic movements have been only slightly affected by later manifestations are the island of Inishkeel and the rocks of Carrickfad and Auninish.

Inishkeel has been affected only slightly by the

tectonics connected to the Ardara pluton. The rocks in Inishkeel and Carrickfad exhibit the effects of a late diaphthoresis altering the regional index mineral garnet to chlorite. This constitutes a second and retrograde metamorphic event. In order to avoid confusion in later parts of this work, between garnet formed by the regional or earliest metamorphism and the garnet formed by the contact effect of the Ardara pluton, a third metamorphism, they will be referred to as 'Old Garnet' and 'New Garnet' respectively.

II. Early Orogenic Movements.

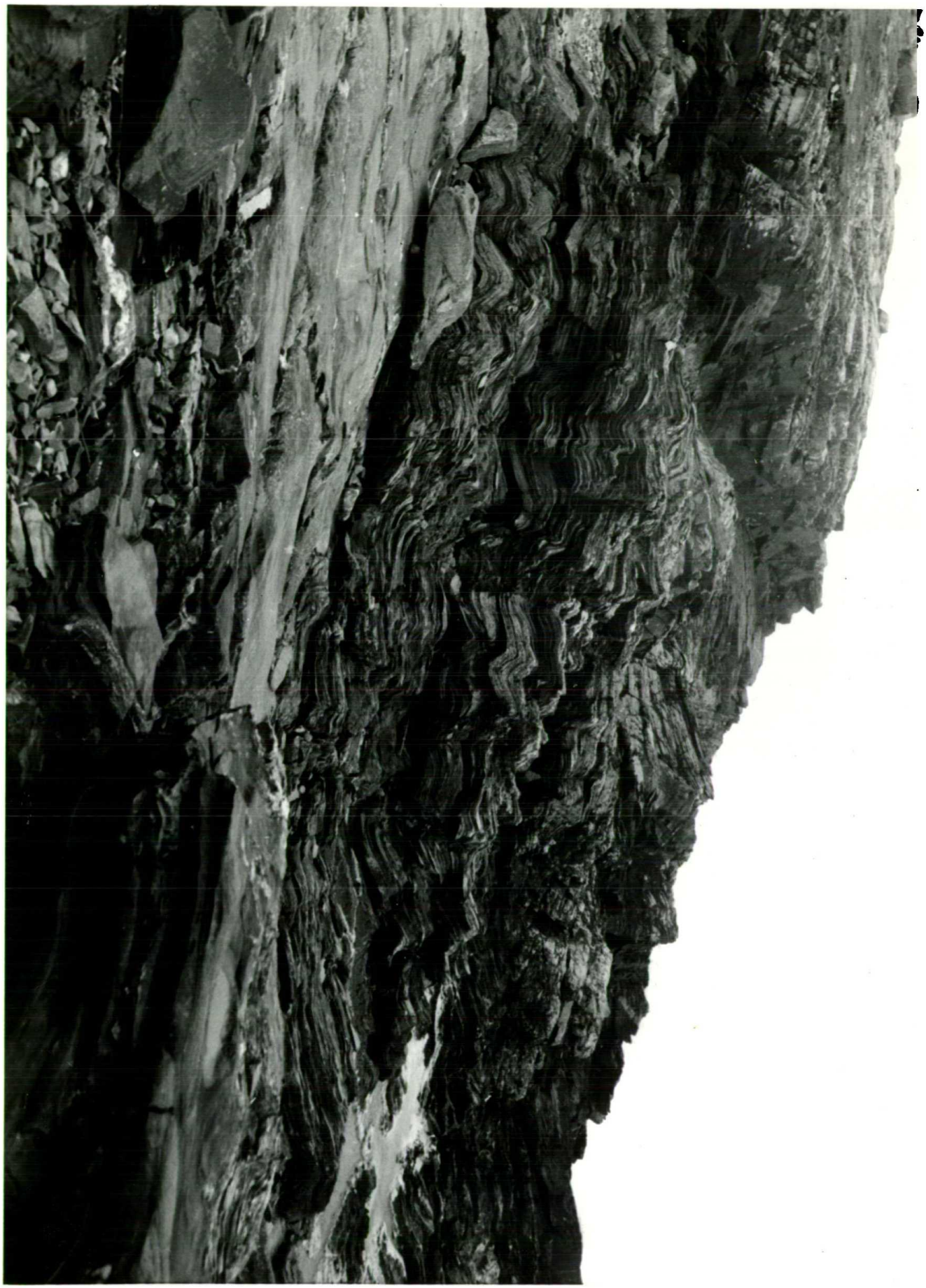
A. General Statement.

The early orogenic movements will be studied mainly in Inishkeel, having been least affected by later tectonics in the area. The island is situated in the north-eastern corner of the writer's area, about ½ mile off Portnoo. It is about 1250yds. east to west, by 800yds. at its broadest part. Its shores are well exposed, and the island has been mapped on the scale of 13" to the mile. The rocks of the island belong to the lithological group known as the Maas Semipelites, and the detailed succession is given on page 26.

The early orogenic movements have thrown the rocks of Inishkeel into small asymmetrical folds trending east-west, with axial planes dipping steeply to the south. These folds are associated with an excellent fracture cleavage. Early

PLATE 1.

Pelitic schists on the north-western coast of Inishkeel Island, showing the regional folding along east-west axes, 'photo looking due west. The folds are asymmetrical with the steep limbs towards the north. The limestone, in the foreground, was rendered plastic and appears to be massive except for its irregularly crinkled micaceous partings.



cross joints have been formed in association with the folding both in Inishkeel and Carrickfad. These cross joints have been deformed by later tectonics and should not be confused with joint systems connected with the tectonics of the Ardara pluton (p.315). The orogenic movements seem to have been the result of forces acting from south to north.

The different lithological horizons in the succession are affected differently by these movements. Thus, while the hard quartz - mica - phyllites have not been folded, the alternately banded pelitic and semi-pelitic schists show the highest development of fold structures. The limestones, however, do not show any evidence of folding and appear to have yielded as if in a plastic state during the movements.

B. Folding in Inishkeel and Carrickfad.

Fig.IB represents the stereographic projection of the fold axes in Inishkeel, and shows a maximum representing a linear structure plunging about 15° due west. The majority of the folds vary between horizontal east-west and a maximum plunge of 30° west, while a small proportion plunge up to 10 - 15° east.

The folds are asymmetrical but never overturned (plate 1). The average fold has its southerly limb dipping at 30 - 40° south and its northerly limb dipping about 65 - 70° north. These folds are very well developed particularly in the pelites and resemble drag folds due to

the movement of the upper beds towards the north. At times, minor folds are located near the crests of the main folds. On the north-eastern part of the island, the graphite-quartz phyllites show incipient drag folding confirming the movement of the upper strata towards the north.

The limestone bands in Inishkeel appear to have been in a plastic condition during the period ofmovements as indicated by the contorted nature of the thin shaly partings. The limestone band on the eastern side of the small bay at Pollowen is highly compressed and stands vertical between the two southerly dipping semi-pelitic horizons. Its continuation on the western side appears as a thick lenticular mass in the well folded banded schists.

The group of isolated rocks called Carrickfad consist of two main units. A western part of hard grey phyllite, lies almost flat and contains several bodies of metadolerite. The latter are massive and lack the slightest foliation. The easterly unit consists of alternately banded pelites and semi-pelites, folded and thrust against the more stable western part during the emplacement of the Ardara pluton. It seems that these pelites had been folded prior to the emplacement of the pluton, though the folds were not overturned at that stage. This is fairly clear from the distortion of earlier cross joins and a strong lineation formed by the intersection of the primary fracture cleavage and the bedding.

C. Primary Fracture Cleavage.

An early fracture cleavage is connected with the regional folding and is very distinct from the late fracture cleavage superimposed upon parts of the same rocks during the emplacement of the Ardara pluton (p.319).

Except for the limestone horizons, all rocks in Inishkeel possess a fracture cleavage of one form or another. It always dips 55 to 70° south (Fig.1B) and is usually parallel to the axial planes of the folds. This early fracture cleavage gives rise to a strong lineation parallel to the fold axes, either shown by the sharp crests of the minute pucker folds or the intersection of the fracture cleavage and the bedding plane or schistosity. The early fracture cleavage in Inishkeel was found to assume the following forms :-

(a) A minute strain slip cleavage with a spacing of 2 - 3mm. apart and forming minute pucker folds in the rock. The mica flakes are broken at the crests of these minute folds, as seen in slice 413. This structure is present in all the pelites in the western part of the island, and is not restricted to individual folds. Where the metasediments show graded bedding, the fracture cleavage gradually disappears towards the sandy layer in a graded unit (Spec.470).

(b) A second type, closely related to the one first described, is in the form of parallel planes of structural

discontinuity spaced at 15 - 20mm. parallel to the axial planes of the folds and occurring throughout the crests and troughs of the folds. The schists form small but sharply angular folds with the planes passing through successive crests and troughs.

(c) A fracture cleavage restricted to small individual folds and exhibiting a distinct fanning on either side of the axial plane of the fold. This type is common in the pelites with limestone partings and the calcareous semi-pelites at the western extremity of the island. Here the fracture cleavage is absent in the calcareous bands and bands of pure limestone (Specs. 424 and 425).

(d) In the dense muscovite - quartz - phyllite of horizons nine, Inishkeel, the fracture cleavage assumes the form of a system of equally spaced sharp fractures.

D. Early Cross Joints.

The regional folding of the metasediments of Inishkeel and Carrickfad was accompanied by the development of cross joints. These joints, which are essentially small scale structures, are closely and equally spaced and trend vertically north-south, normal to the fold axes. They are best developed in the pelitic horizons and are usually filled with hydrated minerals (Specs. 466 and 468). They sometimes appear as gaping fractures, particularly where they have been deformed by the tectonics of the pluton (p.315 and plate 20 A & B).

III. Regional Metamorphism.

A. Introduction.

From the study of neighbouring areas by other members of the Donegal Research Team, it is established that the regional metamorphism accompanying the main orogeny of the area has reached the 'garnet grade', (Cheeseman R.L. 1951 and Mithal R.S. 1952). The early basic intrusions have also been altered to amphibolites.

In the writer's area, by far the larger part of the metasediments have been strongly affected by one or more of the later events in the complex history of the area, resulting in partial or complete obliteration of the regional metamorphism. The metasediments bounding the Ardara pluton have been thermally metamorphosed to form high grade hornfelses. On the other hand, metasediments to the south of the pluton lie in an imbricate zone and have undergone several episodes of drastic deformation.

The only localities in which the regional metamorphism has managed to survive, to a degree permitting its study, are the island of Inishkeel and Carrickfad. The rocks in these two localities exhibit very well the effects of the later diaphthoresis, or second main metamorphism, and some of them even exhibit relatively mild thermal effects due to the emplacement of the Ardara pluton, the third main metamorphism.

The rocks of Inishkeel and Carrickfad include several lithological types. They also include early basic intrusions now metadolerites.

B. Regional Metamorphism of Sedimentary Rocks.

1. Alternately Banded Pelites and Semi-pelites.

The alternately banded pelites and semi-pelites in eastern Carrickfad are medium grey silvery schists - actually phyllonites - alternating with bands of pale pink granulite. Typical pelitic bands are represented by slices 157 and 177, and consist mainly of muscovite, quartz, biotite and chlorite with minor potash felspar, plagioclase, iron oxide and apatite. The muscovite occurs as slender blades lying within the undulating schistosity and are sometimes pushed aside by the later growth of porphyroblasts of 'New Chlorite'. Biotite occurs in small flakes parallel to the foliation and is of a pale brown colour. 'Old garnet' is represented by pseudomorphs of biotite, chlorite and iron ore, around which the schistosity is seen to derviate. Quartz is mainly recrystallised as large grains in a later period.

Slice 468 represents the base of a graded unit in the pelites at Porter's Rock, Inishkeel. The pelitic band consists of muscovite, biotite and graphite with occasional small grains of garnet. The sandy layer which is essentially poorer in graphite contains euhedral crystals of garnet of average diameter 6mm.

'Old Garnet' can also be seen in some of the members of the Upper Portnoo Limestone in the aureole of the Ardara

pluton (p.266). Fragments of the original garnet occasionally survive with rounded aggregates of biotite; and this original garnet shows curved trends of iron ore suggestive of a rolling movement.

2. Muscovite - biotite - quartz phyllites.

The western part of Carrickfad, as well as horizon 9 of Inishkeel, consist of a grey silvery phyllite. It is fine grained and the schistosity is not pronounced. In thin section 447 and 164, representing the rocks in the two localities, they are identical in composition and texture, and consist of muscovite, biotite and quartz with minor felspar, epidote, iron ore, tourmaline and apatite. The biotite and muscovite occur as minute flakes with parallel alignment. The biotite is pale brown in colour, contains minute pleochroic haloes and is in part altered to chlorite. Quartz is minor to the micas and occurs as elongated grains with undulose extinction. Epidote forms irregular grains and fine aggregates around which the foliation deviates. It is sometimes associated with clinozoisite.

3. Graphite - Muscovite - Quartz Phyllites.

The lowermost horizon in Inishkeel, occurring at the N.E. corner of the island, as well as the outermost part of Auninish island, consist of a graphite phyllite. The rock is fine grained and dark greyish black in colour. In thin section (999), from Inishkeel, the rock consists of graphite

both as fine dust particles or elongated aggregates of minute grains. Quartz forms spindle shaped grains while laths of biotite and muscovite are usually associated with fine sericitic material.

C. Regional Metamorphism of Early Basic Intrusions.

1. Introduction.

The bodies of metadolerite and hornblende schist present in the metasediments of the area represent early basic intrusions of a doleritic nature intruded with the sedimentary rocks prior to the main orogeny and regional metamorphism. The majority of these metadolerite bodies appear to have been intruded in the form of thick sills and/or dykes and sometimes as lenticular masses of different sizes. While some are conformable with the sedimentary host, others have been intruded obliquely to the bedding.

Subsequent to the main orogeny and regional metamorphism, the metadolerites have been affected by the later metamorphic changes in the area. The metadolerites in the Clooney area have been thermally metamorphosed by the emplacement of the Ardara pluton, and the metadolerites in the imbricate zone south of the pluton have been further recrystallised as highly sheared hornblende schists.

Metadolerites exhibiting the effects of the regional metamorphism occur in Inishkeel and Carrickfad and will be

considered in the present section. Minor bodies of garnet-bearing metadolerite from Orinish and Auninish will be considered later together with other similar types in the inner parts of the aureole of the Ardara pluton, in view of the reluctance of this type to thermal metamorphism (p.285).

2. Metadolerites of Inishkeel and Carrickfad :-

The flat lying and unmoved western part of Carrickfad contains several boss-like masses of metadolerite each about 100yds. x 60yds. The rock is a medium grained dark green amphibole devoid of any structure. In thin section (165), the rock is seen to retain its original sub-ophitic texture, less frequently an ophitic texture. The original pyroxene of the dolerite is completely altered to uralite. The latter consists of aggregates of slender prisms of pleochroism Z' = green with a bluish tint, Y' = pale yellowish green and X' = pale yellow. Some of these prisms penetrate freely into the felspar laths. The uralitic aggregates have poikilitic inclusions, and are surrounded by rims of a darker colour and devoid of inclusions. The plagioclase laths of the original dolerite still persist and have the composition of basic andesine (An.47-50). Muscovite occurs as skeletal crystals or elongated blades. Quartz is very scarce. The rock is almost devoid of sphene and epidote.

At Inishkeel, a thick sill-like mass of metadolerite

runs across the island in a N.W. - S.E. direction. It is about 750yds. long and varies in thickness between 180 and 120yds. It possesses a distinct foliation parallel to the strike of the metasediments, and contains two large enclaves of banded pyritous phyllite about 30ft. across near the water line. In slice 407, the rock appears to have been almost totally recrystallised, possesses a strong foliation, and consists of pale green hornblende, andesine and oligoclase felspar with minor quartz, iron oxide, sphene and epidote. The plagioclase occurs both as clear grains of oligoclase and as twined crystals of acid andesine (An.32). The amphibole occurs as small crystals of pleochroism Z' = medium to pale green, Y' = yellowish green and X' = greenish yellow. Sphene occurs either as fine particles or rims around the patches of magnetite.

A comparison between the metadolerites at Inishkeel and Carrickfad clearly shows the effect of the shear in promoting the recrystallisation of the metadolerite.

3. Note on Chilled Margins of Metadolerites.

It is a well known fact that masses of metadolerites usually possess highly sheared margins, whether the inner parts of these masses are also sheared or not. The margins of the original basic intrusions have been affected by movements accompanying the metamorphism of such basic igneous rocks. The writer has examined in the field some of these margins,

where two types are apparent with sheared and non-sheared margins respectively. Sheared margins of metadolerite bodies are more frequent than the unsheared types, and were found to resemble the typical hornblende schists to be described in detail on page 284. Non-sheared margins are of less frequent occurrence. Here the rock is either dense and massive - a faithful representative of the original chilled margin - or else of a coarse and speckled appearance.

An excellent example of an unsheared and well preserved chilled margin is to be found on the small rocky beach at Drumshantory. The limestone members here contain dyke-like metadolerites now represented by boudinaged segments (p.304). These possess very well preserved chilled margins intimately welded to the limestone. They are unaffected by the shearing probably due to the soft and easily mobilised nature of its host rock - the pure marble. In thin section (114), it is seen to retain the original cryptocrystalline appearance with well defined laths of the plagioclase (plate 2). The groundmass consist of very fine uralitic-actinolite, epidote and chlorite with a few skeletal crystals of bluish-green hornblende probably after larger pyroxene crystals. Epidote constitutes about 30% of the rock. Well defined relics of felspar laths (0.5 x 0.1mm. to 2 x 0.5mm.) are filled with granular masses of albite-oligoclase, sometimes associated with biotite flakes or garnet euhedra.

PLATE 2.

Photomicrograph of the non-sheared margin of a metadolerite body in the limestone at Drumshantony beach, showing the cryptocrystalline chilled margin of the original doleritic intrusion. The groundmass consists of fine uralitic actinolite, epidote and chlorite, meanwhile the relict laths of felspar now contain granular albite-oligoclase. Ordinary light X 25.



On the other hand, the inner core of the dyke is dark green medium grained and is seen in thin section to have been completely recrystallised and lost its original structures. It consists of actinolite, oligoclase with minor epidote and quartz. Epidote forms trails of granules bordering the patches of amphibole.

Slice 83 represents the speckled and unsheared margin of a thick mass of metadolerite on the hillside N.E. of Clooney. It clearly retains its sub-ophitic texture. Original laths of plagioclase of composition about An.50. are sometimes bent or broken. Large patches of pale green uralite have borders of a blue-green amphibole. The uralite patches include poikilitic actinolite and a few pools of chlorite.

4. Contact Effect of the Inishkeel Metadolerite :-

The contact effect of the metadolerite at Inishkeel upon its surrounding metasediments affords the one case of a preserved thermal effect due to an early basic intrusion in the whole of the writer's area. The calcareous semi-pelitic schists on the west side of the metadolerite are baked and indurated to a considerable degree. The limestone band in the neighbourhood, together with its semi-pelitic bands and partings shows clear signs of local mobilisation. At the eastern contact of the metadolerite with the banded schist of horizon 12, the schist consists

of calcareous sandy layers alternating with bands of graphitic phyllite. The calcareous bands have become white and waxy looking and a poorly developed current bedding is rendered perceptible (Specs.383A and 383B). The calcareous bands which are usually an impure limestone are seen in slice 383 to consist of clinozoisite and calcite with subordinate quartz, actinolite and tremolite. The actinolite occurs as poikilitic prisms of pleochroism Z' = pale lavender green, Y' = yellowish green and X' = pale yellow. Colourless tremolite is subordinate to the actinolite. The phyllitic bands consist of graphite, quartz and pale brown biotite with minor epidote and poikilitic tourmaline with a remarkable degree of preferred orientation.

IV. Summary of Orogenic Movements and Regional Metamorphism.

The sedimentary rocks together with their basic intrusions were subjected to orogenic movements accompanied by a regional or first metamorphism, which was recorded by garnet and biotite in pelitic rocks. Biotite-muscovite-garnet-schists are typical of the pelites; silty sediments give rise to quartz-mica-phyllites and the limestones to crystalline marbles. The regional metamorphism of the early doleritic intrusions involved the alteration of pyroxene to

uralite, and basic plagioclase to oligoclase and albite and ilmenite to magnetite and sphene. The rock retains a certain amount of its original texture. Continued para-crystalline movements are demonstrated by the curved trends in garnet; and the metadolerites are sheared with the consequent recrystallisation of the uralitic aggregates into small hornblende crystals of medium green colour and the rock looses its original structure. Late events in the complex history of the area have restricted the study of the early orogenic movements and the regional metamorphism to Inishkeel and Carrickfad in the north-western corner of the writer's area. Apart from the tectonics and thermal effects accompanying the emplacement of the Ardara pluton, considerable post orogenic movements have both partially and completely obliterated the regional metamorphism. The orogenic movements are essentially a folding of the metasediments along east-west axes. The folds are asymmetrical with axial planes dipping 60° south, and resemble drag folds due to the movement of the upper beds to the north. The folding of the pelites and semi-pelites was accompanied by the formation of an early fracture cleavage parallel to the axial planes, and locally cross joints have been formed. Limestones on the other hand were rendered plastic or even mobile. The forces were essentially acting in a northernly direction.

Chapter FOUR.

LAMPROPHYRE DYKE SUITES AND MINOR GRANITE BODIES.

I. The Lamprophyre-Felsite Dyke Suite.

A. Introduction.

Cutting the regionally metamorphosed country rocks in the northern part of the area, are two distinct and separate dyke suites, a major suite of lamprophyre-felsite dykes and a minor suite of basic lamprophyres. The present section deals with the suite of lamprophyre-felsite dykes.

This lamprophyre-felsite suite occurs in the form of steep and gently dipping dykes as well as a smaller number of flat-lying or folded-like sheets. They are not usually very thick, the majority being one or two feet in thickness.

These rocks are usually fine-grained, and show a marked variation in colour, mainly in shades of brownish grey, grey and greenish grey. They do not, however, exhibit much variation in texture.

A careful study in the field of about ninety five of these dykes and sheets shows that they have been intruded into the folded and metamorphosed country rocks immediately after the main orogeny. The activity of these dykes continued till after the emplacement of the Ardara pluton.

The consideration of cross-cutting relationships between the members of this suite has not led to any certain

relationship between relative age and rock type. On the other hand, cross cutting relationships between members of this lamprophyre-felsite suite and those of the swarm of peculiar and unusually basic lamprophyre dykes, did, in every case, point to the fact that the latter are later, and of much more limited distribution in time, than the main lamprophyre-felsite suite.

These lamprophyre dykes have proved themselves invaluable in the clear evidence they have provided of the movements produced by the emplacement of the Ardara pluton, particularly in such a polymetamorphic and polytectonic area.

B. Distribution.

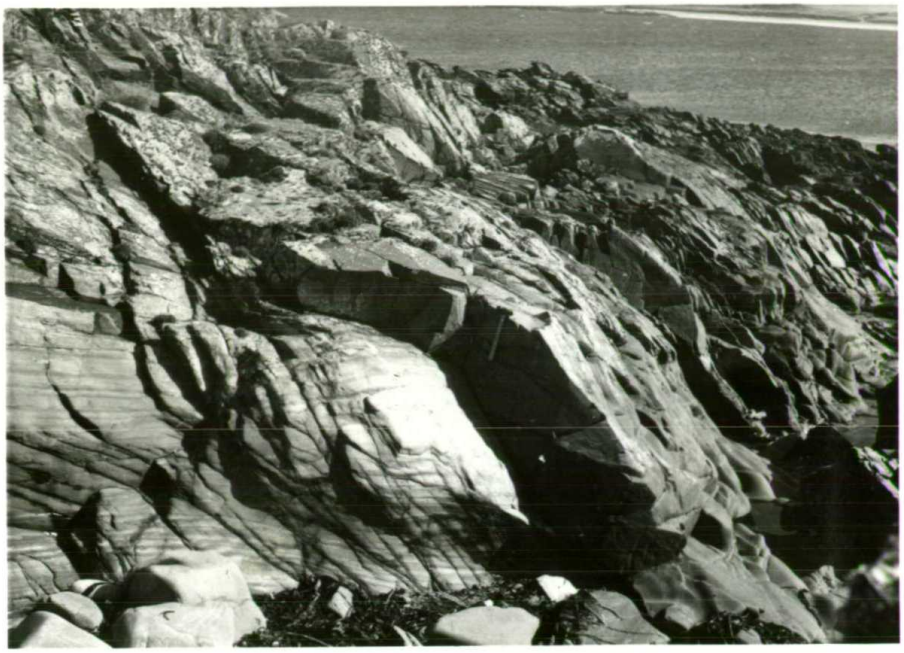
The lamprophyre dykes and sheets are well exposed along the barren and rocky shores of the group of small islands and isolated rocks on the southern shores of Gweebarra Bay, and which form the northern boundary of the writer's area. They are more abundant in Inishkeel, Carrickfad, Auninish and Grabbindoo, as well as on the narrow rocky coast between N.E. Cashelgolan and Drumshantony. By far the larger part of these dykes appear on the well exposed coast line of Inishkeel island; nevertheless they seem to show a marked decrease towards the south or south-east in particular. Their present outcrop is generally confined to the exposed coast and disappear further inland. Out of a total of over

PLATE 3.

A. A flat-lying lamprophyre sheet showing a marked monoclinal structure and apparently intruded into a curved fracture in the banded semi-pelitic schists, eastern coast of Inishkeel Island.

B. A steep lamprophyre dyke with chilled margins and a coarser grained inner part, cutting the pelitic schists on the south-eastern coast of Inishkeel Island.

C. A late member of the suite of lampro-phyre-felsite dykes cutting the steeply folded Interbanded Limestone and Flags in the northern aureole of the Ardara Pluton. The steep folding and intricate sub-vertical structures are associated with the tectonics of the emplacement of the pluton.



A



B



C

ninety dykes and sheets mapped by the writer, only about five or six dykes or large blocks of disrupted dykes have been encountered in the well exposed belt of hornfelsed meta-sediments, between the coast and the northern contact of the Ardara Pluton. Not a single lamprophyre dyke has been found in the mapped area south of the granite pluton.

C. General Morphology of the Dykes.

The lamprophyre - felsite dykes are fine grained and vary in colour between medium greyish brown to dull grey, rarely with a greenish tinge.

An individual steep dyke usually has a uniform thickness, though a flat-lying sheet shows tendencies to vary in thickness from one part of it to another. Thus the lamprophyre sheet north of the small bay called Church Pool at Inishkeel, varies in thickness between 1ft. and 2½ft. Fig. 2 represents the thickness of about seventy five dykes and sheets, and shows the majority of these to be one or two feet in thickness. The thinnest dykes are only about 4" thick.

Chilled margins are sometimes well developed, especially in the steep dykes (plate 3B). The sub-horizontal sheets never possess chilled margins, and are usually finer grained. Apart from chilled margins, no contact effects of any importance have been noticed.

The steeply dipping and vertical dykes are more often straight, and have been intruded, most probably, into sharply

defined fractures. A few dykes, however, show gentle but uniform undulation, which may be due to slight movements in the metasediments at the time of intrusion. Some of the flat-lying sheets have been intruded along curved fractures, cutting across the bedding of the metasediments, the sheet resembling a monoclinal fold (plate 3&). Still others are sill-like, for example, in W.Inishkeel, a 4ft. thick lamprophyre sheet follows conformably a limestone horizon of the Inishkeel group, from Porter's Rock to the western extremity of the island.

The lamprophyre and felsite dykes show a peculiar behaviour on weathering. At times they are seen to withstand weathering very well; in other cases, they weather out in a remarkable manner, forming trench-like ditches, in which remnants of dyke-rocks show a spheroidal weathering. A good example of the strong weathering of lamprophyre dykes is found in the centre of the southern coast of Inishkeel.

Another feature at this last locality is that two lamprophyre dykes, about one foot thick, are each found to bifercate into two smaller dykes at their south-eastern end.

No flow structures or xenoliths have been noted in any member of this suite.

D. Classification of Lamprophyre Dykes.

The suite of lamprophyre-felsite dykes, as seen in the field, comprise a wide variety of intermediate rock types, grouped under the rather elastic term 'lamprophyre'. In addition to variation in grain size, texture, and colour, the main varieties are in the relative proportion of femic constituents. One or two dykes, among the numerous members of the suite, would have a rather basic composition, but, in general, the rock types show a greater tendency towards a poverty in dark minerals. A number of the dykes would be more correctly termed 'felsitic lamprophyres'. But the increase in dark components is so gradual among the numerous dykes, that it would be very difficult to draw a firm distinction between lamprophyres and felsitic lamprophyres. This is especially difficult in thin section. On the other hand, there are only a very few dykes that can be clearly classified as felsites in the field. From the field relations, the felsites and lamprophyres are part of one dyke suite.

The petrographical study of many thin sections has led to the classification of the great majority of the lamprophyres and felsitic lamprophyres into two main types according to the predominant femic mineral; plagioclase-amphibole types or Spessartites, and plagioclase-biotite types or Kersantites.

Thus the dyke rocks can be classified as :-

1. Spessartites
2. Kersantites
3. Felsites

E. Petrography of Rock Types.

1. Spessartites.

In hand specimen, the spessartites are fine grained rocks of a characteristic grey colour with an olive green tinge. Usually the minute slender crystals of amphibole can be easily distinguished, either evenly dispersed in the rock or else as aggregates. One dyke from the limestone quarry, Ardlougher, shows porphyritic crystals of hornblende (Spec.628). The average specific gravity of the spessartites is 2.85.

The spessartites consist mainly of plagioclase felspar, actinolitic hornblende with variable amounts of biotite and quartz. Potash felspar can be present in relatively minor quantities (slice 130) or completely absent (slice 142). The amphibole is sometimes of a bluish colour, as in the late lamprophyre dyke (slice 142). There is also a variation in the proportion of dark minerals, slice 128 for example represents a more basic type of spessartite.

Actinolitic hornblende is the dominant ferromagnesian mineral and occurs together with a variable amount of biotite. The amphibole occurs as slender prisms up to

2 m.m. long with corroded borders. It is coloured pale tan in the centre, but more usually has pale green or colourless borders, Z' = pale lavender green. Y' = pale yellowish green and X' = colourless. Sometimes it contains small inclusions of biotite. The soda-bearing actinolite is present as slender and cracked prisms with a pleochroism Z' = bluish green, Y' = yellowish green and X' = pale greenish yellow. Biotite is honey-brown in colour and is variable in amount. In some slices it forms aggregates in association with actinolitic hornblende and epidote. Plagioclase has a composition between oligoclase and andesine, usually in irregular masses crammed with alteration products and minute needles of amphibole. Potash felspar is sometimes present in small amounts. Slice 130 contains a relatively high proportion of orthoclase and microcline. Quartz appears as small water-clear grains, subordinate to the plagioclase. Secondary sphene and iron ore are the only minor accessories.

Weathered varieties of the spessartites contain chlorite, clinozoisite-epidote and calcite.

2. Kersantites.

The kersantites are finer grained than the spessartites, and their colour is dull and dirty grey, more rarely brownish grey. Their average specific gravity is 2.76.

The kersantites are totally free from potash felspar.

Calcite is usually present. Biotite, the only ferromagnesian mineral, is fairly constant in amount, except in a typical felsitic kersantite as shown in slice 153 of specific gravity 2.70. Amphibole is always present, except in slice 112 where a bluish variety is present as a mere trace.

Biotite occurs as irregular flakes of strong pleochroism; z = y = medium honey brown, x = pale tan to colourless, almost uniaxial. Strong pleochoic haloes occur around apatite grains. Biotite can also occur in irregular aggregates. The Plagioclase is usually an acidic andesine (An.33) with albitic rims. It occurs as small laths 0.1 m.m. long with good albite twinning, though also as untwinned and sericitised masses resembling that in the spessartites. Quartz, still subordinate to the plagioclase occurs as small grains 0.1 to 0.2 m.m. across which sometimes contains acicular needles of amphibole. Calcite is always present, sometimes associated with epidote and iron oxide. Muscovite is occasionally present (153).

3. Felsites.

The few felsites appear as light grey to dirty grey, fine-grained rocks of a low specific gravity (2.64). A typical felsite from the rocky coast between north-eastern Cashelgolan and Drumshantony, is seen to consist, in the section 128, of plagioclase, muscovite and quartz with minor biotite.

Biotite occurs both as very small shreds in the groundmass and as elongated aggregates of the larger flakes. These elongated aggregates show no orientation, and their biotite flakes are very highly corroded by embayments and indentations of plagioclase. The plagioclase which is never twinned, has a composition about that of oligoclase. It is actively attacked by the quartz, giving pseudocataclastic textures. Muscovite occurs as small flakes and seems to be of late secondary origin.

F. Time Relations.

The time relations of this suite of dykes with respect to other minor and major intrusive phenomena and metamorphisms have been fairly well established on the basis of sound field observations. The following are the main points:-

1. The earliest members of the lamprophyre dykes and sheets have been intruded into the folded and metamorphosed country rocks immediately later than, or during the very final stages of the orogeny.

The majority of the dykes are seen to run straight and obliquely across the folds in the metasediments, meanwhile a smaller number show a very gentle but uniform undulation. One dyke is seen to have been intruded through the limestone while the latter was still in a plastic condition.

2. The minor granite body at Solly Rock - Inishkeel, is

later than the earlier members of the lamprophyre-felsite suite. South of Sooly Port - Inishkeel, lamprophyre dykes are cut by an apophysis of the nearby granite body, as well as by a thick pegmatite vein apparently associated with this granite.

3. The swarm of basic lamprophyre dykes is later than the earlier members of the lamprophyre-felsite suite, but older than the minor bodies of granite, for they are intruded along the joints in the latter.

4. During the great thrusting movements from the south-east, the minor thrust planes in the northern part of the area, take advantage of the thick lamprophyre dykes, the latter behave as 'glide planes'. The thinner lamprophyre dykes parallel to the subordinate thrust planes are sheared out.

5. A large number of lamprophyre-felsite dykes together with all the basic lamprophyre swarm are earlier than the emplacement of the Ardara pluton. These dykes and sheets are faulted and dislocated according to a definite movement pattern. Lamprophyre dykes in the inner part of the aureole are boudinaged, disrupted and thermally metamorphosed.

6. The intrusion of lamprophyre-felsite dykes was in progress during the emplacement of the Ardara pluton.

A lampro hyre dyke has been "ptygmatically intruded" into the mobilised and steeply dipping banded limestone in the north-eastern part of the aureole.

7. The latest members of the lamprophyre dykes have been intruded subsequent to the emplacement of the Ardara pluton, for the steeply and intricately folded metasediments of the Upper Portnoo Limestone representing typical steep structures ascribed to the granite tectonics, are traversed by straight lamprophyre dykes (Plate 3C). Yet, no lamprophyre dykes are seen to cut the Ardara granite, but the following points should be considered. First that at the time of emplacement of the Ardara granite, the activity of the dyke suite was obviously declining. Secondly, the dykes are reserved mainly to the north-western parts of the area.

8. The Post-orogenic Thrust Movements and Regional Retrograde Metamorphism was later than the beginning of the lamprophyre dykes activity.

G. The Trend of the Suite of Lamprophyre-Felsite Dykes.

Fig. IA represents the stereographic projection of the normals to the planes of about ninety dykes and sheets on an equal area net. Those few dykes within the aureole which have obviously had their trends altered by the emplacement of the granite pluton, have not been represented on the diagram.

It is clearly seen that out of a total of about ninety dykes, seventy two trend W.N.W. - E.S.E. to N.W. - S.E. and dip at various angles towards the SW. On the other hand, a much smaller proportion of the dykes trend N.E. - S.W.

It has already been stated that the suite of lamprophyric dykes had began its activity subsequent to the regional folding and metamorphism of the area. A relation was sought between the trend of the dykes and the folding structures.

On Inishkeel, the rocks are very well exposed on a broad beach, and the writer has chosen that area to study the relation between the dykes and the folding. Fig.2B. represents 70 fold axes (contoured) in Inishkeel, as well as the fracture cleavage on the folds (circles). The maximum representing the fold axes show that they plunge gently towards due W. or W.N.W. The folds are asymmetrical - though never recumbent - and the axial planes dip at an angle of about 65-70° S. The fracture cleavage exhibits 'fanning' on either side of the axial planes. There is but little doubt that the ffacture cleavage and axial planes of the folds are among the earliest planes of structural weakness to develop in association with the folds.

Now if the normals of the dykes in Inishkeel (solid dots Fig.1A) are compared with the fold axes and the fracture cleavage, it will be seen that the dykes are at an angle of about 25° to the north-west of the fold axes. There is also a similar discrepancy between the dips of the dykes and the fracture cleavage and axial planes.

Moreover, no longitudinal joints have been observed in

the rocks of Inishkeel, though there always remains the possibility of planes of potential weakness.

Steep cross joints are highly developed (p.42 and Plate 20A) and trend N. -S. to N.15° E. Except for one or two cases of moderately dipping dykes, this early and main joint system associated with the folding is independent of the trend of these dykes.

Numerous thrust and fault planes due to the granite intrusion, are not occupied by lamprophyre dykes.

The most striking feature of the trend of the lamprophyre dykes is the fact that those dykes intruded later than the emplacement of the granite pluton, and traversing the steeply dipping and intricately folded contact metasediments (Plate 3C) still retain the N.W. and W.N.W. trend, (circles in Fig.1A).

From the foregoing, it can be concluded that the trend of the lamprophyre dykes is entirely independent of the regional folding of the country-rocks and associated planes of weakness at this level. Secondly, that this dyke suite, in spite of its relatively wide distribution over time, tends to retain its trend.

H. Ptygmatic Intrusion of Lamprophyre Dykes.

South of Sooly Port, Inishkeel, is a small patch of limestone. While the underlying schists are gently folded,

PLATE 4.

A. Part of a lamprophyre dyke in the aureole of the Ardara Pluton showing boudinage structure. The segments of the dyke have been torn apart along plane surfaces thought to have been original joint planes, and the enclosing sillimanite hornfels has clearly 'flowed in' between the segments, near Narin crossroads.

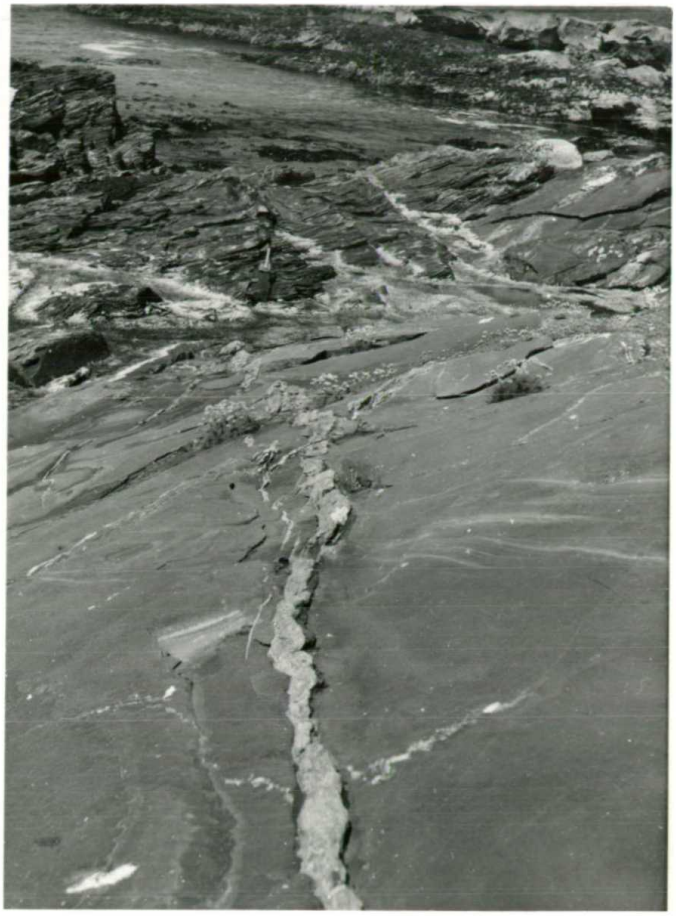
B. Ptygmatic lamprophyre dyke on the north-eastern coast of Inishkeel Island. In the background, the dyke runs straight through the schists towards the observer, meanwhile in the massive crystalline limestone (foreground) the dyke undulates, buckles on itself and in places, it is almost discontinuous. A thin undulating and tapering offshoot of the dyke is seen on the left hand side in the far end of the limestone.

FIGURE 2.

Graph representing the thickness of 75 of the lamprophyre-felsite dykes.



A



B

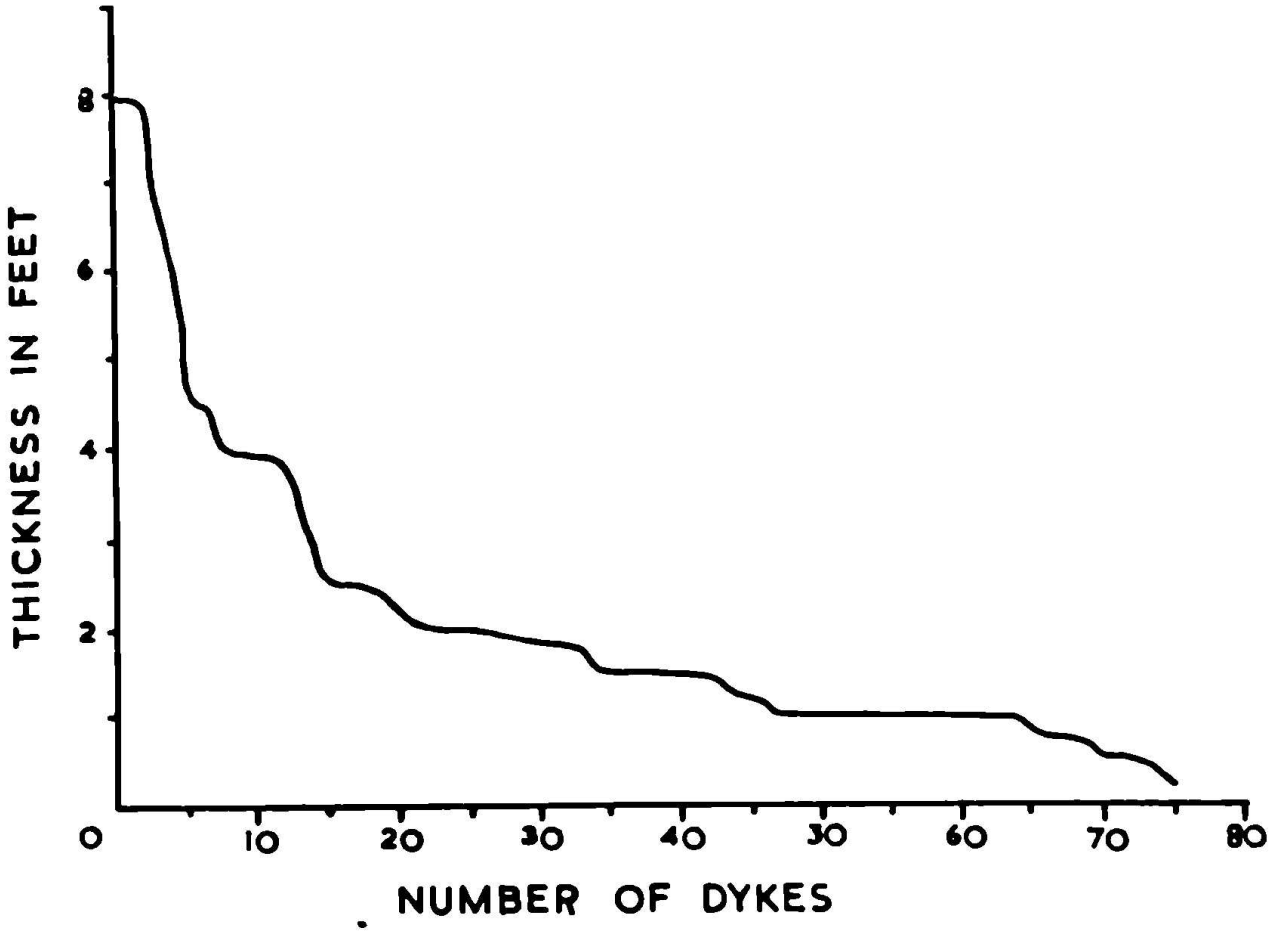


FIG. 2

the limestone appears as a homogeneous recrystallised mass, lacking micaceous partings and evidence of folding. At its south-eastern end, it is overlain by semi-pelitic schists and graphite granulite.

In the pelitic schist below the limestone is a lamprophyre dyke running N.W. - S.E. from the sea towards the limestone. The dyke is about one foot thick, dips 70° S.W. and possesses distinct chilled margins. It is older than the Sooly Rock granite i.e. it is one of the oldest members of the lamprophyre suite. On entering the limestone, the thickness is reduced from one foot to about 2", it undulates and buckles on itself, pinches and swells and in places tapers down to appear almost discontinuous, (Plate 4B). All axes of folding, crenulation and buckling are vertical or nearly so. It is also seen to send off thin and irregular stringers, this has never been noted in any other lamprophyre dyke. As the dyke leaves the limestone and proceeds into the overlying schist, it assumes its original thickness and chilled margins, and trends in precisely the same direction as before it entered the limestone band.

It thus appears that the lower and upper schists were in a solid state and possessed a sharp and straight fissure or joint plane, along which the dyke had been intruded. The limestone, on the other hand, was <u>still</u> in a plastic condition, probably with only a plane of lower cohesion

corresponding to the sharp crack in the schists. The buckling of the dyke material on sub-vertical axes, in the highly viscous and plastic limestone can be explained by the increased pressure of intrusion when the dyke magma met some obstruction further along its course, or even the 'hydrostatic head' of molten lamprophyre material.

The limestone was later intruded by a straight N.E. - S.W. trending lamprophyre dyke.

Had the buckled dyke been intruded into the solid limestone, and the latter subsequently mobilised, the dyke would have now appeared in the form of broken and discontinuous masses 'floating' in the limestone. This is the case with a lamprophyre dyke in the lower Portnoo limestone in the aureole of the Ardara pluton.

The mobilisation of the limestone at Sooly Port is attributed to the final phases of the orogeny, the "ptygmatically intruded" dyke having been shown to be among the oldest members of the suite, and definitely earlier than the emplacement of the Ardara granite.

Another clear case of "ptygmatic intrusion" of a felsitic lamprophyre dyke occurs in the Lower Banded limestone member of the Upper Portnoo Limestone at Drumshantony beach. This limestone dips unusually steeply towards the south-west, and shows evidence of mobilisation due to the Ardara granite.

A dyke of felsitic lamprophyre, about 2½ft. thick, runs across the strike in a very peculiar zig-zag form. The length of the limb of each fold or zig-zag cremulation is only slightly greater than the thickness of the dyke itself. The limbs are roughly at right angles to each other. There is no relation whatsoever between the zig-zag folding or buckling of the dyke and the folding of the mobilised limestone.

I. Summary and Discussion.

It has been shown that the suite of lamprophyre-felsite dykes began its activity immediately subsequent to, or actually during, the very final phases of the main orogeny closely associated with the regional metamorphism of the area. The introduction of this suite continued for a prolonged period, lasting till the end of all plutonic and hypabyssal activity in the area.

There has been several upwellings, waves or outbursts of magma, the latter varying from the small and forcible intrusion associated with highly xenolithic magmatic veins, to the forceful emplacement of large volumes of granite magma in more than one upwelling. There are, in addition, 'explosion breccias' and other apparently related phenomena.

Further, the lamprophyre dykes show a concentration in certain localities, and in any one of these places, they have a definite trend. In the writer's area, they are abundant in

the north-west, where their trend is N.W. - S.E. In Cresslough (McCall 1951), they show an even higher degree of concentration in the northern part - Hornhead and Cresslough. These have a constant trend N.E. - S.W.

The trend of the dykes, in the writer's area, was found to be independent of the presence of local planes of weakness, and their trend, on the whole, does not seem to be governed by the presence of planes of structural weakness or discontinuity. However, there is no evidence to judge if the trend of the dykes, even in part, is governed by deeply buried magmatic bodies, directly or indirectly responsible for the material of the lamprophyres as suggested by other writers on the subject of lamprophyres.

The presence of tan-brown amphibole with green borders, its association with variable amounts of biotite, and finally the relation of the biotite and muscovite need first be made clear by wider petrographic study of these lamprophyres. The writer will, at a later date, attempt a wider petrographic and chemical study on the seventy specimens of lamprophyre dykes of this suite.

II. Minor Granite Bodies.

A. Introduction.

Along the coast line which forms the northern boundary of the area, is a series of small granite bodies. They are granodioritic in composition, and have some characters in common. The time relations of this series are fairly well established particularly with regard to the two suites of lamprophyre dykes.

The largest of the minor granite bodies is at Sooly Rock, in the northern part of Inishkeel. It contains large enclaves of the enveloping schist, and sends off a vein containing a number of smaller fragments of the wall rock. The second occurrence is in the central part of the group of isolated rocks known as Grabbindoo. It has a vein-like apophysis crammed with xenoliths. This granodioritic body has a considerable effect on its contact metasediments both as regards disruption, marked induration and contact metamorphic effect. The third occurrence forms a group of small masses south of Orinish.

B. Sooly Rock Granodiorite - Inishkeel.

1. General description. In the middle of the northern shore of Inishkeel island, is a small granitic body about 260yds. long (E.-W), by 25yds. (N.-S) at its widest part. It is crescent shaped, its concave northern side forming the water line. Its contact with the metasediments is largely

covered by boulders and shingle from Sooly Port. In the few small exposures where the contact is seen, the metasediments are indurated, baked and partly mobilised, meanwhile the granodiorite is notably basified and acquires a dark colour due to the development of large biotite flakes.

2. Petrography. In hand specimen, the rock is medium-grained, whitish grey, with well developed plates of biotite about 2 m.m. across. In thin section (375), the rock is granodioritic in composition, and shows distinct cataclastic textures mainly in the quartz and biotite. Plagioclase is predominant, and the enhedral crystals have a more basic core, usually andesine (An.37). The outer borders have a general composition of An.20., but may be as sodic as An.12. No oscillatory zoning is seen. Pericline twinning is particularly well developed. Smaller euhedra of plagioclase have myrmekitic fringes. The potash felspar occurs either as orthoclase or microcline and is microperthitic, with a large proportion of spindle shaped areas of albite. The boundaries between the potash felspar and the quartz are straight and clear, but the boundaries between either individual grains of potash felspar or between the latter and plagioclase are marked by thick embayments of myrmekite. The biotite flakes which are about 2 m.m. across are usually bent or broken. It is practically uniaxial with pleochroism

z = Y = greenish brown, x = pale yellow. Biotite symplektite is very well developed, together with brush-like outgrowths of pale green muscovite in optical continuity with the biotite. The quartz shows moderate cataclastic effects with highly sutured interboundaries and strong undulose extinction. Epidote, non pleochroic but distinctly zoned together with some clinozoisite, is associated with the biotite. Secondary muscovite is abundant in the plagioclase and sphene is accessory occurring mainly in the biotite.

3. Apophyses and Field Relations. The Sooly rock granodiorite sends off two apophyses in the form of sheets, seen along the south-western border of Sooly Port. These sheets dip gently towards the S.W. The upper sheet is about two feet thick and the lower one about 3ft. thick, and they are separated by a two foot thick older lamprophyre sheet. The sheets are distinctly poorer in fermic constituents. The lower sheet contains several sharply angular xenoliths of the enveloping schist. Another apophysis from the main body is in the form of a vertical dyke, 2½ft. thick, trending S.S.E., this cuts a dyke of felsitic lamprophyre.

Quartz veins, 4" to 6" thick, fill a set of principal joints in the granodiorite, trending N.N.E. - S.S.W. and dipping 45° N.W. Along these joint planes filled with quartz, were intruded four basic lamprophyre dykes (of the second suite) and a fifth dyke of acid lamprophyre.

At its S.W. corner, the granite is cut by a vertical pegmatite vein trending N.-S. apparently older than the basic lamprophyre dykes.

4. Contact Effects of the Granodiorite. The contact of the granodiorite body is marked by a zone up to 10ft. wide, of induration and baking of the metasediments. The schist is seen to lose progressively its schistosity and distinct pucker lineation towards the contact, in place of which it acquires a dull and rather massive appearance.

At Sooly Rock, the granite contains two large blocks of the schist, the larger one of which measures about 60ft. across. Specimen 370 from the large enclave resembles a typical banded hornfels. In thin section, the rock is seen to consist of pelitic, quartzose and calcareous bands.

The pelitic bands consist of red-brown biotite - hornfels type - and recrystallised quartz. The blades of biotite are arranged in a zig-zag manner after the former strain slip cleavages in the schist. These bands are studded with pseudomorphs of biotite, sphene and epidote after garnet.

The calcareous bands contain clinozoisite, quartz and finely disseminated white mica.

C. Granodiorite Boss at Grabbindoo.

I. General Description. In the western part of Grabbindoo is a boss-like mass of granodiorite, elliptical in shape and measuring 85yds. (N.W.-S.E). by 40yds. (N.E.-S.W). The rock resembles that at Sooly Rock, except that it has a number of large enclaves of the schist at its margin. Some of the enclaves are not completely detached from the wall rock. The latter is indurated and mobilised to a much higher degree than would naturally be expected around such a minor granite mass. At first, the rock appears as a dull and massive hornfels, but closer examinations show the metasediments to have experienced drastic deformation and irregular and tight isoclinal folding; sometimes the structural elements are entirely lost. This effect extends for a distance of over 100yds. on either side of the granite. The mobilised and baked metasediments are also characterised by abundant veins and clots of quartz.

2. Petrography of the Contact Metasediments. In thin section, the hornfelsed envelope rock appears as a biotite-garnet-andalusite-hornfels.

The Andalusite is replaced by schimmer aggregates pseudomorphosed after chriastolite. In the pseudomorphs, opaque dust retains the symmetrical cross characteristic of chiastolite, and included in the pseudomorphs are also

corroded regional garnets. Chlorite grows from the outline of these pseudomorphs, and bears a very close resemblance to the 'New Chlorite' found as porphyroblasts in the groundmass of the rock. New Chlorite both inside the pseudomorphs of schimmer aggregates and in the groundmass shows marked alteration to biotite, particularly along its borders. Garnet belongs to at least two generations. In the more pelitic layer, where the pseudomorphs after andalusite are more frequent, subhedral crystals of garnet are also more abundant. Meanwhile, another type of garnet, usually corroded and associated with chlorite and biotite is of more even distribution throughout the rock. The proper discrimination between different garnets is rather difficult.

8. Xenolithic Granodiorite Vein. The granodiorite body at Grabbindoo sends a dyke-like off-shoot trending towards the east. It is about 100yds. long and its width varies between 3ft. and 5ft. The contact between the dyke-like vein and the highly mobilised metasediments is irregular and lacks contrast. It terminates at its eastern end as two bifercating and tapering veinlets.

This vein is crammed with xenoliths of pelitic and semi pelitic schist, amphibolite, diorite and biotite granulite. The xenoliths usually are circular and elliptical in section, less often are they sub-angular. Angular sections are rare

and restricted to massive xenoliths which might be of igneous origin, probably Lamprophyric.

The size of the xenoliths varies widely between ¼" and 9" across. Some elongated xenoliths show a parallelism with the vein. As to the nature of the xenoliths, a large proportion of these appear to be composed largely of biotite, suggesting a pelitic origin. In thin section, these pelitic xenoliths consist of aggregates of decussate biotite flakes set in a base of quartz and secondary calcite. Biotite symplektite is also highly developed in these biotitic xenoliths. Another common type of xenolith is amphibolitic in nature, and there are different stages of interaction between the pure amphibolite and the granitic host.

Thus all the combined characters of these xenoliths suggest that they had been carried up by the magma from a much lower level, and that they had remained in that part of the magma for some time before intrusion to the present level.

4. Petrography of the Xenolithic Granodiorite. In thin section, the granodiorite of this xenolithic vein clearly shows early cataclastic textures. The plagioclase seems to belong to two different generations. A relatively more basic type, basic oligoclase to andesine in composition, occurs either as individual subhedral crystals, or else with more acidic rims. Fresh acid oligoclase forms rims to the older

type or is present as individual crystals with slight oscillatory zoning. The quartz shows extremely strong undulose extinction, to the extent that while one part of a crystal is in extinction another part of the same crystal may show interference colours of light grey. The grains have sutured outlines and a few small and rounded grains persist along boundaries of larger quartz grains. Biotite of a dark redbrown colour, is partly altered to chlorite. The lamellae are usually slightly bent. Epidote is a notable accessory.

D. Summary and Conclusions.

The minor granite bodies, along the N. boundary of the area, are granodioritic in composition, and seem to be related to each other, particularly in time. Their time relations with regard to other events in the history of the area are as follows :-

1. They are later than the earliest members of the lamprophyre-felsite dyke suite.

2. Earlier than the swarm of basic lamprophyre dykes.

3. Probably earlier than the regional retrograde metamorphism.

At Grabbindoo, the intrusion was of a forcible nature, and the uprising magma was probably in a somewhat viscous state. It succeeded in detaching fragments of the wall-rock from a lower level. The upper part of the magma, which

naturally collected the detached fragments of wall rock, was intruded into whatever side fractures encountered by the rising magma. The xenolithic vein at Grabbindoo seems to represent one of these irregular fractures filled with such xenolithic granite.

To account for the rounded nature of the xenoliths in the xenolithic vein, particularly those pelitic in composition, the writer is inclined to suggest that both magmatic attack and abrasion have been operating. In view of the forceful nature of the granite intrusion, large fragments of detached massive wall rock would be expected to have their edges rounded in spite of the well lubricated medium. On the other hand magmatic attack is probably responsible for the shape and alteration of pelitic xenoliths. The latter usually appears as disc-like and spheroidal masses.

It is necessary to state that this xenolithic vein is entirely different from intrusion breccias and related phenomena present in the neighbouring areas. Pitcher and Read (1952) have concluded that an intrusion breccia, in the close neighbourhood, was not magmatic or igneous.

The main granodiorite at Grabbindoo appears to be only the top of a large mass burried under a thin cover, and responsible for the relatively wide contact effects. The forcible nature of the emplacement of this mass, even at this present level, is obvious from the blocks of enveloping schist appearing as enclaves near its margins. While some are

completely detached, others are still intact.

The country rocks were originally biotite-muscovite-schists with Old Garnet. The contact effects were mainly the formation of chiastolite and a second generation of garnet; the chiastolite sometimes has inclusions of the 'Old Garnet'. The andalusite was later altered to pseudomorphs of schimmer aggregates together with the partial alteration of garnet to chlorite. It is not certain whether these latter alterations are due to the diaphthoresis associated with the formation of 'New Chlorite' which is also present in the groundmass of the rock.

At Sooly Rock, Inishkeel, the forcible intrusion effect of the granite is also evident from the angular xenoliths in its apophyses.

III. The Basic Lamprophyre Dykes.

A. Introduction.

A minor swarm of basic lamprophyre dykes and sheets makes its appearance in Inishkeel and Carrickfad along the south shores of Gweebarra Bay. Eight dykes and sheets have been mapped, and they constitute a distinct group entirely independent of the main suite of lamprophyre-felsite dykes. The rocks of this small group are predominantly basic in composition, and exhibit a marked variation in colour, texture, grain size and to some extent in composition. Seven out of the eight members of this group are of a dark green colour, and consist mainly of biotite, amphibole and chlorite with subordinate felspar. They are classified as Spessartites and include only one Kersantite ; the eighth dyke is more correctly termed Biotite-porphyrite. However, all the biotite bearing types, the spessartites, are in an advanced stage of decomposition and are highly charged with carbonates, and the biotite is largely chloritised. The basic lamprophyres, in general, contain abundant pyrites.

This minor swarm does not show any transition into the main suite of lamprophyre-felsite dykes

B. Distribution and Description of Dykes and Sheets.

In Inishkeel island, the basic lamprophyre dykes and sheets occur at three localities. The first one of these

occurrences is at Porter's Rock, in the north-western part of the island, where a flat-lying sheet 4ft. thick, follows conformably the limestone horizon in that locality. From there, it extends towards the west to reappear once again on the west coast and still associated with the limestone. At both these exposures, this basic lamprophyre sheet is seen to be faulted and displaced by the tectonics associated with the emplacement of the Ardara pluton. The rock which is medium to coarse-grained and dark green in colour is classified as a type intermediate between a spessartite and a kersantite.

The second occurrence of a basic lamprophyre forms a 3ft. thick sheet along the south coast of Inishkeel, at a point 400yds. west of Island Mouth. The sheet strikes N.W.-S.E. dipping gently towards the south-west, and is seen to cut four dykes trending roughly east-west and belonging to the main suite of lamprophyre-felsite dykes. The rock is very similar to that at Porter's Rock.

At Sooly Rock, Inishkeel, five dykes of basic lamprophyre have been intruded along the main joints of the minor granite body in that locality. These joints trend N.E.-S.W., and the majority of these joint planes along which the lamprophyre dykes had been intruded, were previously occupied by pegmatites. The latter are now in contact with the hanging wall. The five lamprophyre dykes in the Sooly Rock granite vary in thickness between 2ft. and 4ft. ; four of

them are fine grained dark green Kersantites, while the fifth is a biotite-porphyrite.

At Maddybunlins, east Carrickfad, a 4ft. thick dyke of basic lamprophyre trends east-west dipping gently to the south. This dyke is undulating and seems to have been involved in some movements. The rock is a coarse-grained spessartite with notably finer grained parts representing the margins of the dyke (Spc.172).

C. Petrography.

The sheet of basic lamprophyre at Porter's Rock appears in hand specimen as medium to coarse grained of a dark green colour and has a Sp.gr. of 2.86. It is between a spessartite and a kersantite. In thin section (414), the rock consists of biotite, actinolite, plagioclase felspar and chlorite, with minor rutile, epidote, calcite, quartz and pyrite. The biotite is largely altered to chlorite, with the shedding of rutile mainly in the form of sagenite nets. The sagenite nets occur only in the central portions of the altered biotite flakes, and in some basal sections, a hexagonal rim free of rutile surrounds the plate. The biotite occurs either as thin elongated prisms 1-2 m.m. across or forms intergrowths with the amphibole. Its pleochroism is Z = Y = greenish brown and X = pale yellow. Actinolitic hornblende is less abundant than the biotite, and occurs largely as corroded patches 1 m.m. across, or else in the form of aggregates

closely associated with the biotite. Its pleochroism is Z' = pale green, Y' = pale lavender green and X' = colourless. The biotite (including chloritised biotite) together with the amphibole constitute about 75% of the rock. Andesine plagioclase of composition about An.46 constitutes the felsic part of the rock, and occurs as irregular crystals and masses up to 1 m.m. long. It is crammed with alteration products. Epidote is fairly common throughout the rock, in the form of small crystals, pleochroic in yellow and greenish yellow, or as fine aggregates. Carbonates form small patches up to 1½ m.m. across; pyrite cubes are fairly common and quartz is of rather limited occurrence, mainly as small clear grains.

The medium and fine grained kersantite dykes at Sooly Rock appear in thin sections (372 and 373) to consist of biotite, chlorite, carbonates, quartz, felspar, rutile and epidote. The biotite is of a dull greenish brown colour partly breaking down to chlorite with sagenite nets. Biotite also occurs as irregular aggregates resembling clots. Chlorite (-ve penninite) occurs in individual flakes or aggregates of elongated blades, and rarely forms rounded pools with small flakes of reddish biotite. Its pleochroism is Y = Z = pale lavender green and X = colourless; the axial angle is very small. Carbonates are very common mainly as large masses. One or two lenticular crystals seem to suggest the presence of siderite. Quartz occurs as clear interstitial masses.

The felspar is rather subordinate and is practically undeterminable due to alteration products.

The spessartite dyke at Maddybunlina, east Carrickfad, is dark green, medium grained, with a distinctly finer-grained margin. The Sp.gr. is 2.93. Slice 172 shows both the finer grained margin as well as part of the coarser grained rock. The rock consists mainly of actinolitic hornblende, with subordinate chloritised biotite, acid plagioclase and minor quartz. Calcite, rutile, iron oxide, epidote and sphene are accessories. The actinolitic hornblende has a pleochroism Z' = medium green to buff green, Y' = light olive green and X' = pale greenish yellow ; usually the central parts of the amphibole crystals are pinkish buff in colour, but this characteristic is restricted to the coarser grained part of the dyke. Sometimes the actinolitic hornblende is intergrown with thin borders of tremolite. The amphibole in the finer grained margins of the dyke is green in colour, and appears to be relatively less corroded. Fragments of honey-brown biotite still survive in pools of a colourless and almost isotropic chlorite. Chlorite is sometimes present as spherulitic and pear shaped fibrous aggregates, very faintly pleochroic. The felspar seems to be andesine, but it is highly decomposed . Quartz occurs as small clear grains.

The biotite-porphyrite dyke at Sooly Rock appears in thin section (376) to consist of plates of biotite and masses

of carbonates in a microcrystalline matrix of quartz and felspar. The biotite is of a brownish colour and occurs as thin elongated plates or else as minute shreds in the groundmass. In some parts of the thin section, the biotite flakes show a certain degree of alignment in the form of undulating trends suggesting a certain degree of flow while the dyke magma was about to congeal. Biotite interleaved with green chlorite is seen to take the place of perfect six sided amphibole. The fine matrix of the rock consists of an intergrowth of quartz and felspar.

D. Age Relation and Comparison with the Lamprophyre - Felsite Suite.

The main points fixing the age of the swarm of basic lamprophyre dykes relative to the other events in the history of the area are as follows :-

1. The basic lamprophyres were intruded after the earlier members of the main suite of lamprophyre-felsite dykes.
2. The basic lamprophyres are later than the minor granite bodies.
3. The basic lamprophyres are earlier than the emplacement of the Ardara granite.

It has already been stated that this swarm of basic lamprophyre dykes constitute a distinct group entirely independent of the main suite of lamprophyre-felsite dykes.

The following are the main points of difference between the major and minor groups of dykes :-

1. The field evidence indicate that the basic lamprophyres have been intruded over a relatively short period compared to the main suite of lamprophyre-felsite dykes.

2. Seven out of the eight members of the basic lamprophyre group are basic in composition, average Sp.gr. 2.89, while the lamprophyre-felsite dykes are intermediate and acidic in composition.

3. In spite of their small number, the basic lamprophyres exhibit a notable variation in composition, texture, grain size and colour, in strong contrast to the other group.

4. The basic lamprophyres are in an advanced stage of decomposition, being generally charged with carbonates, in the lamprophyte-felsite dykes only a very small proportion are mildly altered.

5. The basic lamprophyres have no generalised trend, and are seen to be intruded along existing planes of fracture.

Chapter FIVE.

POST OROGENIC THRUST MOVEMENTS AND DIAPHTHORESIS.

I. Introduction.

The area to the south of the Ardara pluton forms a great imbricate zone running N.E. - S.W. In this zone, a thick Quartzite group - presumably the eastern continuation of the Slieve Tooey Quartzites - is thrust against, and unconformably overlies, part of a thick succession of pelites, semi-pelites and calc-silicate rocks of the Glenties Series.

The Glenties Series first appears to the south-east of Ardara, where it is separated from the rocks of the Loughros Peninsula by a structural dislocation. Thence it extends to the north-east for a distance of about 8 miles to Glenmacannive on the eastern boundary of the present area; it is known to occur further north-east towards Fintown. In the writer's area, the Glenties Series lies between the southern boundary of the Ardara pluton and the base of the Quartzite Group. This belt varies in width between $^2/_3$ and 1½ miles. It includes a band of mylonitic gneiss about 5 miles long.

The Quartzite group which connects the Slieve Tooey Quartzite Group of the Slieve League Promontory with the quartzites of Agla and Lough Finn, occurs in the present area as four large thrust blocks overstepping the Glenties Series, the dislocation being referred to as the Carbane Thrust. This series of quartzite thrust blocks is dis-

discontinuous over a distance of about 2 miles between Tullyhonwar and Owenea Lough, where a group of semi-pelites is well exposed. This group, the Strawoaghter Semi-pelitic group, which is, in other places, unconformably overlain by the Quartzite group, is itself separated from the Glenties Series by a thrust - the Strawoaghter Thrust. The latter is also overlain by the Quartzite thrust blocks.

In the south-western corner of the area, a low angle thrust slice emerges from below the Quartzites and lies unconformably over the Glenties Series.

The main point in the structure of the area is the relation of the N.E. - S.W. trending belt of structural units, including the Glenties Series and the Quartzite Group, to the Mulnamin anticline. The former belt had been thrust against the southern and south-western flank of the Mulnamin anticline, essentially prior to the emplacement of the Ardara pluton. The position of the Glenties Series in relation to the Maas Succession along the south-western flank of the Mulnamin anticline indicates that the present southern boundary of the granite pluton marks approximately a major thrust, extending from near Ardara to the north-east towards Fintown. This major thrust, the Glenties Thrust, which also becomes particularly obvious when the section across the 'neck' of the pluton is considered, is responsible for the shearing out of the upper lithological groups of the Maas Succession along the south-western and southern flank of the Mulnamin anticline.

Minor thrusts have developed parallel to the two major dislocations, the Glenties Thrust and the Carbane Thrust. One of these minor dislocations has been occupied by a long sheet of tonalite - now the Mylonitic Gneiss of Carbane.

The major movements in the north-western direction are quite distinct from the early orogenic movements in the northern and north-north-eastern direction accompanied by the regional metamorphism. In their turn, the present post-orogenic movements are associated with a second metamorphism, a regional retrograde metamorphism or diaphtheresis in S.W. Donegal. This retrograde metamorphism has caused the change of the regional or 'Old Garnet', the index mineral of the first regional metamorphism, to pseudomorphs of 'Old Chlorite', distinct from porphyroblasts of 'New Chlorite' which has also been formed during these movements.

Further movement of the Quartzite group over the Glenties Series, subsequent to the emplacement of the Ardara pluton, has affected the mylonitisation of the tonalite band to form the Mylonitic Gneiss of Carbane, and the destruction of the southern aureole of the Ardara pluton.

The rocks of the Glenties Series near the pluton were also subject to even later movements apparently associated and partly contemporaneous with the emplacement of the pegmatitic fringe of a late member of the Donegal Granite

Series across the 'neck' of the pluton.

The general structure of the area lying to the south of the pluton will be considered here. On the other hand, the phyllonitic rocks and mylonitic gneiss present in the imbricate zone as well as the tectonics subsequent to the emplacement of the Ardara pluton will be dealt with in their appropriate places.

II. The Glenties Series and the Strawoughter Group.

The Glenties Series consists mainly of a thick series of pelites, semi-pelites, calc-silicate rocks, with minor bands of limestone and quartzite (p.30). It also includes an important band of mylonitic gneiss, representing an original sheet-like intrusion of tonalite.

As has been said, the Glenties Series first appears near Ardara and proceeds towards the east and further towards the north-east for a distance of over 8 miles within the writer's area, and has been followed further to the north-east towards Fintown by Mr.Cheesman of the Donegal Research Team. This series forms a belt about $^{2}/_{3}$ to $1\frac{1}{2}$ miles wide, lying between the southern margin of the Ardara pluton and the base of the Quartzites. The metasediments all dip at 60 - 70° south and south-east, parallel to the main structure in the zone of imbrication.

The peninsula of Loughros does not consist of the same rocks as those of the Glenties Series, but appears to be com-

parable with those of the Rosbeg group. The Glenties Series is separated from Loughros peninsula by a major structural dislocation concealed beneath the notable thickness of cover directly south of Ardara. The Glenties Series, with its band of mylonitic gneiss, is partly overstepped by the Quartzite group.

In the area between Tullyhonwar and Lough Owenea, where the quartzite is missing over a distance of about 2 miles, the Strawoaghter Semi-pelitic group is fairly well exposed, and it is clearly seen that this group is, in other places, completely over-ridden by the Quartzite group.

The Glenties Series is separated from the Strawoaghter Semi-pelitic group by the Strawoaghter Thrust. This thrust emerges from below the quartzite between Tullyhonwar and Kilrean Upper, and extends for a distance of 2 miles to the south-west, bounding part of the mylonitic gneiss and the Stackinillar quartzitic band, and finally traverses Owenea Lough. Together with the mylonitic gneiss and the whole of the Strawoaghter group it disappears under cover west of Owenea Lough. The exact hiatus along this dislocation cannot, as yet, be estimated.

The Strawoaghter Semi-pelitic group seems to occupy some position between the Glenties Series and the Quartzite group. As to the stratigraphic relation of the Glenties Series with respect to the Maas Succession, the former may

probably represent a lithological group or groups higher than, but not necessarily directly above, the Rosbeg group. The presence of rocks in Loughros peninsula readily comparable to those of the Rosbeg group, as well as the presence of rocks of the Glenties Series underlying the Quartzites and the Monargan thrust slice sough-east of Ardara, seem to suggest the possibility that the Glenties Series exists below the quartzite of Bracky Hill and Glengesh. In this case, the western continuation of the Glenties Thrust would run into Loughros Beg Bay ; the whole of Loughros peninsula has, in that case, been separated from the rocks of the area east and south-east of Ardara by a dislocation trending roughly north-south. However, the main structure of the area, prior to the emplacement of the Ardara pluton, is entirely independent of stratigraphic affinities between the Glenties Series, the Strawoaghter group and the Quartzites on one hand, and the Maas Succession on the other hand.

III. The Quartzite Group.

A. General.

The Quartzite group forms a high ridge of hills bounding the area on the southern and south-eastern sides. This high ridge stands rather conspicuously relative to the low flat-lying ground of the Glenties Series and the Ardara pluton. It consists of a series of thrust blocks connecting, as already noted, the quartzites of Slieve Rooey and Glengesh

in the Slieve League promontory with the quartzites of Agla and Lough Finn in the east. Within the writer's area, the Quartzite group occurs as three large masses, the Drumnasilla thrust block on the eastern boundary of the area, the Crockbrack thrust block, and the Ardvalley thrust block in the south-western corner of the area.

A great low angle thrust slice emerges from below the Ardvalley quartzite thrust block, and lies unconformably over rocks of the Glenties Series.

The structural boundary between the Quartzite group and the Glenties Series, the Carbane thrust, does not represent a thrust plane in the sence that it is a steep reversed fault, but rather that the Quartzites have been carried over the whole of the Strawoaghter group and parts of the Glenties Series with its band of mylonitic gneiss, the plane of dislocation dipping gently to the south-east.

B. The Drumnasilla Thrust Block.

The Drumnasilla thrust block occurs on the eastern boundary of the area ; it is 1¼ miles long (north-east to south-west) and reaches a height of 746ft. at the summit of Drumnasilla Hill. This mass has a steep north-easternly side facing the mylonitic gneiss on Carbane Hill. These two units are separated by a narrow valley, the Carbane Thrust at the foot of the quartzite being very clear in this locality. The quartzite does not readily show any bedding,

but it is distinctly shattered and veined with quartz. The quartzite is highly brecciated particularly where it forms the wall-like south-eastern boundary of Lough Glennacannine. The south-western extremity of this thrust block slopes rather gradually under cover of the Priest Mount drumlin. It is separated from the next thrust block of Crockbrack by a wide valley embracing the Owenea River.

C. The Crockbrack Thrust Block.

This mass of quartzite is 2¼ miles long from the northern part of Meenachallow, near Owenea River, to Tullyhonwar along the road to Donegal Town. It reaches a height of 809ft. at the summit of Crockbrack. The quartzite dips at about 35° south-east, but local variations in dip and strike are very common. Considerable shattering of the quartzite is seen along the north-north-eastern slopes of Meenachallow as well as in the stream at the foot of the hill. Brecciation on a finer scale also occurs along joint planes in the quartzite. The actual boundary between the quartzite and the mylonite gneiss is seen in the stream flowing in a north-easternly direction from the fault effecting the mylonite gneiss. Quartzite breccias are seen in contact with crush breccias of the mylonitic gneiss.

The extent of the overstepping of this quartzite thrust block over the Strawsaghter group and the Glenties Series with its band of mylonitic gneiss is very evident from the map of

the area. From the rather limited part of the Strawoughter Group mapped by the writer, it is seen that the overstepping of the Quartzite group in the north-western direction over the underlying rocks is not less than 1300 yds.

D. The Ardvalley Thrust Block.

The Ardvalley quartzite thrust block is situated in the south-western part of the area. It is about 2 miles long west-north-west to east-north-east and contains two main peaks Mogumna Hill 583ft. in the north-western part, and Ardvalley 1042ft. at its north-western end. This quartzite block is separated from the Glengesh block to the west by a deep valley through which the road to Killybegs runs south. The Mogumna quartzite dips at angles of 35° to 50° S.S.W. Considerable brecciation and shattering are observed at the foot of the Quartzite at Ardlougher.

E. The Cronkeeran - Glendowan Block.

The Cronkeeran-Glendowan block is about 1 mile long north-east to south-west, and from about ¼ to ½ mile broad. It consists mainly of banded quartzite standing vertical N.E.- S.W. but its south-easternly part consists of highly disrupted and slickensided semi-pelites and pelites. The block is bounded on its south-eastern side by a vertical fault running in the steep sided

valley of Glendowen. The quartzite, though usually vertical, occasionally appears to dip steeply on either side suggesting a closely folded structure. It also exhibits a distinct mullion structure occurring either horizontally N.E. -S.W. or plunging gently to the south-west. On the other hand, in the road-side quarry near the winding track to Glendowen, the highly deformed and slickensided pelites and semi-pelites show drag-folding indicating a movement to the north-west.

The boundary of the Cronkeeran block with that of Ardvalley is hardly exposed, but both the topography and overall field observations seem to suggest that the latter had been thrust against the former probably during a late phase of the movements.

In general, the position of the Cronkeeran -Glendowan block is rather awkward, particularly in view of the presence of rocks of the Glenties Series, the mylonitic gneiss, and rocks of the Strawoaghter group to the south-east of it. Although the exact nature of the tectonics associated with this block is not fully understood, nevertheless, it appears to have been another thrust block which has subsequently subsided by vertical faulting.

IV. The Moy-Monargan Thrust Slice.

A. General Statement.

The Ardvalley quartzite thrust block is underlain by

an extensive low angle thrust slice lying in between it and the underlying rocks of the Glenties Series. This slice presents a distinct contrast in lithology and strike to both the Quartzite group and the underlying Glenties Series. It measures slightly over 1¼ miles in length and is about 1 mile wide at its broadest part. In general this thrust slice forms a plateau-like mass above the Glenties Series and ascends very gently towards the Quartzites.

As stated on p.34, the rocks of this thrust slice are dominantly psammitic in nature consisting mainly of siliceous granulites, quartz flags and thin bands of semi-pelites and limestone. These rocks, which have not, as yet, been found to occur in any other part of the area, are provisionally grouped as the Monargan Psammitic group. There is no evidence in the rocks of this group whether they are 'right way up' or 'younging' to the south.

The rocks of this group were shown to have the following presumably stratigraphic succession beginning with the highest member :-

(iii) Ardlougher Semi-pelites and Pelites. 150ft.
including two bands of limestone each about 20ft. thick.

(ii) Moy Quartz Flags. 400ft.
with a band of limestone and another of semi-pelite each about 30ft. thick.

(1) Monargan Siliceous Granulites and Quartzites 500ft.

including a band of yellow limestone and with a boulder bed at its base.

The boulder bed occurring along the northern boundary of the thrust slice is best exposed in the large crag at Carrickilver by the side of the old road to Donegal Town. It extends to the north-east till Doochill South, its strike conforming to the boundary of the amphibolitic mass of Stormhill; this latter amphibolitic intrusion apparently having pushed aside the boulder bed against the other rocks of the thrust slice. This boulder bed is associated with a thin limestone band, and while at Carrickilver the limestone occurs in the lower part of the boulder bed, near Doochill South it occurs in the upper part of the boulder bed. At Stormhill, the boulder bed is overlain by a thin band of high grade semi-pelitic hornfels.

In addition to the deformation and disruption observed in the metasediments of this exotic thrust slice, apparently due to the considerable movements to which it has been subjected, the whole mass is rendered even more complex by the later intrusion of a most variable suite of amphibolites, dioritès, appinitic rocks and related types. It also appears that these intrusive rocks have had a mobilising effect upon

the metasediments, though a hornfelsing effect is seldom recorded, probably due to late movements causing a certain degree of retrogression. These intrusive diorites and appinitic types are in every way related to the other similar rocks in the area to the south of the pluton, and are quite distinct from the older metadolerites.

B. Structure of the Thrust Slice.

The Moy-Monargan thrust slice rests on the south-western part of the Glenties Series, this part showing the gradual change in strike from east-north-east, east-west to west-north-west towards Ardara. Thus on the eastern side of the thrust slice the pelites of the Glenties Series dip at 60 - 75° S.S.E., meanwhile on the western side of the thrust slice they dip at 50 - 60° S.S.W. The Quartzites overlying the thrust slice dip at 40 - 50° S.S.W. The rocks of the thrust slice usually dip at 30 - 40° due south, and the succession is clearly seen to trend in an east-west direction extending below the Ardvalley thrust block on the west side.

The northern margins of the thrust slice, stands like a wall or ledge, and at Stormhill, the shape of the bodies of metadolerite conform to the outline of the thrust slice.

Lineations and minor folds, particularly in the Moy quartz-flags, plunge at 20 to 30° in a direction S.4 0° W.

Some of the small folds in the quartz flags resemble drag folds indicating a movement of the upper beds to the north-west, compatible with the general movement picture.

It has already been stated that the Quartzite group is thought to have been carried over the Strawoaghter Semi-pelitic group and part of the Glenties Series with its band of mylonitic gneiss, along what appears to be a low dipping plane of thrust. Here the thrust slice seems to confirm the observations in the Glenties Series in general.

C. Morphological Description and Petrography of Rock Types.

1. The Monargan Siliceous Granulites and Boulder Bed.

The Monargan siliceous granulites consist mainly of fine-grained grey-green granulites with quartzitic bands of varying thickness. At Carrickilver, the boulder bed which consists of some quartz and granitic boulders up to 4" across in a granulitic matrix, stands in bold crags along the face of the thrust slice. At this locality, as well as to the south-west of it across the main road, the rocks have completely lost their structures and appear as massive greenish grey granulites with occasional large porphyritic crystals of pink felspar. In places where the effect of the associated diorites and amphibolitic mass is of a slightly milder nature, the original bedding of the rock still survives locally and exhibits free swirling.

In the central part of the granulites, the latter have

been rendered notably mobile and the quartzitic bands are disrupted and are seen to float at random in a base of green granulite.

Mobilisation is also clearly seen at a locality about 100yds. east of the appinitic body in the Monargan siliceous granulites. Here, disrupted bands of glassy quartzite appear to have moved freely in a base of impure quartzite and quartz-granulites.

To the extreme west of Odogherty, greenish grey granulites, in contact with the body of coarse amphibolite, is also highly mobilised and shows incipient migmatisation. The northern part of the Monargan granulites is the least deformed and mobilised. The granulites are locally banded grey and pink (Spec.840).

To the north-west of Odogherty, a band of white quartzite is underlain by a band of yellowish limestone, and both are cut by the amphibolites and diorites in that locality. In the amphibolites and diorites, a band of epidote-rich rock associated with excellent appinitic types is exactly on the same strike as the limestone band.

2. Petrography of the Monargan Granulites and Boulder Bed.

A representative of the grey-green granulites forming the matrix of the boulder bed at Carrickilver is seen in slice (811) to be a quartz-chlorite-granulite consisting of quartz, chlorite, felspar, muscovite and epidote in their

order of abundance. The quartz occurs as small grains with interlocking and sutured boundaries. The chlorite is pleochroic bright grass green and pale straw and forms minute shreds. The rock contains a notable amount of altered felspar out of which a few grains of oligoclase were identified. Only under cross nicols does the rock appear to possess a structure, due to the elongation of minute individuals of quartz.

The mobilised green granulite in the centre of the Monargan granulites (slice 842) consists mainly of epidote and chlorite in equal amounts with minor quartz, potash felspar and acid plagioclase. Rutile and sphene are accessory. The epidote is usually very turbid.

3. The Moy Quartz Flags.

The Moy quartz flags is the second main member of the Monargan Psammitic group and consists of quartz flags, quartzites with minot quartz-muscovite granulites. These dip south at 30 - 40° and generally do not exhibit so strong a deformation as do the rocks in the northern part of the thrust slice. However, along their northern margin with the coarse and fine-grained diorites, the quartz flags and quartz-muscovite-granulites show clear mobilisation and crinkling over a zone from 5 to 10ft. wide.

The quartz flags are followed by a semi-pelitic band

about 30ft. thick and a limestone of about the same thickness - the Moy Semi-pelite and the Moy Limestone. This limestone is a sugary grey marble, characterised by bands 1" to 2" thick consisting mainly of muscovite, quartzite and clinozoisite (slice 825).

4. The Ardlougher Semi-Pelites and Pelites.

The presumed uppermost members in the Monargan Psammitic group is a series of semi-pelitic and pelitic schists with two minor bands of limestone, each about 20ft. thick.

The pelites and semi-pelites are altered mainly to biotite-muscovite-sillimanite-hornfelses by the action of the altered amphibolites and diorites on their northern side. A typical hornfels (slice 828) consists of red-brown biotite, muscovite with trails of opaque dust, felty aggregates of fibrolite occurring mainly within the muscovite, and minor felspar. Iron oxide and tourmaline are notable accessories.

The band of limestone nearest to the diorite is altered to a green calc-silicate rock.

V. Diaphthoresis.

A. Introduction.

It has been shown that the early orogenic fold movements from the south and south-south-west have been accompanied by the regional metamorphism, converting the folded sedimentary rocks into metamorphic rocks of the 'garnet grade',

and the early basic intrusions into metadolerites. Similarly, the post orogenic thrust movements from the south-east were accompanied by a second main metamorphism, a regional retrograde metamorphism. This has caused the alteration of the regional index mineral or 'Old Garnet' to pseudomorphs of 'Old Chlorite', as well as the development of porphyroblasts of 'New Chlorite'. No corresponding retrograde changes have been observed in metadolerites and early lamprophyric dykes.

Due to the third main metamorphism - the thermal metamorphism associated with the emplacement of the Ardara pluton- the diaphthoresis as well as the earlier regional metamorphism have been obliterated from the rocks of the larger part of the area. In the small part of the writer's area exhibiting the diaphthoresis, the formation of porphyroblasts of 'New Chlorite' appears to be connected with a lineation plunging moderately to the south-west.

B. Small Structures Related to the Post-orogenic Movements.

R.S. Mithal (1951) has noted a lineation plunging moderately to the south-west in the whole of the area to the west of the Ardara pluton, and has found it to date between the regional metamorphism and the emplacement of the pluton. He has also shown this lineation to be connected with the development of the 'New Chlorite'.

In Inishkeel and Carrickfad, the only localities within the writer's area unaffected by the emplacement of the

Ardara pluton or by the post granite tectonics, the presence of this lineation, its time relation and its close association with the porphyroblasts of 'New Chlorite' are fully confirmed. Particularly at Carrickfad, large porphyroblasts of 'New Chlorite' show a marked development and preferred orientation parallel to the lineation plunging to the south-west. The lineation in Inishkeel, Carrickfad and the outer parts of the Portnoo Limestone plunges at 25 - 35° in the direction S.35° - 50° W.

At Inishkeel, several minor thrusts occur in the north-eastern part of the island, and cause the shearing out of portions of a number of lamprophyre-felsite dykes. These thrusts are also probably connected with the post-orogenic thrust movements.

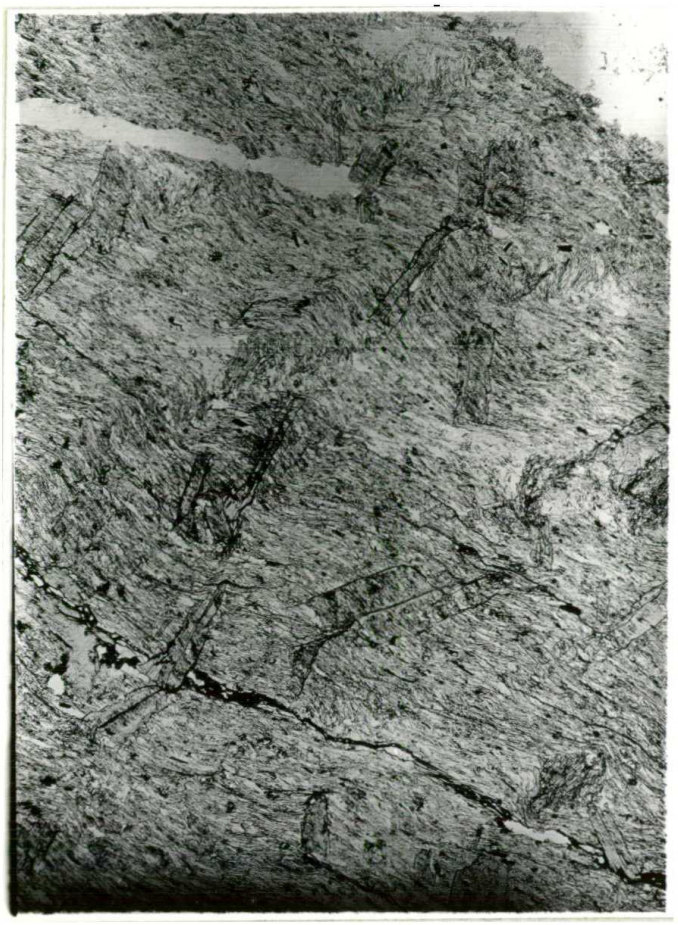
C. Petrography of Phyllonites with 'New Chlorite'.

I. Phyllonitisation at Carrickfad.

In the quartz-mica-phyllites in the western part of Carrickfad, minute pseudomorphs of 'Old Chlorite' after the 'Old Garnet' are changed to biotite by the contact effect of the Ardara pluton. 'New Chlorite' has not been formed in these fine-grained phyllites. On the other hand the alternately banded pelitic and semi-pelitic phyllonites in the main eastern part of Carrickfad show a striking development of elongated porphyroblasts of 'New Chlorite'. These are oriented p rallel to a lineation plunging 35° in the

PLATE 5.

Photomicrograph of the muscovite-biotite phyllonites at Carrickfad with porphyroblasts of 'New Chlorite', The porphyroblasts which show a marked degree of preferred orientation have trails of inclusions from the groundmass. The outer borders of the porphyroblasts are altered to biotite due to the contact effect of the Ardara pluton. Ordinary Light X 25.



direction S. 36° - 40° W. Even in thin section, the orientation of these porphyroblasts is very clear (plate 5).

In thin sections 157 and 177, the regional garnet is replaced by pseudomorphs of 'Old Chlorite', the latter show clear signs of later alteration to biotite. 'New Chlorite' occurs as porphyroblasts up to 2 m.m. x ¾ m.m. lying parallel to a rather weak strain-slip cleavage. Trails of inclusions from the groundmass pass unhindered through the porphyroblasts. These include iron oxide and some quartz grains. Muscovite, which is very abundant in the groundmass of the rock is seldom seen as inclusions in the chlorite porphyroblasts. The chlorite is very pale green to colourless and shows very low interference colours, mainly ultra browns. The difference in susceptibility of the two chlorites towards the thermal effect of the granite pluton is discussed on page 272.

2. Phyllonitisation at Inishkeel.

At Inishkeel, 'New Chlorite' is well developed only in the pelitic and semi-pelitic phyllonites, but does not possess the high degree of preferred orientation as that at Carrickfad. In slice 413, 'New Chlorite' is almost isotropic and occurs as elongated porphyroblasts up to 3 m.m. long, either along the trace of the older strain-slip cleavage (the regional fracture cleavage) or across it. 'Old Garnet' is replaced by pseudomorphs of 'Old Chlorite', the latter being only partially altered to biotite in view of its

distance from the granite pluton.

3. Diaphthoresis in the Strawoaghter Semi-pelitic Group.

At Tullyhonwar Bridge and along the southern shores of Owenea Lough, some semi-pelitic bands exhibit distinct pseudomorphs of chlorite after the regional garnet. Although these chlorite pseudomorphs are very distinct in the muscovite-biotite-phyllonites of these localities, yet in thin section the pseudomorphs appear to have experienced later deformation, thereby probably recording the later post-granite movements of the Quartzite group.

VI. Summary.

Subsequent to the main orogeny and Regional Metamorphism in the area, thrust movements from the south-east of considerable magnitude, have caused the thrusting of a thick belt of metasediments trending N.E. - S.W. against the south-western flank of the Mulnamin anticline. This thrusting along the Glenties Thrust - now marked approximately by the southern boundary of the Ardara pluton - was responsible for the elimination of the upper lithological groups of the Maas Succession in the great anticline.

The north-easterly trending belt of metasediments is a great imbricate zone consisting of a thick quartzite group thrust against and unconformably overlying the

Strawoaghter Semi-pelitic group and part of the Glenties Series, along a low angle thrust plane - the Carbane Thrust. Near the south-western corner of the area, a large low angle thrust slice emerges from below the Quartzite group and lies unconformably over rocks of the Glenties Series. A subsidiary plane of dislocation parallel to the two main thrusts, the Glenties Thrust and the Carbane Thrust, was intruded by tonalite in the form of a sheet-like body - now the Mylonitic Gneiss of Carbane.

These Post-Orogenic Thrust Movements from the South-East were accompanied by a second main metamorphism, a regional retrograde metamorphism causing the alteration of the regional or 'Old Garnet' to pseudomorphs of 'Old Chlorite' and the development of porphyroblastic 'New Chlorite'. In some places, the latter possesses a preferred orientation parallel to a lineation plunging moderately to the south-west and connected with the main thrust movements.

Chapter SIX.

THE ARDARA GRANITIC PLUTON.

1. Introduction.

The Ardara Granitic Pluton forms the south-western extremity of the main Donegal Granite Series and consists of a composite circular body, about five miles in diameter, with a protrusion of 'neck', cut across by one of the members of the Donegal Granite. It is situated to the north of the towns of Ardara and Glenties, and along its northern boundaries are the localities of Maas, Clooney and Narin. The main body of the pluton together with the 'neck' have an area of about 20sq. miles, out of which over 17 sq. miles have been mapped by the writer.

The pluton can be divided into two distinct parts; a relatively narrow outer part consisting of a coarse-grained tonalite is in contact with the enveloping country rocks and a medium-grained granodiorite forms the main core of the pluton. A large part of this granodiorite is highly contaminated - now a quartz-diorite in composition - and contains abundant dark xenoliths. Thus the pluton consists of three main rock types ; a coarse tonalite, a contaminated xenolithic quartz-diorite and a biotite granodiorite, the latter representing the original uncontaminated magma.

The main body of the pluton has a pronounced circular structure, the outer parts possessing a foliation parallel to

the margin of the pluton. The distribution of the main rock types also conforms to this structure. The coarse-grained tonalite possesses a strong foliation and forms an almost continuous outer mantle to the pluton 250 to 1000yds. wide and covering an area of 3 sq. miles. The contaminated xenolithic quartz-diorite occupies the northern and north-eastern parts of the pluton as well as the 'neck'. Together with some slightly xenolithic but uncontaminated biotite-granodiorite, it forms a circular foliated zone ½ to 1/3 mile wide around a central body of biotite-granodiorite. The latter is situated in the centre of the pluton, lacks any perceptible foliation, is entirely free of xenoliths and represents the original magma. However, the biotite granodiorite in the northern part of the pluton, which is foliated and possesses a few dark xenoliths, is identical in composition to the massive centre of the pluton and together are called the central granodiorite.

The 'neck' of the pluton, consisting of xenolithic quartz-diorite together with tonalite, is cut across by a fine-grained pegmatitic fringe of a member of the Donegal Granite Series, provisionally named the 'pegmatitic fringe of the Doocharry Granite'.

The outer foliated periphery of the pluton contains veins of aplite, pegmatite and quartz. These have been studied mainly from the structural point of view.

Sheets and dyke-like veins of fine-grained granodiorite are also of common occurrence in the pluton, and sometimes extend into the contact altered metasediments.

Porphyry dykes intrude the granitic pluton and the country rocks and mark the latest granitic phenomena.

A few dolerite dykes of apparently Tertiary age occur within the present area.

II. The Foliated Tonalite.

A. Introduction.

The outermost member of the Ardara pluton consists of coarse-grained tonalite with a strong foliation in part gneissic and trending parallel to the outer margin of the pluton. This foliated tonalite forms a 'skin' or outer mantle to the pluton, separating the main medium-grained granodioritic body from the metasediment envelope. Along the northern margin of the 'neck' the tonalite is absent and the xenolithic quartz-diorite is in contact with the amphibolitic complex of Meenalargan. In the northern part of the pluton, the tonalite forms an arcuate band varying in thickness between 450yds. and 650yds., and in the north-east its width varies from 260yds. to 400yds. At Letterilly, the tonalite mantle gradually tapers off against the outer margin and the xenolithic quartz-diorite is either in direct contact with the amphibolitic complex of Meenalargan or is separated from

it by a thin discontinuous screen of highly variable rocks related to the tonalite. Along the southern margin of the pluton, the tonalite forms a continuous band about 6½ miles long, beginning at Woodtown, north of Glenties, where it is about 450yds. wide and extending westward to Ardara, where it reaches a maximum thickness of over 1000yds.

The tonalite always tends to form high-ground relative to the other two main rock types in the pluton, as well shown in the northern and north-eastern parts of the pluton. Similarly it forms the high-ground of Gortonacart Glebe, Doochill North and the hill north of the Ardara drumlin. This belt of high-ground stands much higher than the land to the north, which is occupied by the xenolithic quartz-diorite and central granodiorite.

In the field, the tonalite is very distinct from the other rock types in the granitic complex, and is of very uniform character. The only variation in the tonalite, apart from local abundance of xenoliths, is a slight variation in the relative proportion of the large crystals of plagioclase.

The tonalite is a medium to coarse grained rock, generally pale ash-grey in colour, with a strong and distinct foliation. This increases in intensity towards the outer margin, where it becomes distinctly gneissic. Near the contact with the xenolithic quartz-diorite, the tonalite acquires a pink colour. It contains large euhedral and sub-euhedral crystals of plagioclase about 1 c.m. long; the other con-

stituents are of much smaller grain size. The ferromagnesian minerals, mainly biotite, lie in the plane of foliation; and where the rock is gneissic, the biotite forms augen-shaped wisps around the large plagioclase crystals. No linear element is present in the place of foliation.

The tonalite is characterised by the presence of abundant xenoliths, the larger part of which are originally from the enveloping metasediments, including semi-pelites, calc-silicates, pelites, quartzites and siliceous granulites, in their order of abundance. The larger part of the semi-pelitic xenoliths as well as a few calc-silicate and dioritic types occur as small and very thin plates lying parallel to the foliation of the rock. The frequent occurrence of these xenoliths, their size and even distribution throughout the rock is very striking and seems to characterise the tonalite. The other xenoliths of sedimentary origin usually occur as slabby or irregular masses, usually retaining their sedimentary structures and sometimes even their structural elements, such as strain slip cleavage. All the slabby xenoliths are aligned with their longest axes parallel to the foliation of the rock.

Amphibolitic, dioritic and appinitic xenoliths are of less frequent occurrence compared to those of clear metasediment origin, and are only locally abundant. Unlike the corresponding xenoliths in the xenolithic quarts-diorite,

they are much less altered by their tonalite host, and also do not appear to have been flattened out - these amphibolitic xenoliths include fragments of foliated and sheared metadolerite.

The central granodiorite contains a large mass of tonalite about 40yds. across at a point 1 mile east of Owenea Bridge and about 300yds. north of the tonalite - granodiorite contact.

B. The Outer Margin of the Tonalite.

Within the writer's area, the tonalite possesses a remarkably straight outer margin devoid of indentations and irregularities. Sharp contacts between the marginal gneissic tonalite and the hornfelsed metasediments are well exposed in several localities. At the Marin cross-roads, numerous sharp contacts between the gneissic tonalite and the dull massive sillimanite-cordierite-hornfels occur over a distance of about 200yds. Here the contact is usually marked by a band of tourmaline or tourmaline-quartz-rock from 2" to 1ft. thick. At Clooney, the sharp contact between the tonalite and the cordierite-hornfels and calc-silicate bands is again marked by the presence of tourmaline. West of Ballyiriston Bridge, the contact of the tonalite with metadolerite is sharp and no apparent transfer of material is seen. In the Maas area, the tonalite stands some 30ft. above the sillimanite-hornfels, in the form of a ledge 1 mile

long. The contact is sharp and remarkably straight.

The outer margin of the pluton in the Letterilly area and all along the northern boundary of the 'neck' is of a complicated nature. From near Meenalargan Village for a distance of 2½ miles along the contact towards Letterilly House, the xenolithic quarts-diorite is almost in direct contact with the amphibolitic complex of Meenalargan. It is separated from the latter by a thin discontinuous screen consisting of a variety of diorites, migmatitic and banded diorites, more basic varieties of tonalite and even normal tonalite. Along the boundary of the amphibolitic complex, embayments and crevices are occupied by tonalite slightly different from the normal tonalite. The largest of these masses is about 300yds. long and is situated 1/3 mile west of Meenalargan village, along the outer margin of the pluton. The protrusions of the amphibolitic complex along the contact all appear to be deflected towards the west. This together with the internal structure of the xenolithic quartz-diorite of the 'neck' indicate that the tonalite had been swept from this part of the margin of the pluton by the xenolithic quarts-diorite. When the contact is followed towards the west, to the point where the tonalite occurs at the contact, the tonalite is seen to possess rather sharp boundaries against the highly mobilised semi-pelitic bands of the Mulnamin Calc-silicate Flags of the Maas Succession.

The outer margin of the tonalite west of the railway station at Glenties contains several small masses of pelitic hornfels marking the original contact of the tonalite and the Glenties Pelites prior to the emplacement and wedging of the pegmatitic fringe of the Doocharry Granite.

In the southern part of the pluton, excellent contacts of the tonalite and the semi-pelites with their thin quartzit ribs are seen at the eastern foot of the Ardara drumlin and proceed towards the east for about one mile. Other sharp contacts also occur near Garvegort School and to the west of it.

C. Petrography of the Tonalite.

1. General Characters. The foliated tonalite is a medium to coarse-grained rock of a pale grey to light pink colour, and consists mainly of plagioclase felspar, potash felspar, quartz, biotite and hornblende with minor sphene and epidote. Apatite and opaque iron-oxide are minor accessories. The largest part of the plagioclase occurs as euhedral and subhedral crystals about 10 m.m. long and are of a pale grey colour with yellowish bands representing altered parts. The remaining quartz-felspathic constituents are much finer-grained and the felspar is of a pale pinkish colour. Biotite is the only ferro-magnesian mineral readily discernible in the hand specimen; and the flakes all lie in the plane of foliation. The average sp.gr. is 2.70.

2. The Minerals. Plagioclase occurs as several types, the most distinct of which are the following :-

(i) Large elongated crystals about 10 m.m. and up to 12 m.m. The core of these crystals consists of andesine of average composition An.34, rarely approaching An.38 and devoid of any zoning. This is surrounded by more narrow sodic rims of oligoclase of composition near An.18, usually ½ m.m. wide. These borders of oligoclase are sometimes marked from their cores by fine dust inclusions or a reddish staining. Borders of oligoclase also appear to replace potash felspar and quartz very actively. The relative abundance of these large plagioclase crystals varies considerably at times, slice 248 shows an abundance of these large crystals.

The large crystals of plagioclase are characterised by inclusions the most important of which are :-

(a) Inclusions of quartz in optical continuity occurring mainly near the centres of the plagioclase crystals (250). The boundaries of these quartz inclusions are always serrated with one set of the twin lamellae of the plagioclase protruding into the quartz.

(b) Inclusions of hornblende as irregular masses, usually of the pale green poikilitic type with darker green borders. Sometimes stout crystals of diopside occur surrounded by pale uralite and bright green amphibole (249).

(c) Inclusions of biotite occur associated with epidote ; while the latter appears unaffected by the plagioclase, the biotite is highly corroded leaving brush-like remnants.

(d) Apatite grains up to ½ m.m. across.

The tonalite occurring near the quartz-diorite contact is dark pink in colour, and the plagioclase appears, in thin section, to be crammed with fine reddish dust as well as irregular fragments of clinozoisite and epidote.

(ii) Smaller crystals of plagioclase occur with an average length of 1 m.m. and showing gradual zoning from a core of composition An.30. to the periphery of composition An.15 approx. These small crystals have very irregular boundaries particularly against microcline which it appears to replace with the production of myrmekite. This plagioclase is entirely devoid of inclusions.

Potash felspar occurs mainly in the form of microcline, rarely as orthoclase, sometimes it is as microcline microperthite. It is largely interstitial associated with the quartz. Where the rock shows a gneissic foliation and the large plagioclase form augen surrounded by selveges of biotite, microcline crystallises in the 'shaded areas' at either end of the plagioclase augen. Sometimes one set of twinning in the microcline is exactly opposite the albite twinning in the plagioclase, and thus the microcline resembles outgrowths

to the plagioclase (249). The microcline contains abundant grains of quartz. It is partly replaced by quartz and myrmekitic embayments.

Quartz is interstitial, and is usually devoid of inclusions except fine trails of opaque dust. The quartz is seen to replace the microcline very actively and very commonly forms semicircular embayments into the microcline.

Biotite occurs as large flakes up to 2 m.m. long, and less frequently 3½ m.m. long. Its pleochroism is Z = Y = dark green, sometimes blackish green, X = bright straw yellow. The colour of the biotite changes to reddish brown at the margin of the pluton (234 and 248). The majority of the biotite flakes are bent or broken. Sometimes it forms augen-shaped selvages around the large crystals of plagioclase. Usually it forms bands marking the foliation of the rock in association with the other ferro-magnesian minerals.

The biotite is usually corroded by the acid plagioclase whether the latter occurs as outer rims to crystals or forms small irregular masses. The biotite appears as brush-like remnants. Sometimes it is corroded by quartz into small tabular particles in optical continuity, as in slice (251). Biotite symplektite is highly developed in many slices (261 and 251). The biotite tends to alter, shedding iron oxide dust and granular sphene along its cleavages. Sometimes it alters to chlorite in fine scaly aggregates (249).

The Amphibole usually has a variable character from one slice to the other, or even within a single slice. In general, the amphibole is either pale green or almost colourless actinolite and in the centre of the crystal aggregates are abundant poikilitic inclusions. These masses have rims of green hornblende, with pleochroism Z' = dark grass green sometimes with a bluish tinge, Y' = yellowish green and X' = greenish yellow to straw yellow. These rims are normally devoid of poikilitic inclusions, but at times, the whole particle of amphibole may consist of the dark green hornblende and contains poikilitic inclusions in its centre. Small particles of dark green hornblende with euhedral form occur with these patches of uralitic amphibole. The amphibole in the rock is more recrystallised than that occurring as inclusions in the large crystals of andesine plagioclase. In slice 265, the hornblende possesses vermicular tunnels of quartz resembling biotite symplektite. Hornblende is locally absent in slice 535 from Maas.

Sphene is of a bright reddish brown colour, occurring either as irregular grains with inclusions of quartz, or as lozenge shaped crystals up to 1½ m.m. long.

Epidote, pleochroic greenish yellow to colourless, occurs either as irregular masses or as euhedral crystals embedded in the biotite.

Apatite can occur in large grains up to ½ m.m. across,

but more usually as grains about ½ m.m. across contained in the biotite. It is also enclosed in the large crystals of andesine plagioclase. The apatite shows a remarkable increase towards the outer margin of the tonalite (261, 272 and 234).

Iron oxide usually occurs as fine opaque dust associated with the biotite and as minute grains associated with the sphene.

3. Replacement Textures in the Tonalite.

(a) Replacement of Quartz and Microcline by Oligoclase felspar.

The oligoclase rims surrounding the large crystals of andesine appear, in all probability, to be of a rather late age and to have replaced both quartz and microcline to a considerable extent. These oligoclase borders sometimes contain remnants of microcline in optical continuity with adjacent plates of microcline, or there may be several isolated fragments of microcline in perfect optical continuity. The oligoclase borders frequently contain blebs and irregular fragments of quartz which are either all in optical continuity or else adjacent fragments are arranged in sets, each set being in optical continuity and representing the remnants of one single quartz grain. The best example of this type is seen in slice 234 from a contact of the tonalite and hornfels near Clogher. Just outside the dividing line between

FIGURE 3.

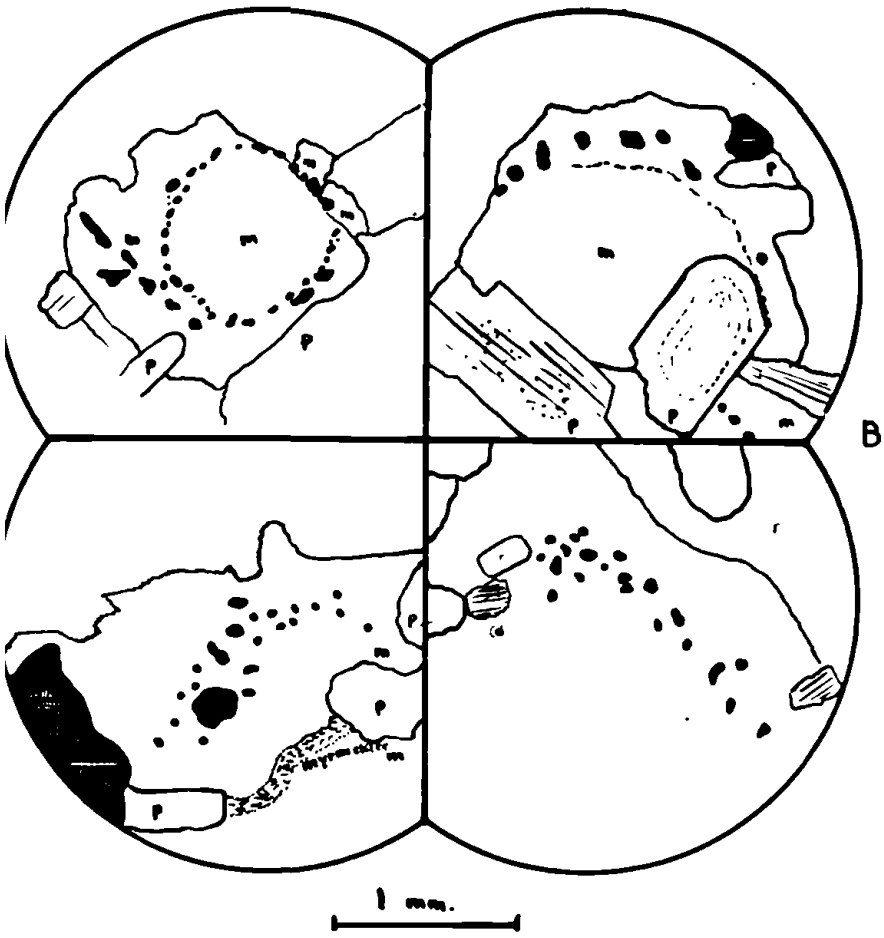
A. Replacement of quartz by the phenocrysts of plagioclase in the outer tonalite. The quartz grains in every one of the marked sets of grains are in optical continuity and seem to represent the remnants of a large quartz grain originally lying at the boundary of what is now the andesine core of a plagioclase crystal.

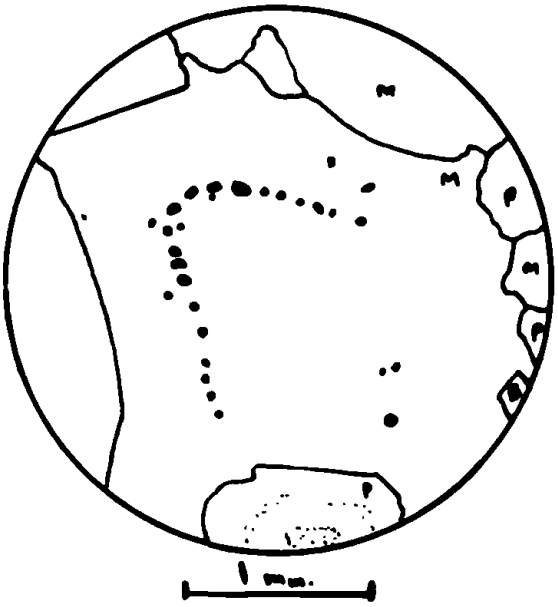
B. Trails of minute inclusions of quartz grains in microcline (m) (thin sections 610 and 552).

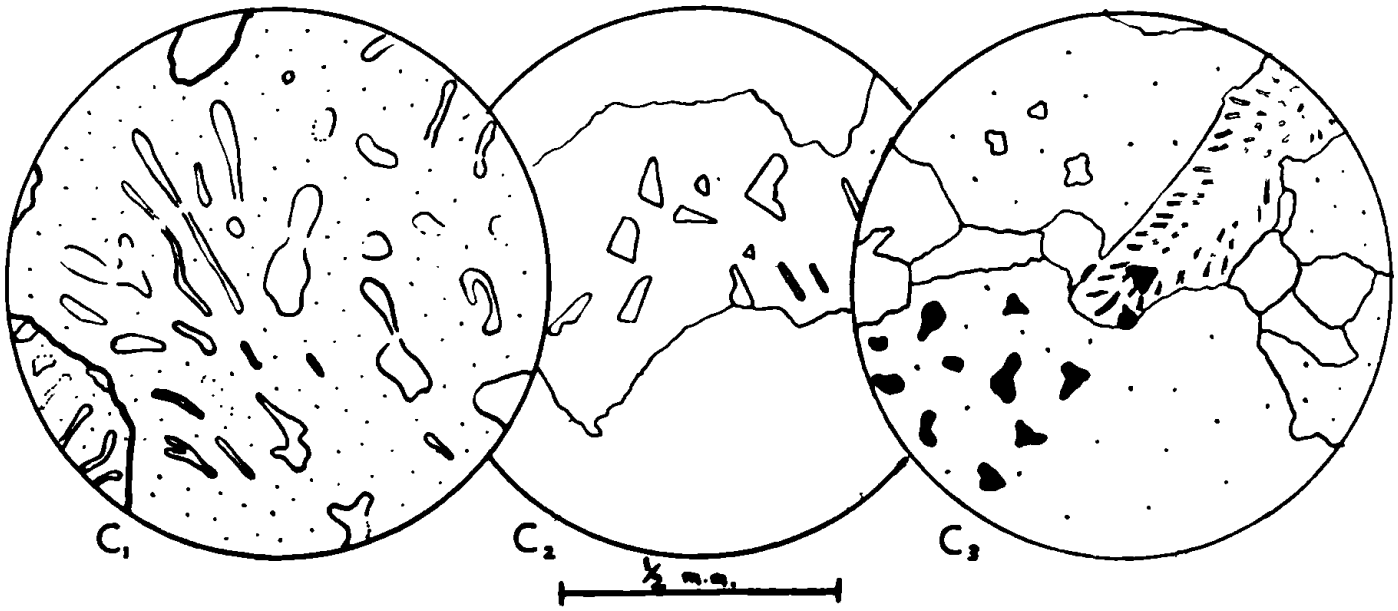
C. Primary intergrowths of microcline and quartz in an aplite vein (slice 232) usually assume a myrmekitic texture (C1) and very rarely a granophyric texture (C2). In C_3, secondary myrmekite is seen to replace the microcline, only engulfing the primary intergrowths of quartz.

FIG. 3









the andesinic core and the border of oligoclase, a straight row of quartz inclusions is arranged, so that sets of adjacent grains are in optical continuity (Fig.3A).

(b) Replacement of Microcline by Quartz.

As stated before, practically every thin section of the tonalite shows distinctly that the quartz is actively replacing the microcline and encroaching upon the latter in the form of small circular and semi-circular embayments (250). The microcline of the tonalite in general shows a marked abundance of inclusions of rounded grains of quartz. These are particularly common in slice 246. The quartz blebs show haphazard distribution in the microcline, and usually lack optical continuity. In spite of the limitation of the thin sections, it seems that these peculiar inclusions do represent actual quartz grains replacing the microcline as described above, and cut by the plane of the thin section. This texture is similar to the isolated blebs of myrmekite which occasionally appear in potash felspar.

4. Cataclastic Textures in the Marginal Tonalite.

In addition to signs of early deformation seen in all parts of the tonalite, such as the bending of plagioclase and the breaking and bending of biotite flakes, the tonalite towards the margin of the pluton - characterised by the gneissic foliation - exhibits, in thin section, definite signs of

cataclasis. In slices of the marginal tonalite, especially 234, cataclastic textures are present in zones lying between adjacent phenocrysts of plagioclase. These zones, marked principally by the curving selveges of thin blades of biotite, contain abundant granulated quartz and felspar. This granulation of quartz, now seen only in the marginal tonalite could have been formed in the following ways.

(i) Cataclastic textures in the quartz were possibly formed throughout the tonalite but the structure was 'healed up' by a second reheating.

(ii) It has been formed only in the marginal tonalite as a result of extreme shearing in the colder marginal parts, whilst the inner part of the tonalite was in a highly plastic condition, with most of the quartz still unrecrystallised.

(iii) This granulation of quartz at the margin of the pluton may be due to later movement of the granite as a more or less solid mass.

D. MODAL COMPOSITION OF THE TONALITE.

Thin Section No.	244	249	250	251	254	256	261	302	Average
Sp.gr.	2.73	2.65	2.74	2.73	2.69	2.69	2.71	2.69	2.70
Plagioclase	53.8	44.6	49.7	54.1	39.3	40.2	41.2	45.0	46.1
Potash felspar.	16.0	25.8	22.4	15.5	25.7	24.1	21.6	20.0	21.5
Biotite	16.6	11.8	10.2	13.7	15.7	14.5	17.4	11.5	14.0
Quartz	11.6	14.4	11.7	10.2	14.9	18.3	13.1	14.7	13.6
Hornblende	0.4	1.1	3.4	2.9	1.7	1.4	3.4	6.3	2 6
Sphene	0.6	0.6	1.2	0.8	0.8	1.0	1.3	1.3	0.7
Epidote	0.6	1.1	0.8	2.3	1.2	0.4	1.0	0.6	1.0
Apatite	0.4	0.4	0.4	0.3	0.7	tr.	1.0	0.6	0.5
Iron Ore	tr.	0.1	tr.	0.1	tr.	tr.	tr.	tr.	
Total	100.0	99.9	99.8	99.9	100.0	99.9	100.0	100.0	100.0

E. Xenoliths in the Tonalite.

1. General. The outer tonalite is characterised by frequent xenoliths, about 2 to 3 xenoliths per 10 sq.yards, mainly of metasedimentary origin together with a minor proportion of amphibolitic xenoliths. The metasedimentary xenoliths include semi-pelites, pelites, calc-silicate rock, limestone, quartzite and impure siliceous granulites. The most frequent xenoliths are those of a semi-pelitic nature. All these xenoliths are oriented with their longest axes parallel to the foliation of the tonalite.

Amphibolitic xenoliths, on the other hand, include a wide variety of fine-grained and coarse-grained amphibolites, diorites, appinitic types as well as foliated metadolerites. Most of these xenoliths are not flattened but occur in the form of rounded or sub-angular blocks. They are remarkably abundant in a small area about 40yds. across situated at the north-eastern margin of the pluton, half-way between Maas and Letterilly ; here a very wide variety of types is included. Along a wall-like margin of the tonalite at Maas, the contact of the pluton is usually covered by a thin crust of mobilised hornfels adhering to the tonalite. Where this crust is absent, the vertical contact can be seen to be studded with dark sub-angular xenoliths of various types.

Generally speaking, the tonalite has not picked up its xenoliths from the present level as these usually differ

from the country rocks in contact with the granite. Thus at a point situated some 300yds. due west of B.M. 18.3, near Ballyiriston Bridge, the tonalite is in direct contact with metadolerite yet it is entirely devoid of xenoliths of an amphibolitic nature and contains only its characteristic semi-pelitic xenoliths as thin streaks parallel to the foliation.

The summit of Doochill North, near Ardara, is marked by a large enclave about 100yds. long extending in the east-west direction, parallel to the foliation of the tonalite and consisting of banded siliceous granulite and semi-pelite. It is highly folded and mobilised in part. It is thought to represent either a roof pendant or a huge block detached from the roof.

At Letterilly, the tonalite contains a large raft of limestone which has not reacted with the granite. At the same locality, the tonalite contains small xenoliths of a peculiar migmatitic semi-pelite which, in hand specimen, resembles a medium-grained dioritic rock.

2. Semi-pelitic Xenoliths. The larger part of the enclaves in the tonalite are of a semi-pelitic nature, pelitic xenoliths are subordinate. The semi-pelitic xenoliths can be further subdivided into two distinct categories or groups, mainly on their field occurrence.

The first type of xenoliths occurs as thin streaks lying parallel to the strong foliation of the tonalite;

their length is uaually more than ten times their breadth and they vary in size between 2" by ⅛" to about 20" by 1". These have definitely been in a plastic condition and usually appear as thin streaks lying along the foliation of the tonalite. Their persistence throughout the tonalite and their more or less even distribution seem to characterise the rock type. Rarely do these retain traces of original bedding. In thin section, they are fine-grained and their minerals are identical to those in the tonalite. A typical thin streak is seen in slice 246, and consists of thin blades of biotite resembling that in the host rock and a mosaic of quartz, oligoclase and potash felspar.

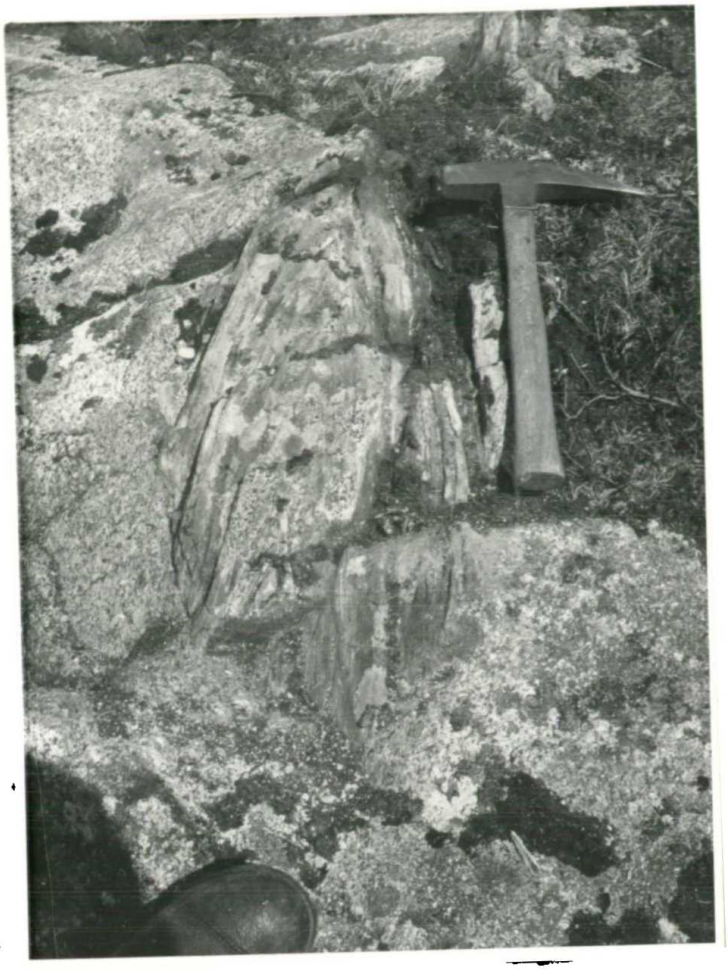
The other type of semi-pelitic xenoliths, irrespective of their size, have not been rendered plastic by the tonalite, and retain the original angular or slabby form, the sedimentary structures and the delicate structural elements as small scale strain slip cleavage and very fine shears. Their identity is so well preserved that some can be assigned to known lithological groups in the country rocks. These xenoliths are undoubtedly smaller in number than the other streaking types of xenoliths. The following are typical examples :-

At Clogher West, a large enclave about 5ft. across, and consisting of mobilised semi-pelitic hornfels, contains a folded fragment of calc-silicate band 'floating' in the

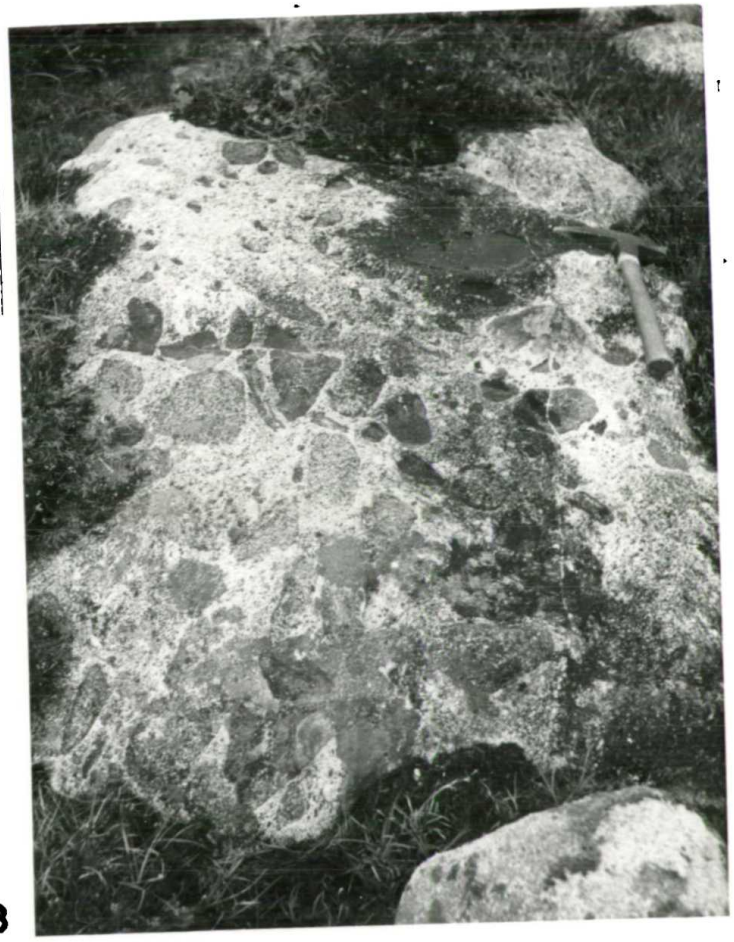
PLATE 6.

A. Folded semi-pelitic xenolith in the foliated tonalite, near Burdeck, Lough Fad.

B. A 'swarm' of amphibolitic xenoliths showing striking differences in size, shape and degree of interaction with and resorption by the contaminated quartz-diorite.



A



B

mobilised hornfels. This xenolith is precisely identical to the mobilised hornfels with the angular mass of calc-silicate rock, located about half-way between Letterilly House and Boleyard.

Along the alley leading to Burdeck, a folded semi-pelitic xenolith measuring 27" by 12" is seen to retain its very fine fracture cleavage (Plate 6A). Many other slabby semi-pelitic and even pelitic xenoliths still retain their fine fracture cleavages. In this respect, and as stated on p.73, it is of interest to note that the minor granite body at Sooly Rock, Inishkeel, has caused the total re-crystallisation of large xenoliths detached from almost the present level.

Slabby semi-pelitic xenoliths with bands of contrasted composition are rather common ; though these rocks are usually recrystallised, they retain all their original structures. Slice 134 shows recrystallised tourmaline 9 x 4 m.m. containing abundant inclusions of quartz and plagioclase.

All xenoliths of this second type are merely rotated by the viscous magma to lie with their longer axes parallel to the foliation.

3. <u>Calc-silicate Xenoliths</u>. Xenoliths of calc-silicate rock are not of frequent occurrence, and are usually in the form of small subangular blocks up to 8" across. They are of a buff to pale green colour with a greasy appearance.

A typical xenolith from the tonalites at Maas (slice 533) consists of a fine aggregate of garnet, idocrase, tremolite, clinozoisite, epidote and sphene with subordinate quartz and felspar. Some calc-silicate xenoliths are of a peculiar spangled appearance and contain flakes of muscovite (Spec.339).

4. Quartzitic Xenoliths. Xenoliths of quartzite and banded siliceous granulite are restricted to the Maas area, where the tonalite is invaded by the xenolithic quartzdiorite. These occur as large masses 4 to 6ft. across. Further towards Letterilly, the tonalite contains two or three small slabby xenoliths of quartzite. In thin section (521), the rock consists of a mosaic of quartz grains, with subordinate potash felspar and minute flakes of chloritised biotite. A large xenolith of quartzite occurs in the tonalite near Ardara, almost along the contact with the inner granodiorite.

5. Amphibolitic and Dioritic Xenoliths. The tonalite contains a very wide variety of dark xenoliths, distinct from all the xenoliths so far described and to which a metasedimentary origin cannot always be ascribed. Some of these xenoliths are amphibolites of calc-silicate origin.

These vary from the usual foliated metadolerite, speckled metadolerite, fine- and medium-grained amphibolites to variable fine-grained diorites and even appinitic types.

A typical xenolith of metadolerite comes from the margin of the tonalite between Maas and Letterilly. It is

associated with a large variety of types of amphibolites including appinites. In slice 532, the amphibole occurs as large masses of pale green uralitic aggregates surrounded by brownish green hornblende showing good crystal form. The uralite contains occasional remnants of a pale-coloured pyroxene, while the hornblende is usually associated with biotite, iron oxide has rims of sphene and rutile. Plagioclase occurs as small crystals of composition about An.45-50.

The tonalite of the northern sector contains a small number of angular and subangular xenoliths of fine-grained diorite about 2 - 3ft. across. These diorites are of a rather variable appearance but are generally dark greyish green in colour. They consist of pyroxene, hornblende and andesine with subordinate biotite, potash felspar and quartz. Some of these dioritic xenoliths appear to be of a calc-silicate parentage.

A representative xenolith from North Binwee, Kilcloney, (slice 263) consists of pale green to colourless diopside in stout crystals surrounded by green hornblende. The biotite is of a dark greenish brown colour. An andesine of composition An.40-46 occurs as small laths 1½ x ½ m.m. Smaller crystals of oligoclase-andesine have a composition of An.30. Potash felspar, both as microcline and orthoclase is interstitial and contains abundant myrmekitic embayments.

A few feet away, another amphibolitic-dioritic xenolith appears in the field to have been altered considerably by the tonalite. In thin section 262, the rock consists of pale actinolitic hornblende with subordinate biotite, oligoclase felspar and quartz.

Another xenolith from a place south-west of B.M.143.5, Binwee, is medium-grained and contains dark spots in a pale greenish matrix. In thin section (292), the rock consists of almost colourless diopside, in crystals 1 m.m. across, surrounded by a thin rim of uralite followed by an outer zone of green hornblende in perfect corona structure. The outer hornblende has the following pleochroism Z' = grass green, Y' = bright yellow green and X' = greenish yellow. Biotite is subordinate to the pyroxene and amphibole, and occurs as ragged and corroded flakes. The plagioclase occurs either as large crystals of albite-oligoclase (An. 10 - 15), or as smaller crystals of basic oligoclase (An.28). Epidote occurs in conjunction with the biotite.

6. Xenoliths of Lamprophyric Origin. At Clogher West, at a point about 200yds. west of Rocking Stone, a large subangular xenolith is found in the tonalite. It is fine-grained, medium grey in colour with dark basic clots about 10 m.m. across. In thin section (274), the rock appears to consist mainly of hornblende, biotite, andesine with subordinate quartz. The hornblende is pale grass green some-

times with almost colourless patches. It occurs either as small irregular particles, in part with poikilitic inclusions. The small dark clots consist of aggregates of highly poikilitic hornblende sometimes fringed with biotite. Biotite is subordinate to the hornblende and has the following pleochroism, Z = Y = dark greenish brown, X = pale golden yellow. It occurs as small flakes of even distribution or as large corroded flakes, the parts of which are in optical continuity. Zoned andesine forms elongated laths up to 1 m.m. long. The cores have a composition of An.42, while the outer borders are about An.30. Sphene and epidote are minor accessories.

A similar fine-grained xenolith about 5ft. across occurs to the north-east of Binwee. In slice 288, the rock consists of green hornblende with subordinate biotite, laths of andesine (An.36), quartz and minor potash felspar.

The presence of the characteristic dark clots, the composition, texture and general petrographic characters shows these rocks to be independent of the amphibolite-diorite xenoliths, and suggest a lamprophyric origin. They probably represent early members of the lamprophyre-felsite suite relatively rich in ferro-magnesian components.

7. Special Occurrences of Xenoliths.

Summit of Doochill North. The highly foliated tonalite forming the high-ground north-east of Ardara and Doochill North, has at its summit a huge enclave about 100yds. long

east-west, and 50yds. wide. The rock is a thinly banded siliceous granulite with occasional semi-pelitic bands. It is highly mobilised, shows signs of disruption and is cut by several dyke-like veins of the central biotite-granodiorite. The northern part of this huge raft is well exposed in a large roadside quarry. Here the banded siliceous granulite with its semi-pelitic partings shew lit-par-lit injection (Spc.684). This block is probably either a pendant or a detached block from the southernly dipping roof of the pluton.

Letterilly. A large elongated raft of limestone occurs in the tonalite north of Letterilly House and about 50yds. from the contact. It measures about 50yds. long, including an unexposed part, and is about 60yds. wide. The limestone is more or less pure, coarsely crystalline and is pale grey in colour. It shows no signs of interaction with the tonalite host.

A few feet north of this limestone enclave occur several large xenoliths 5 - 7ft. across. These are migmatitic in nature, and while certain parts of the xenoliths show ghost sedimentary structures, other parts have lost their identity and appear in hand specimen as variable quartz-diorite. The granite surrounding these peculiar migmatitic xenoliths is not the normal tonalite, but a coarse variety consisting of the large phenocrysts of plagioclase of the tonalite set in a felty aggregate of ferro-magnesian minerals, mainly biotite and hornblende.

III. The Xenolithic Quartz-Diorite.

A. Introduction.

The second of the main rock-types in the Ardara pluton is the xenolithic quartz-diorite, and in the circular structure of the pluton, it occupies an intermediate position between the central granodiorite and the outer tonalite, by which it is separated from the metasediment envelope of the pluton.

This rock is essentially a biotite-hornblende-quartz-diorite, and in the field, it is fairly distinct from the outer tonalite but less distinct from the central granodiorite. It is medium-grained, light grey to pinkish buff in colour, with a strong foliation marked by the alignment and flattening of its ferro-magnesian minerals which usually occur in small clots.

It is characterised by the presence of xenoliths, more or less evenly distributed throughout the rock about, 3 or 4 per sq.yard area ; these may be locally more abundant. All the xenoliths are of a dark green colour, and are of either amphibolitic or dioritic character; they include a minor proportion of amphibolites of calc-silicate origin. In contrast to the outer tonalite, not a single xenolith of pelitic, semi-pelitic or quartzitic origin has been encountered The amphibolitic xenoliths are generally small in size, but may reach a maximum of some 20ft. across. They exhibit

almost every stage of interaction with, and incorporation by, the granite. All the xenoliths appear to have been in a plastic condition in the viscous magma, and their flattening in the plane of foliation and drawing out into spindle-shaped bodies is of great interest from the structural point of view. The origin of these xenoliths is, very probably the amphibolitic complex of Meenalargan.

This biotite-hornblende-quartz-diorite is thought to be a contaminated hybrid rock, and to have attained its present composition as a result of contamination by the assimilation by a granodiorite of several types of amphibolite, calc-amphibolite and associated appinitic and dioritic types. This magma was presumably of about the same composition as that of the central granodiorite. The main phase of the interaction and contamination with the amphibolitic complex of Meenalargan is thought to have taken place at a much lower level.

The intrusion of the xenolithic quartz-diorite marks the most important stage in the emplacement of the pluton, and was subsequently followed by the second and relatively minor upwelling of magma now constituting the larger part of the central granodiorite.

The xenolithic quartz-diorite is cut by veins of pegmatite and aplite, and these also contribute to the structural study of the pluton. Its joints are distinct and the rock does not weather to the same extent as the central granodiorite

The quartz-diorite in the 'neck' has been subject to late movements, with the result that a secondary structure has been impressed upon the rock, which increases in intensity from the south-west to the north-east, progressively obliterating the primary structures of the rock.

B. Distribution of the Quartz-Diorite and its Outer Contacts.

I. Distribution. Within the writer's area, the xenolithic quartz-diorite covers an area of about 6.1 sq.miles. In the northern sector of the pluton, it forms a belt varying in thickness between $\frac{1}{2}$ and $\frac{1}{3}$ miles; at Letterilly, it forms a broad strip between the tonalite and the central granodiorite being over $\frac{3}{4}$ mile wide. It also constitutes a large part of the 'neck' of the pluton, as well as large area covering about 2 sq. miles extending between Letterilly in the north, Lough Ananima in the south, Lough Lackagatermon in the west an Meenalargan in the east.

In the northern and north-eastern sectors of the pluton, the xenolithic quartz-diorite has a maximum width of 800yds. in the area between the north of Lough Adooey and Killayenna Lough, and in the area between Derryduff Hill and Lough Namanlagh.

That part of the xenolithic quartz-diorite mapped by the writer can be divided into three sectors each of which has its own characteristics. A northern sector in the

locality of Lough Fad is characterised by the abundance of xenoliths, good contacts with the tonalite and the presence of mappable boundaries with the central granodiorite. The second important sector is located about Lough Aanima and the 'neck', and this is characterised by the fact that it exhibits the effects of the second upwelling of magma upon the primary structures of the quartz-diorite, though the north-eastern part of the 'neck' shows late secondary structures. The third or north-eastern sector connects the two former sectors and extends from Lough Namanlagh to Letterilly and Lackagatermon ; it does not show any particular feature and is not well exposed.

2. Contact with the Tonalite in the Northern Sector.

In the northern sector, the contact of the xenolithic quartz-diorite and the outer tonalite assumes the following forms. The first type of contact seems to suggest a certain degree of movement between the two granite types. This begins from a point situated half-way between Narin cross-roads and Kilcloony Church, and extends towards the east to Burdeck and Lough Fad North. The contact is marked by a zone from 5ft. to 10ft. wide, in which the granite contains peculiar thin bands of slightly darker colour which are finer-grained than the lighter coloured ones alternating with them (Plate 9A). The dark coloured bands resemble schlieren and indicate that the xenolithic quartz-diorite, with its amphibolitic

xenoliths, which are in an advanced stage of incorporation, has probably suffered considerable movement along the contact while still in a plastic condition. This zone is of fairly uniform character and extends for about 1000yds. On either side of this zone of movement the rock types are fairly distinct.

In contrast, the contact between the xenolithic quartz-diorite and the tonalite in the eastern half of the northern sector lacks the banded zone of movement and is a mappable contact running between outcrops of the two rock types, such as at Binwee and east of Lough Killayenna. At the latter locality, the contact follows Bonny Glen following the line of small loughs.

3. Outer Contact in the North-Eastern Sector.

The boundary between the xenolithic quartz-diorite and the tonalite in the north-eastern sector follows the larger part of Lough Namanlagh, near the south-eastern end of which the contact is distinctly mappable. The contact is usually marked by a depression. No mappable contacts are observed towards Letterilly, and at this locality the contact between the two rock types can only be mapped with difficulty owing to the slightly finer grain size of the tonalite especially where the tonalite tapers down along the outer margin of the pluton, ½ mile south-east of Letterilly House.

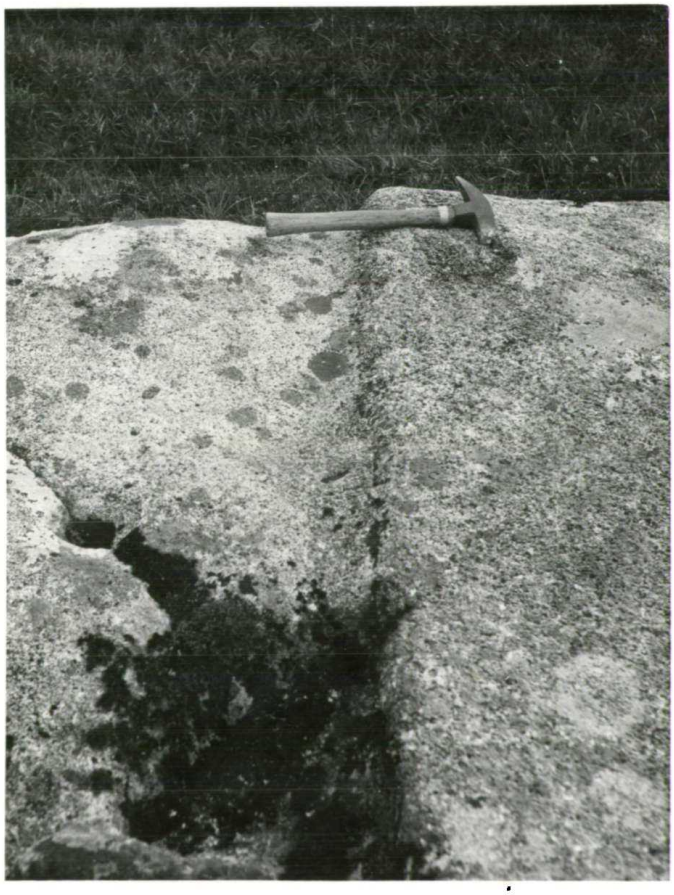
PLATE 7.

A. The xenolithic quartz-diorite and the coarse tonalite interdigitate with numerous sharp contacts near Maas. Note the parallelism in the foliation of both rock types and also their parallelism with the drawn out xenoliths in the quartz-diorite.

B. The sharp contact between the xenolithic quartz-diorite (left) and the coarse outer tonalite, near Maas.



A



B

The best contacts between the xenolithic quartz-diorite and the tonalite are found in the small area west of the Hotel at Maas, where the quartz-diorite invades the outer tonalite (Plates 7A and B). This will be considered in detail in the section dealing with the structure of the pluton (p.203).

4. Contacts of the Xenolithic Quartz-Diorite in the 'Neck'.

Mappable contacts between the xenolithic quartz-diorite and the tonalite in the southern part of the 'neck' approximate the Sruhangarve river, running east to west towards Lough Ananima. The contact lies a few feet to the south-east of the track leading to Sruhangarve quarry, and the two rock types are fairly distinct, in spite of the secondary structures in the granites of this locality.

C. Petrography of the Quartz-Diorite in the Northern Sector.

1. General Characters. The xenolithic quartz-diorite of the northern sector is fairly distinct in the field from either the tonalite or the central granodiorite. It is medium grained and lacks the large porphyritic plagioclase of the tonalite, and differs from the central granodiorite in being richer in ferro-magnesian constituents and in lacking the characteristic equigranular texture of the latter type. The xenolithic quartz-diorite is also distinguished in the field by the presence of xenoliths particularly abundant in the

quarts-diorite in the northern sector. The rock possesses a pronounced foliation marked by the flattening of its ferromagnesian constituents which occur in clots up to 5 m.m. across. These dark clots consist mainly of aggregates of biotite, hornblende, epidote, sphene and iron oxide. The colour of the rock varies from light grey to dark pink or greyish buff according to the decomposition of the plagioclase. Sometimes the rock contains a few phenocrysts of oligoclase-andesine, but this occurrence is restricted to the quarry near the Parochial House. The average specific quantity is 2.71.

2. The Minerals. The xenolithic quarts-diorite of the northern sector consists of plagioclase, microcline, quartz, biotite, hornblende, epidote and sphene with the minor accessories rutile, iron oxide, apatite and zircon. In the thin sections examined, pyroxene, occurring as an unstable relic in the process of alteration to amphibole, is restricted to the immediate contact with a large amphibolitic xenolith.

Plagioclase is usually an oligoclase of composition An.18-25, rarely does it reach andesine, as for example in slice 196 where it has the composition An.28-30. The plagioclase occurs as small crystals 1 - 2 m.m. in maximum length, exhibiting the carlsbad and albite twinning. The zoning is usually gradational as shown by the slight sericitisation of only one or two broad oscillatory zones. The plagioclase

has few inclusions apart from secondary epidote and muscovite - small particles of hornblende are occasionally present. In some examples, the plagioclase is highly sericitised while in others it is relatively fresh. The plagioclase crystals sometimes lack regular boundaries and are engulfed in microcline, and in a few instances, the plagioclase crystals are bent as in slice 199.

Potash felspar is present in the form of microcline with very subordinate orthoclase. The microcline is rarely microperthitic and occurs interstitially though less often as plates up to 2 m.m. across, with sericitised centres. The microcline is being actively replaced by plagioclase with myrmekitic embayments encroaching upon it. It is also corroded by quartz (196 and 199, particularly 209).

Quartz occurs interstitially and contains no inclusions apart from trails of fine opaque dust. It is usually cracked and highly strained.

Biotite occurs as flakes up to 1½ m.m. long and has the following pleochroism, Y= Z = medium to dark brownish green, X = pale yellow to gold yellow. The laminae are sometimes bent (196, 199, 213) and usually have inclusions of enhedral apatite, and less frequently zircon grains with pleochroic haloes. The biotite occurs in close association with the hornblende and epidote. It is sometimes interleaved with chlorite - mainly -ve peninnite - with secondary sphene

along cleavages (231). As in the tonalite, the biotite, where in contact with the plagioclase it is usually corroded and possesses brush-like remnants in the plagioclase.

Hornblende occurs as large and irregular prisms varying from a vrey fresh-looking enhedral form to an amphibole which is apparently in the process of being resorbed. Its pleochroism is Z' = green with a bluish tinge, Y' = yellowish green and X' = dark green. At times the hornblende possesses pale green centres (222 and 231) and sometimes it has poikilitic inclusions of quartz and felspar. A symplektite structure is rather rare (196).

Epidote occurs as irregular masses and subeuhedral crystals up to ½ m.m. across, usually pleochroic in greenish yellow to colourless, in some of the slices it shows a particularly strong pleochroism. It is usually associated with the biotite and hornblende. It is sometimes associated with clinozoisite and very rarely it has cores of orthite (221).

Sphene is usually associated with the dark clots and occurs as corroded masses about ½ m.m. across, or wedge shaped crystals up to 1 m.m. long. It usually shows strong pleochroism. Secondary sphene occurs along the cleavages of chloritised biotite. Rutile occurs usually as grains and needles in the biotite. Apatite euhedra occur in the biotite and hornblende, and iron oxide is common in the dark clots.

D. Modal Composition of the Xenolithic Quartz-Diorite.

Slice No.	196	209	213	22.	222	224	233	281	Average
Sp. gr.	2.70	2.71	2.73	2.64	2.72	2.71	2.72	2.69	2.71
Plagioclase	46.8	43.1	46.4	44.6	46.9	46.5	55.6	47.5	47.80
Potash Felspar	15.7	15.0	15.5	18.3	14.8	16.0	11.1	12.5	14.92
Quartz	12.5	15.0	14.3	16.4	12.3	16.9	14.7	14.1	14.52
Biotite	14.7	12.4	13.7	10.4	11.3	14.0	11.2	15.4	12.89
Hornblende	3.3	6.0	6.8	6.3	11.2	5.0	5.4	5.6	6.20
Epidote	4.8	2.5	2.1	2.7	1.9	1.6	1.9	4.2	2.80
Sphene	1.0	1.0	1.2	0.7	1.4	tr.	tr.	tr.	0.54
Iron Oxide	1.0	tr.	tr.	tr.	tr.	tr.	tr.	tr.	0.12
Pyroxene	-	-	-	-	1.1	-	-	-	0.12
Total	100.0	100.0	100.0	99.9	99.9	100.0	99.9	100.0	99.91

According to Lindgren's (1900) revised definition of a granodiorite, the rock is very nearly a quartz-diorite and is so named to distinguish it from the other two granodiorites in the pluton.

E. Petrography of the Xenolithic Quartz-Diorites in the 'Neck'.

1. General Description. The xenolithic quartz-diorite in the 'neck' of the Ardara pluton has been subject to late movements impressing upon the rock distinct secondary structures (p.213). These deformed rocks first appear near Sruhangarve Bridge and increases progressively towards Meenalargan village, where the quartz-diorite becomes strongly rodded. Thus the quartz-diorite in the 'neck' varies in appearance from place to place, though it seldom looses its identity. Apart from the variation in the appearance of the rock, due to variation in the intensity of the superimposed secondary structures, slight local variations in the relative proportion of the ferro-magnesian minerals have been noted.

2. Xenolithic Quartz-Diorite of the Sruhangarve Area. At Sruhangarve Bridge, the xenolithic quartz-diorite is very well exposed in the quarried face by the side of the road, with its amphibolitic xenoliths all flattened in the plane of foliation. In hand specimen, the foliation is rather weak but the dark constituents show a linear arrangement. In thin sections (670 A and B) the rock possesses mild cataclastic textures and granulation. The plagioclase occurs as crystals 1½ m.m. long and is sometimes strongly bent. The composition varies from An.25 in the cores of the crystals

to An.20-24 for the outer rims. Potash felspar occurs mainly as orthoclase changing to microcline along cracks and around inclusions, and is usually micro-perthitic. It encloses particles of myrmekite along its borders. The quartz is mainly interstitial, with strong undulose extinction. Large grains are broken into smaller particles which form minute rounded grains along the boundaries of large plagioclase crystals. The biotite has the following pleochroism, Z = Y = dark green and X = golden yellow, and occurs in bent flakes associated with the amphibole, sphene and epidote. It contains small grains of apatite. The hornblende occurs either as broken and corroded crystals with a pleochroism Z' = dark green with a bluish tinge, Y' = dark grass green and X' = golden yellow, or less often, as a medium green variety with pale coloured and poikilitic centre. Sphene occurs as irregular masses up to 1 m.m. long which have a strong pleochroism.

The rock in the Sruhangarve quarry is decidedly richer in ferro-magnesian constituents than the average xenolithic quartz-diorite, and as seen in thin sections (66oA and B), it exhibits stronger cataclases than that near the bridge. The plagioclase crystals, which are usually slightly bent, are enveloped by wisps of small flakes of biotite and granulated quartz and felspar. These small biotite flakes are usually broken and bent. The cataclastic textures in the rock appear to be 'healing up'.

3. Xenolithic Quartz-Diorite of the Stranaglogh Area.

In the Stranaglogh area, in the centre of the 'neck', the secondary linear element in the granite is strongly developed, yet the rock is notably coarser-grained than that at Sruhangarve. Here the rock has the composition of the normal xenolithic quartz-diorite, and the ferro-magnesian constituents occur in small clots. Slice 680 is from the main quarry of Stranaglogh, along the track leading to Loughrillan, the rock shows notable cataclasis and does not show any tendency to recrystallise. The quartz grains are broken into smaller grains with highly sutured boundaries, and exhibit extreme undulose extinction. One part of a crystal may be in extinction while another part may exhibit yellowish white interference colours. The rock lacks the incipient augen structure consisting of granulation around plagioclase crystals, as seen at Sruhangarve. The hornblende occurs both as the dark green variety and the pale green variety with poikilitic centres. The latter type is intergrown with, and partly replaced by biotite.

4. Xenolithic Quartz-Diorite in the Area South of Loughrillan.

In a zone about 250yds. wide along the northern contact of the 'neck' and extending between Cobbagrow and the road leading to Loughrillan, the xenolithic quartz-diorite almost lacks the strong linear element and possesses a weak foliation. The rock is medium-grained, of a whitish grey colour and the

femic constituents occur in clots. In slice 693, it appears to be similar to the normal xenolithic quartz-diorite, except that the potash felspar is largely orthoclase and that it contains accessory tourmaline which is pleochroic pink and brown.

5. Xenolithic Quartz-Diorite near Meenalargan Village.

In the north-eastern corner of the 'neck', near Meenalargan village, the xenolithic quartz-diorite is distinctly rodded, and the femic constituents form thin bands and rods. In thin section 792, from a quarried exposure along the 'top road', the rock is finer-grained than the average type in the 'neck'. Crystals of plagioclase have rounded corners and are roughly encircled by trails of minute biotite flakes and granulated quartz and felspar. The rather abundant myrmekite in the rock seems to accentuate its cataclastic appearance. The hornblende and biotite are darker than usual.

6. Xenolithic Quartz-Diorite in the Letterilly-Lackagatermon Area.

The area of Lackagatermon and Letterilly form the passage between the Xenolithic quartz-diorite of the northern sector and that of the 'neck'. The xenolithic quartz-diorite is well exposed only in the main localities. The first is in an elongated strip running N.W. - S.W. and including Lough Adeny, Glenadeeny and Lough Doo, the south-eastern continuation of which consists of the well exposed mass at

Letterilly. The third locality is at Lackagatermon.

The xenolithic quartz-diorite at Letterilly contains abundant amphibolitic xenoliths, and the rock itself is richer in hornblende (S35). The hornblende occurs both as medium green and dark brownish green varieties, and both the plagioclase and biotite are strongly bent. The xenolithic quartz-diorite at Lackagatermon is very similar to that of the Lough Fad area, the plagioclase here exhibiting good oscillatory zoning.

F. Xenoliths in the Quartz-Diorite.

1. General Description. The xenolithic quartz-diorite is a contaminated hybrid rock characterised by the presence of dark inclusions of basic composition. These latter inclusions are referred to, throughout this work, as xenoliths, implying a foreign origin for the basic rock, quite distinct from autolith or cognate material secreted by the magma. Perhaps a more suitable name for the majority of the present inclusions would be 'reaction xenolith'.

The xenoliths in the xenolithic quartz-diorite show a more or less even distribution throughout the rock, and it is very seldom that this biotite-hornblende-quartz-diorite is lacking in dark xenoliths. The xenoliths, in fact, distinguish the rock type in the field, particularly from the central granodiorite.

The xenoliths least altered by the granite comprise amphibolites and amphibolites of a calc-silicate origin usually referred to as calc-amphibolites. A few xenoliths of undoubted metasedimentary origin have been encountered and identified as calc-silicate masses. The xenoliths exhibit all stages of interaction with the granitic host. Although the xenoliths show a greater abundance in the northern sector than in any other part of the xenolithic quartz-diorite, yet the latter is not more basic in composition in this northern sector.

The majority of the xenoliths are small in size measuring only a few inches across, but less frequent they reach a dimension of 2ft. Several large xenoliths attain a size of about 20ft. across. The largest single enclave of amphibolite measures about 50ft. by 35ft. and is exposed to a height of 12ft. It is situated at B.M. 170.2, south of Lough Killeyenna on the road to Lough Fad. It is cut by ramifying veins of granite and pegmatite and possesses both sharp and gradational contacts with the quartz-diorite. The small xenoliths are flattened in the plane of foliation, and appear on the flat surfaces of the exposures as elongated spindle-shaped bodies lying horizontally parallel to the arcuate structure in the pluton. An insignificant proportion of the xenoliths are subangular or rounded in shape, and these are distributed evenly throughout the rock. Large xenoliths and rafts are usually subangular, roughly ellipsoidal

or merely have rounded edges and corners.

In general, xenoliths show all stages of interaction with the quartz-diorite host, gradually becoming lighter in colour till finally they form 'ghost xenoliths' on the verge of being finally lost in the contaminated quartz-diorite.

2. "Swarms" of Xenoliths. At several localities in the Lough Fad and Ballymackylduff areas, xenoliths occur in unusual abundance in small and localised patches. These xenolith-rich patches are usually elongated parallel to the arcuate structure and vary in size from about 8ft. to about 160yds. in length. The relative abundance of the xenoliths varies considerably. At Ballymackylduff, the quartz-diorite contains a large number of subangular and rounded xenoliths of amphibolite very closely spaced with the granitic material merely cementing them together; the individual xenoliths vary from 9" to 4ft. across and appear to be least affected by the granite. In other patches with abundant xenoliths, the latter are of uneven distribution.

Such restricted patches of host rock crammed with xenoliths seem to be of common occurrence in xenolithic igneou rocks. Grout, F.F. (1937, p.1560), referring to the xenoliths in the Boulder batholith, California, 'locally they are larger and more abundant and constitute 'swarms' in which the bulk of the dark inclusions is greater than that of the matrix'. He also mentions several cases of 'swarms' of

xenoliths in different igneous bodies. Reave, W.H. (1938) describes dolerite-gabbroic xenoliths in contaminated syenites and alkali syenites from Singida, Uganda, and refers to them as 'intrusion breccia'. Hurlbut, C.S. (1935, p.64), states that over small areas in the Bonsal tonalite, S.California, the inclusions made up about 30% of the volume of the rock, while the normal xenoliths constitute about 8 - 10%.

Individual xenoliths within the same 'swarm' show striking differences as regards size, shape, and or more importance, their degree of interaction with the granitic host. As an example, a small swarm of xenoliths south of the Lough Fad road is remarkable for the different condition of its xenoliths (Plate 6B). Some of the very dark coloured xenoliths are angular and show insignificant or no reaction with the granite host. Other xenoliths, almost in contact with the latter, show varying stages of interaction with and incorporation by the granite. The ultimate stage is the formation of 'ghost xenoliths' the boundaries of which are usually gradational and the xenolith is in the act of losing its separate identity. Sometimes a single xenolith in an advanced stage possesses a defined margin on one side while in the other parts it is perfectly gradational with the granite host.

Reave (op.cit.p.37) describing the same phenomenon in his intrusion breccia 'The xenoliths are of all sizes

and shapes. Some are entirely undigested, some partly digested and others so completely so as to be scarcely recognisable as xenoliths'.

Nockolds, S.R. (1932, p.442), referring to the xenoliths in the contaminated granite at Bibette Head, Alderney, 'They are in all stages of dissolution and disintegration'.

To account for this feature, the writer would suggest the following, most probably acting together :-

(i) Xenoliths having been detached from different levels. It seems very probable that the quartz-diorite magma had been contaminated at a very low level and it is also seen in contact with the amphibolitic complex at the present level. The probability that xenoliths were detached at a relatively high level is strengthened by the angular nature of some xenoliths showing no reaction at all with the granite. These have not been long enough in the magma to become even plastic.

(ii) Original differences in composition of the xenoliths. There are a great variety of rock types in the amphibolitic complex of Meenelargan, and such differences would probably influence the degree of interaction with the granodiorite.

(iii) That the unreative xenoliths represent the unaltered cores of originally larger xenoliths, the altered outer parts of which have been removed by the movement of the magma. This possibility is, in many cases, ruled out owing to the sharply angular nature of the unchanged xenolith. Moreover,

the apparently unaltered xenoliths are practically always surrounded by a rim of pegmatitic material 2 to 20 m.m. wide.

3. Hornblendic Schlieren. Along the northern shores of Lough Fad, halfway between Burdeck and Binwee, the xenolithic quartz-diorite is distinctly banded parallel to the arcuate foliation. It contains dark schlieren ½" to 1" in thickness consisting mainly of hornblende with subordinate biotite. These schlieren alternate with light coloured bands, some of which are even lighter coloured than the average rock (Spec.315 and Plate 9A). The dark hornblendic schlieren are associated and interbanded with thin tapering bands a few millimeters thick consisting of fine-grained calc-silicates with minor psammitic partings. The rock is entirely devoid of recognisable amphibolitic or dioritic xenoliths. This seems to indicate that the usual amphibolitic and calc-amphibolitic xenoliths have been incorporated in the rock, mainly by mechanical commingling, in a zone of advanced differential movement while the granite was still plastic. This zone, together with other thin strips occurring to the south of Binwee, is similar to the streaky zone of contact between the quartz-diorite and the tonalite, all representing zones of movement and shear in strong contrast to the patches with 'swarms' of xenoliths where little or no movement of the granite is recorded.

4. Origin of Xenoliths. In distinction from the outer tonalite, the xenolithic quartz-diorite is entirely devoid of enclaves which can easily be recognised to be of metasediment origin and ascribed to the lithological groups of the confining country rocks. All xenoliths of the quartz-diorite are amphibolites, calc-amphibolites and their derivatives including appinitic and dioritic types. The quartz-diorite within the writer's area is separated from the metasediment envelope by the tonalite, and only along the northern boundary of the 'neck' is the quartz-diorite in contact with the amphibolitic complex of Meenalargan, extending for a distance of about 2½ miles from Meenalargan Village in the east to Glen Mullenmore near Letterilly. Also from the map of the area, it can be seen that the tonalite had been swept away by the incoming magma of contaminated quartz-diorite. It thus appears that the dark xenoliths in the quartz-diorite have been detached from the Meenalargan amphibolitic complex. Apart from the fact that the least altered xenoliths can be readily recognised as identical with the amphibolites of Meenalargan, a comparison of the rocks in thin section with those from Meenalargan have confirmed the relation.

Moreover, the persistance and even distribution of the xenoliths in the contaminated quartz-diorite suggest that the magma had come in contact with the Meenalargan complex at a

very low level, where the contamination of the magma is presumed to have taken place. Being also in contact with the amphibolitic complex at the present level, the magma apparently was able to incorporate xenoliths over a considerable range in level.

G. Petrography of Xenoliths.

1. General Statement. In general, the dark xenoliths in the quartz-diorite exhibit a wide variety in grain size, composition and colour. Fine, medium and coarse-grained varieties occur, some with an appinitic appearance. The colour is between medium green to dark blackish green. Sometimes the rock is spotted with pink felspar, less frequently, the xenoliths contain whitish pink xenoblasts of quartz and felspar. The presence of large flakes of biotite in varying proportions in some of the xenoliths increases the variation of the types.

As the discussion of the alteration of xenoliths by the host magma will involve brief descriptions of xenoliths in a rather advanced stage of reaction, a separate petrographic description of such xenoliths is avoided.

2. Xenoliths of Calc-Amphibolite. Xenoliths readily recognisable as of calc-amphibolite origin are less frequent and the best example (slice 205) comes from the field adjacent to the Parochial House, Kilcloney. The rock is

medium-grained, of a patchy appearance and consists of hornblende, actinolite-tremolite, diopside, epidote, plagioclase and potash felspar with subordinate quartz and sphene. The hornblende occurs as large prisms up to 6 m.m. long of pleochroism Z' = lavender green, Y' = greenish yellow and X' = pale yellow. Actinolite and tremolite occur as slender prisms, and less often, as stouter plates very pale green or colourless. Diopside forms small stout crystals of a pale green colour and is subordinate to the amphibole. Microcline occurs as large plates up to 7 m.m. across, with the ferromagnesian minerals as inclusions ; it also occurs interstitially. Oligoclase and quartz are subordinate to the microcline. Epidote forms irregular masses and aggregates, less frequently it forms large grains with borders of clinozoisite. A strongly pleochroic sphene occurs as irregular masses.

3. Biotite-rich Amphibolites. Though biotite is present in practically all amphibolitic xenoliths, some are particularly rich in biotite. These amphibolites consist mainly of pale green actinolitic hornblende and do not show much reaction with the granite host. Slice 187 from Burdeck, and slice 201 from the large quarry at Kilcloney, are almost identical and representative of this type. Actinolitic hornblende occurs as large prisms up to 3 m.m. across, and has a pleochroism Z' = pale green, Y' = pale

greenish yellow and X' = colourless. Parts of the pale green amphibole are sometimes colourless, while in other crystals the cores are of a lighter colour and contain poikilitic inclusions. A few of the prisms are bent. Biotite is in slightly lesser proportion than the amphibole, and is of a dark brown colour. It occurs as flakes up to 2 m.m. long, closely associated and intergrown with the amphibolite. The biotite flakes are usually bent. The microcline microperthite which is largely interstitial, contains inclusions of apatite, and is embayed with myrmekite along its borders. Oligoclase-andesine of composition An.28-33 occurs as small euhedra, and is subordinate to the potash felspar. Quartz occurs in small quantities mainly as small grains. Apatite is a notable accessory.

Another variety of this type is poorer in biotite and consists mainly of pale green actinolitic hornblende, together with pink microcline and subordinate quartz and plagioclase (slice 197) from the quarry at Kilcloney.

These xenoliths, whose amphibole is almost identical to the green amphibole in the Meenalargan rocks, bear a similarity to the slightly dioritised Meenalargan rocks.

H. Origin of the Quartz-Diorite.

1. Action of the Magma on the Amphibolitic Xenoliths.

A petrographical study of different xenoliths and of different

parts of xenoliths in the quartz-diorite, has shown that the action of the latter upon the amphibolitic xenoliths ultimately led to the conversion of the minerals of the xenoliths to minerals identical to those in the host rock. However, the detailed and systematic study of these changes, step by step, is almost impossible, owing to the widely variable nature of the original material of the xenoliths - the rocks of the Meenalargan amphibolitic complex.

It seems, however, that the plagioclase in the xenoliths has been altered to oligoclase of composition An.25, similar to that in the quartz-diorite. The dioritic rocks of Meenalargan are known to contain andesine felspar and the dioritic and amphibolitic xenoliths in the outer tonalite contain laths of basic andesine (p.130). Andesine plagioclase has never been encountered in the xenoliths in the quartz-diorite.

The amphibole in the least altered xenoliths is identical to that of the dioritised varieties of the Meenalargan rocks, a pale green actinolitic hornblende. This is usually altered to a dark green variety in the more altered xenoliths (335 and 395).

In addition to original biotite in the least altered amphibolitic xenoliths, biotite is usually seen to be growing at the expense of the darker green hornblende. This is more pronounced in the quartz-diorite itself where the hornblende in the small dark clots is even seen to be resorbed.

Diopside comes originally from the calc-silicate rocks and amphibolites with banded calc-silicates occurring at Meenalargan. It now appears only as an unstable relic. In the corresponding xenoliths in the outer tonalite, diopside is surrounded by a rim of pale uralite followed by another rim of dark green hornblende forming a perfect reaction rim, but in the xenoliths of the quartz-diorite, it lacks this rim of uralite and is embedded in the usual dark green hornblende. The diopside remains in this form not only in the 'ghost xenoliths', as (195), but also in its very rare occurrences in the amphibole of the quartz-diorite itself.

Subsequent to the action of the magma upon its xenoliths resulting in the convergence of the mineral facies, the magma started to introduce quartz-felspathic material into the xenoliths metasomatically. The continuation of this process results in the xenoliths gradually loosing their identity and ultimately vanishing in the host rock, forming an intermediate stage known as a 'ghost xenolith'.

Slice 225, across the contact of an amphibolitic xenolith from Lough Fad, shows very clearly the changes effected in the xenolith and its subsequent incorporation in the quartz-diorite. The thin section includes about 12 m.m. of the unaltered core of the xenolith and about 40 m.m. of its outer contact. The core consists of about 85% pale green actinolitic hornblende and about 15% epidote with almost no

quartz-felspathic material. The actinolitic hornblende is of the usual type characterising the unaltered xenoliths and occurs as small irregular prisms and fine aggregates which are pale green to colourless. The epidote occurs as irregular masses which are strongly pleochroic in shades of lemon and yellow. This core is surrounded by a zone 3 - 6 m.m. wide consisting of dark green hornblende in the form of stout crystals arranged in a decussate manner, and with pleochroism Z' = medium green, Y' = olive green and X' = pale straw yellow, identical to that occurring in the contaminated quartz-diorite. The incoming of microcline, oligoclase and quartz gradually causes the disruption of the zone of small hornblende crystals into small patches and the recrystallisation of the small individual crystals of hornblende.

Slice 226 of the rock a few centimeters from this last xenolith shows the rounded aggregates of hornblende encircled by biotite flakes.

The same mechanism can be seen in operation in specimen and slice 335 of another xenolith from Lough Fad. With the introduction of quartz-felspathic material into the xenoliths, xenoblasts are formed in the xenoliths (Spec.341).

The very final stage in the alteration and incorporation of a 'ghost xenolith' is seen in slice 195 where all the minerals are similar to those in the granite.

2. Formation of the Quartz-Diorite. It has just been shown that the minerals of the xenoliths are gr cually changed to minerals similar to those in the granite, and subsequently the xenolith is more or less dispersed into the granite in the form of small aggregates and clots of biotite and hornblende. These clots characterise the quartz-diorite as a rock type. The processes of mineralogical readjustment include mutual exchange of elements between the xenoliths and the host magma. If the four main reactions involved in the assimilation of xenoliths by the magma are considered, the original magma will be found to have gained Ca, and a smaller amount of Mg, and to have given up K, Na, Al and Si.

Mineralogical Change.	Gain by Magma.	Gain by Xenolith.
Basic Andesine to Oligoclase.	Ca	Na, Si.
Actinolitic Hornblende to Aluminous Hornblende.	Ca, Mg.	Al, Na.
Hornblende to Biotite.	Ca, Mg.	K.
Diopside to Hornblende.	Ca, Mg.	Fe, K.

The impoverishment of the magma in soda, potash, alumina and silica would ultimately subscribe to a higher percentage of the ferro-magnesian minerals in the contaminated quartz-diorite, while the addition of lime and magnesia to the magma would undoubtedly bring about a certain degree of desilication.

IV. The Central Granodiorite.

A. Introduction.

The third rock type in the Ardara granitic pluton is the central granodiorite. It occupies the central part of the pluton, has a roughly circular outline, is about 3½ miles in diameter and covers an area of about 8.1 sq.miles within the writer's area.

It is medium-grained biotite-granodiorite, and the distinction between it and the xenolithic quartz-diorite is not merely the presence of abundant xenoliths in the latter type, for they differ in composition and texture, and appear in the field as two rock types. Nevertheless, the xenolithic quartz-diorite is thought to have had originally the same composition as the central biotite-granodiorite.

A large part of the central granodiorite seems to have been emplaced at a slightly later date relative to the main pluton, probably in the form of a second upwelling of magma piercing its way through the centre of the pluton while this latter part was still in a somewhat molten condition. This second upwelling of magma is apparently accompanied by a considerable wave of heat. The part of the central granodiorite in contact with the tonalite in the southern part of the pluton, though containing occasional dark inclusions, has precisely the same composition as the xenolith-free biotite-granodiorite from the centre of the pluton. Because

of its relative position in the pluton and its structure, it may be suggested that it represents a later phase of the main upwelling of magma appearing after all the seriously contaminated and highly xenolithic quartz-diorite magma was exhausted. It thus affords a sort of transition between the two end members of the same granodiorite magma, the earlier stage having been considerably contaminated.

As a rock type, the central granodiorite is quite distinct from both the xenolithic quartz-diorite and the outer tonalite. It is medium-grained, with a marked equigranular texture. The fresh rock is usually of a medium pink colour, but is changed to a very pale grey and ash grey by the effect of the peat. This bleaching by the action of peat has been found to reach a maximum depth of 7ft. at the quarry situated at the end of the lane passing by Beagh School.

The central granodiorite is more strongly affected by weathering than the other granitic types, and thus forms the low-lying country in the central part of the pluton. This has also helped in obliterating the joint planes. The difference in the weathering of the central granodiorite and the xenolithic quartz-diorite is seen on crossing the boundary between the two rock types at any of the well exposed places, such as at Loughs Gunnell and Nagurrah, at about 300 yds. north of Loughs Nabrettage and Adoocy, or even at

Lackagatermon Lough south-west of Letterilly. The passage into the central granodiorite is marked by the appearance of a layer 2" to 7" thick of the weathered products of the granite, consisting largely of rounded pellets of quartz. The boundary of the central granodiorite with the xenolithic quartz-diorite at Lackagatermon Lough is marked by a narrow depression trending N.W. - S.E., and includes a small stream running into Lackagatermon Lough. Here, both the rapid disappearance of xenoliths and the peculiar weathering of the granodiorite help in distinguishing the two rock types.

The central granodiorite is studded with a large number of small quarries from which fresh specimens have been collected.

The central granodiorite is relatively poor in pegmatite aplite and quartz veins, particularly in its northern part. Veins, however, are abundant in the area between the Beagh and Owenea Bridges.

The central granodiorite possesses several protrusions and offshoots, these penetrate both the quartz-diorite and the outer tonalite. They are non foliated, and the rocks are readily recognised as related to the central granodiorite. The most important of the offshoots are located at Killayenna Lough quarry, at Bonny Glen, and at the quarry to the west of the Parochial House, Kilclooney.

B. Petrography of the Central Granodiorite.

1. General. The central granodiorite is medium-grained with a marked equigranular texture. The rock is fairly homogeneous and varies only in regard to the colour of the felspar which are pale whitish grey to dark pinkish red. The microcline is rather distinct with its large cleavage faces and inclusions of biotite. Occasionally, the rock contains small rounded biotitic clots with a pale green core of chloritised biotite. The rock has an average specific gravity of 2.64.

In thin section, the granodiorite is medium-grained with a hypidiomorphic texture, and consists mainly of plagioclase felspar, quartz, potash felspar, biotite and epidote. Sphene, apatite, rutile, zircon and iron oxide are accessory minerals; chlorite and muscovite are secondary.

2. The Minerals. Plagioclase appears principally in two forms. Large crystals of plagioclase, basic oligoclase in composition; and smaller euhedra of albite-oligoclase. The two types are particularly distinct in (661) and 603). The larger plagioclase crystals occur as phenocrysts from 2 x 3½ m.m to 1 x 2½ m.m., their composition varies between An.24 and An.27 although the composition of the plagioclase in slice 608 has been determined as An.33. They usually have more albitic rims, and show little oscillatory zoning.

The oligoclase felspar is highly sericitised, the abundance of very fine reddish brown inclusions imparts a strong pinkish red colour to the rock. The plagioclase is sometimes underterminable due to a high degree of alteration, and when oscillatory zoning is present, one set of alternating zones is more sericitised than the other. Inclusions of clinozoisite-epidote also characterise the large oligoclase crystals, and secondary muscovite is also present in thin sections (544, 653, 565, 603 and 608). These large oligoclase crystals are usually broken and bent, the significance of which is discussed on p.169. Only in one or two cases has this oligoclase been seen to replace quartz.

The small euhedra of albite oligoclase have a composition about An.8-15, and occur as crystals $\frac{1}{2}$ x 1 m.m. They are also included in the plates of microcline. This albite-oligoclase is further characterised by the fact that crystals exhibit sharp oscillatory zoning, are entirely devoid of inclusions and very rarely show banding.

The <u>potash felspar</u> has a distinct cleavage in the hand specimen and grows up to about 12 m.m. across. It is usually microcline but orthoclase may be present as in (609). This special variety of rock comes from the quarry at the Beginning of the Ardara - Maas road and contains 6.8% orthoclase out of a total of 16.6% potash felspar. The microcline and orthoclase are usually microperthitic except

in slice (561) where this texture is absent.

The microcline is usually interstitial in relation to the large plagioclase crystals, and in some cases, tends to form a kind of mantle outgrowth around some plagioclase crystals. On the other hand, it includes practically all the small euhedra of albite-oligoclase, as well as the majority of the biotite with its associated chlorite and epidote. Pseudocataclastic textures usually develop along the boundary of either two grains of orthoclase and microcline.

In contrast to the plagioclase felspar, the potash felspar does not show the least signs of bending or breaking, except in slice (605) where only one crystal is traversed by a crack. The microcline sometimes retains very peculiar trails of inclusions of quartz grains, this will be considered separately.

All the quartz occurs interstitially to the other minerals and includes a small part of the biotite and apatite and all the sphene. The quartz is also of special interest and a careful study seems to suggest a secondary origin for a part of this mineral. In thin sections (544, 551. 552 and particularly 561) the patches of quartz, which are about 3½ m.m. across, are traversed by cracks filled with very fine opaque dust, the cracks are either at random or show a roughly reticulate pattern as in slice (553). Sometimes the very fine

opaque dust is seen, under high power, to be filling the original crack and some of it is included in the quartz all along the crack. Yet all this apparently cracked quartz is in larger and presumably recrystallised masses. In all the thin sections of the central granodiorite, however, including those with this cracked quartz, large patches of quartz occur which lack both the cracks and the fine opaque dust. Both types exist in contact in slice (552). All the quartz possesses indented and sutured boundaries, contains trails of granulation and exhibits strong undulose extinction.

Biotite occurs in the form of stout flakes up to 2 x 1 m.m. which are very often broken and bent. It is olive green to dark green in colour, with a pleochroism Z = Y = dark green and X = pale golden yellow. It is usually included in the microcline, and less so in the quartz. The biotite is strongly corroded leaving remnant fragments within the more acid marginal outgrowths of the plagioclase. The biotite shows varying degrees of alteration to chlorite, with which it is usually interleaved, simultaneously shedding rutile, iron oxide and sphene along the cleavages. Inclusions in the biotite comprise rutile needles, apatite and zircon.

Muscovite occurs mainly as a secondary mineral in the form of small flakes within the larger crystals of oligoclase. It rarely occurs in the microcline.

The chlorite is after biotite, and is often -ve penninite polarising in anomalous blues and browns. In slice (562) a part of the chlorite is thought to be clinchlore, while in slice (565) an isotropic variety has not been specifically identified.

Sphene occurs mainly in the quartz in the form of wedge-shaped crystals up to 1½ m.m. long. Secondary sphene occurs along the cleavages of chloritised biotite.

Small crystals of apatite and zircon are included in the biotite and rutile needles may also occur in this environment. Iron oxide is present in very small quantities.

3. Evidence of Early Movement. The study of numerous thin sections of the granodiorite has revealed several types of textures, all of which seem to indicate that the rock had suffered a certain degree of cataclasis followed by the influx of potash and silica, and the formation of more potash felspar and secondary quartz. It is necessary to emphasize the fact that this presumed early cataclasis is independent of the late cataclasis associated with the formation of fault breccias, and which will be referred to later (p.180).

The main cataclastic textures can be briefly summarised as follows :-

(a) The large porphyritic crystals of oligoclase are either strongly bent or broken (slices 608, 605, 609, 553 and Plate 8A). The distribution of the broken plagioclase

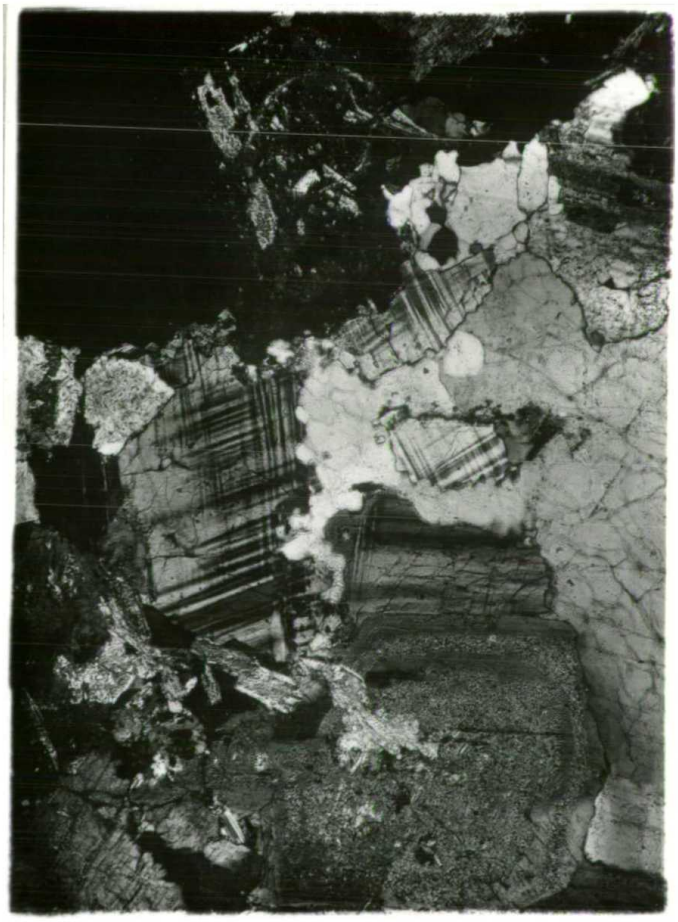
PLATE 8.

A. Severe bending and breaking in the larger crystals of oligoclase is characteristic of the central granodiorite. Note the strong strain effects in the quartz in the upper left hand side. Cross nicols X 20.

B. Quartz actively replacing microcline and encroaching upon it in the form of circular embayments. A remnant of microcline bounded by festoon-like embayments still survives in the quartz. Central granodiorite, crossed nicols X 30.



A



B

crystals is very wide and can be said to occur throughout the central granodiorite, though concentrated in the area between Lough Adenny and the south-western sector.

Strongly bent biotite is an associated texture.

(b) In thin sections (610, 552, 544, 590, 553, 613) representing almost every part of the central granodiorite, the microcline is seen to include trails of quartz grains, the trails generally running parallel to the periphery of the microcline plate (Fig.3B). The fact that these inclusions of quartz grains are in definite trails in an outer zone seems to indicate that the microcline has attained its present form as a result of a second outgrowth. This is seen more obviously when the trail of inclusions is accompanied by a feint shadow of minute iron oxide inclusions and hydrated oxide staining. Thus these quartz grains were, in all probability, in their present position before the secondary growth of the microcline and their trails indicate roughly the size of the primary microcline crystal. A most important fact about these quartz grains is that they are not in optical continuity. From observations in the numerous thin sections of the granite types in the pluton, and particularly the xenolithic quartz-diorite and outer tonalite, it has been established that inclusions of quartz grains occurring in trails within the outer borders of plagioclase crystals, and representing remnants of quartz replaced by the

plagioclase, are either all in perfect optical continuity or show continuity in groups of adjacent grains, each group representing a remnant of a single quartz crystal. It can be inferred, therefore, that these inclusions represent original quartz grains of their present size, or else represent the surviving remnants of small interlocking quartz grains forming a sort of zone of granulation around the original crystal of potash felspar. The original crystals of microcline do not show any sign of bending, while the plagioclase is broken and the quartz granulated due to the relatively higher rigidity of the microcline.

(c) As seen in thin section, the granodiorite is usually traversed by zones of granulated quartz grains simulating the effects of mild mylonitisation. These zones of mylonitisation are usually found in contact with plagioclase crystals, (603, 605, 565), and seem to indicate zones of granulation around the plagioclase ; the grains show a progressive coalescence. This granulated quartz is seen in contact with other large patches of secondary quartz.

(d) It has been stated in the petrographic description of quartz, that this mineral tends to occur as two types, one of which seems to indicate that it has been shattered and later recrystallised as larger masses. The other type of quartz lacks evidence of early cataclasis and may be of secondary origin. This latter type of quartz is seen more

clearly where it is in contact with the older and cracked quartz, and secondly that it usually forms large masses in strong contrast to the zones of granulation.

The foregoing description of the cataclastic textures seems to suggest that the rock, at a relatively early stage, experienced a certain degree of cataclasis while still hot. This caused the bending and breaking of plagioclase crystals and flakes of biotite, and the shattering and granulation of the quartz, particularly around crystals of plagioclase and potash felspar. Subsequent influx or internal migration of potash and silica would give rise to the formation of outgrowths to the potash felspar and secondary quartz.

4. Replacement Textures.

Numerous cases of replacement among the different felspars or between potash felspar and quartz have been noted in thin sections. Textures that could possibly be ascribed to the interlocking of crystals in three dimensions have been discarded, and only those representing genuine replacement have been considered. These textures recur again and again in a great many slices. The different varieties will be considered in their presumed time order.

(a) Primary Replacement of Quartz by Plagioclase. The large crystals of oligoclase with more acid and albitic rims are sometimes found to contain small irregular inclusions of quartz forming a rough trail parallel to the edge of the

crystal. These inclusions are either all in optical continuity, suggesting that they represent the remnants of a resorbed quartz grain, or they are divided into two or more sets of adjacent grains in optical continuity, each of such groups presumably representing a resorbed quartz grain. This texture is less frequent in the central granodiorite as compared to the outer tonalite, and is assumed to have taken place during the congealing phase.

(b) Primary Replacement of Plagioclase by Microcline.

The apparent replacement of parts of the plagioclase crystals by microcline and the presence of remnants of the plagioclase within the microcline is commonly observed. A good example is seen in slice (565). This is also thought to be characterising the earlier phases of congealing.

(c) Replacement of Microcline by Quartz is among the most common and outstanding replacement textures in the central granodiorite. The quartz is seen to corrode and resorb the microcline in the form of circular embayments. This particular resorption seems to be more active relative to other replacement textures, and in the majority of cases, remnants of microcline bounded by festoon-like embayments still survive in the quartz (Plate 8B). From the general characters of this texture, it seems to be a late manifest tion in the crystallisation of the rock.

(d) Late Replacement of Potash Felspar by Plagioclase

with or without the production of myrmekite. Boundaries between potash felspar and plagioclase are usually marked by myrmekite embayments encroaching upon the potash felspar. At times, remnants of microcline occur behind the advancing myrmekite front (552 and 608). In other cases, a crystal of plagioclase is seen to have attained its present size by resorbtion of, and encroachment upon, adjacent plates of potash felspar with myrmekite texture occurring only in some parts.

Boundaries between plates of potash felspar are usually marked by myrmekite bands about 0.1 m.m. thick, sometimes giving pseudocataclastic textures (608). This seems to be due to the effect of late sodic solutions moving along intergranular boundaries.

C. Modal Composition of the Central Granodiorite.

Slice No.	544	552	553	561	565	603	605	608	609	average.
Sp. gr.	2.65	2.65	2.63	2.64	2.64	2.63	2.61	2.63	2.64	2.636
Plagioclase.	45.3	50.0	56.0	53.0	42.2	56.7	47.8	49.2	47.6	49.75
Quartz	26.5	27.5	21.6	20.2	23.1	17.6	33.6	20.9	23.1	24.35
Potash Felspar.	22.7	14.8	13.6	14.6	27.4	16.0	12.6	16.6	13.0	16.81
Biotite	4.7	7.5	8.0	8.8	7.0	9.0	4.0	10.7	9.5	7.69
Epidote	0.7	tr.	0.8	3.4	0.2	0.7	tr.	2.1	1.7	1.07
Sphene	tr.	0.2	tr.	Nil.	Nil.	tr.	Nil.	0.5	0.1	0.09
Muscovite	tr.	Nil.	Nil.	tr.	Nil.	tr.	2.0	tr.	tr.	0.22
Rutile	tr.	tr.	tr.	tr.	tr.	tr.	tr.	Nil.	tr.	
Apatite	tr.	tr	tr.	tr.	tr.	tr.	tr.	tr.	tr.	
Zircon	Nil.	Nil.	tr.	tr.	Nil.	Nil.	Nil.	tr.	tr.	
Iron Ore	tr.	tr.	tr.	tr.	0.1	tr.	tr.	tr.	tr.	
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.98

D. Xenoliths in the Central Granodiorite.

1. Occurrence and Distribution of Xenoliths. The central granodiorite contains only a small number of dark xenoliths in the area around Beagh School and Tullycleave Hill. They resemble those in the xenolithic quartz-diorite in appearance, and do not include any which are of metasedimentary origin. At Beagh School, the xenoliths are few in number, rather irregular in shape, about 2" to 3" across, and consist mainly of biotite. The xenoliths in the area between the Tullycleave Hill drumlin and Owenea Bridge are also few in number; they are about 7" across and are of a dark green micaceous nature. The xenoliths around the junction of the Ardara - Maas road are aligned parallel to the weak foliation of the granodiorite.

2. Petrography of the Xenoliths. In thin section, the xenoliths consist mainly of biotite with subordinate hornblende and epidote, with interstitial grains of quartz and felspar. Biotite constitutes about 70% of the rock and occurs as closely packed decussate flakes. The pleochroism is Z = Y = dark green and X = pale golden yellow. Hornblende occurs in small irregular and corroded particles and constitutes about 10% of the rock. Its pleochroism is Z' = medium bluish green, Y' = dark lavender green and X' = golden yellow to straw. Epidote constitutes about 20% of the rock and occurs as large grains and aggregates up to 1 m.m. across.

It is pleochroic, greenish yellow to colourless. Less frequently it occurs as euhedral crystals inside the biotite. Quartz and felspar are very subordinate and occur as small interstitial grains.

Slice 663 from a quarry at B.M. 84.0, at the north-western foot of the Tullycleave drumlin, shows the contact of one of these xenoliths with the granodiorite host. The latter appears quite normal and does not show any basification even to within ½ m.m. of the xenolith. The granodiorite is entirely free of amphibole.

E. Apophyses of the Central Granodiorite.

1. General Description and Petrography. The central granodiorite sends off several apophyses into the older granitic types, the quartz-diorite and the tonalite. These veins of biotite-granodiorite are not foliated and seem to have been intruded into the older granitic envelope at a quite late phase in the emplacement of the pluton.

The first of these small intrusions is seen in the large road-side quarry at the north-eastern corner of Killayenna Lough. The quarry, which is about 100yds. long by 50yds. wide, lies in the outer tonalite, only a few yards from the contact with the xenolithic quartz-diorite. A dyke-like vein of light pink biotite granodiorite, about 15ft. wide, traverses the quarry in a north-south direction.

The rock is fine- to medium-grained, pale pink in colour and has a Sp.gr. of 2.59 (average central granodiorite Sp.gr.2.64). In thin section (1452), the rock consists mainly of plagioclase, quartz, microcline and biotite, and has almost the same texture as the average biotite-granodiorite. The plagioclase is mainly oligoclase (An.15-18) and occurs in good crystals up to 3 m.m., exhibiting oscillatory zones crammed with alteration products. Some oligoclase crystals have albitic out-growths enclosing granules of quartz. The microcline occurs as fresh plates enclosing small plagioclase euhedra and poikilitic inclusions of quartz grains. The quartz, together with some of the microcline, occurs interstitially, and boundaries between quartz grains are sutured. The biotite which is dark green in colour, is identical to that of the central granodiorite and is sometimes interleaved with chlorite (-ve penninite). Sphene, apatite, rutile and zircon are accessory.

Another important occurrence of an unfoliated offshoot of the central granodiorite is found in the small strip of land between the two small loughs at Bonny Glen. The exact nature of this intrusion is not clear due to cover of its contacts, but the rock is readily distinguished from the surrounding quartz-diorite.

In the quarry on the west side of the Narin-Ardara road near the Parochial House at Kilclooney, the rock is unfoliated, medium- to fine-grained, and represents another

of the offshoots of the biotite-granodiorite. The rock is, however, slightly deficient in quartz relative to the granodiorite, but the texture and composition nevertheless suggest its close relationship. In thin section (208), the nature of the microcline which contains the small euhedra of plagioclase and the plagioclase with the characteristic oscillatory zoning strongly support its affinities.

2. Modal Composition of Apophyses.

	Average Central Granodiorite.	Offshoot at quarry, Kilcloony(208)	Vein at Killayenna Lough (1452).
Sp. gr.	2.64	2.65	2.59
Plagioclase	49.75	50.4	36.5
Quartz	24.35	20.3	31.8
Microcline	16.81	15.3	23.8
Biotite	7.69	7.9	5.0
Epidote	1.07	1.7	2.0
Sphene	0.09	0.1	tr.
Muscovite	0.22	tr.	1.0
Chlorite	tr.	4.3	tr.
Total	99.93	100.0	100.1

F. Late Cold Cataclasis in the Central Granodiorite.

The central granodiorite in the area lying between the north-eastern shores of Lough Nameeltoge, Tullycleave Beg and Tullymore School, seems to have experienced late shattering movements of a rather drastic nature. This area is a belt well over ½ mile long trending in a N.E. - S.W. direction. It seems most probable that this belt of brecciation has a continuation below the Tullymore drumlin, as the shattering was found to increase from Lough Nameltoge towards the north-east, where it reaches a maximum at the quarry behind Tullymore School, at the foot of the huge drumlin.

The granodiorite in the north-eastern shores of Lough Nameeltoge shows abundant planes of dislocation and the rock is in part incoherent, and in the quarry near Lough Nameeltoge, the unfoliated granodiorite is seen to be cut by numerous closely spaced planes of movement trending steeply in a direction approximately N.30° E. In thin section (609) a few plagioclase crystals are bent and the quartz shows extreme undulose extinction and possesses sutured boundaries.

In the quarry face at Tullymore School, the rock which is deep red in colour, occurs as broken irregular blocks which disintegrate at a touch with the hammer. Some of the planes of fracture are found to contain slickensided crush-breccia up to 3" thick. All planes of movement are coloured

with different shades of green. Slice 610 represents the granodiorite from this quarry. The plagioclase is bent and broken, the quartz shows very high undulose extinction and possesses sutured edges and is sometimes granulated in certain zones. All the biotite in the rock is bent and broken and has been altered to chlorite and iron oxide.

The breccia is strongly grooved and slickensided and consists of small fragments of pink felspars in a fine grained base which is dark green in colour. In thin section (612) it consists of angular and subangular grains of plagioclase, microcline and more rarely quartz cemented in a groundmass of finer and sharply angular fragments of these minerals with chloritic material. The larger fragments of microcline are seen to include the plagioclase euhedra as in the normal rock type.

V. Pegmatitic Fringe of the Doocharry Granite.

A. General Description. The outer coarse tonalite and the xenolithic quartz-diorite in the 'neck' of the pluton are cut across by a fine-grained granitic rock, forming a pegmatitic fringe of another member of the Donegal Granite Series Within the present area, it appears as a fine-grained rock with a distinct foliation and linear elements. The foliation in the rock varies in intensity from place to place, and the lineation is identical to the secondary linear structures in

the xenolithic quartz-diorite in the 'neck'. As seen on the map of the area, it cuts both of the older granite types in the 'neck', mainly in the form of thick interdigitating veins. There are good contacts with the outer tonalite with gneissic foliation, and several large enclaves of the tonalite occur within the fine-grained granite. The latter has also been intruded along the original contact of the tonalite with the Glenties Series. This original south-eastern margin of the 'neck' - now a tonalite-granite contact - is marked by occasional thin screens of mobilised hornfels in contact with the tonalite; the most clearly shown mass occurs due north-west of the hospital at Glenties. The wedging in of this fine-grained granite has caused the pushing aside of the tonalite as will be considered later. The fine granite near its margin against the tonalite is faulted and highly shattered. In the quarry at Woodtown as well as in the bed of the nearby river, the granite is of a dark pink colour and is almost brecciated. The margin of the fine grained granite against the Glenties Series is marked by a highly sheared medium-grained pegmatitic fringe up to 100yds. wide. This pegmatitic fringe, which is very poor in ferro-magnesian minerals, is almost a mylonitic gneiss with thin lenticular augen structure (Spec.675). In the north-eastern part of the 'neck', thick pegmatitic veins of the granite contain large rafts of the rodded and lineated xenolithic quartz-

diorite. The intrusion of the fine-grained granite was undoubtedly effected during the more advanced phase of the late movements which have caused the secondary linear structures in the neck.

B. Petrography.

The main rock within the writer's area is a fine-grained rock with a distinct foliation and thin yellowish lenticles along the foliation. It consists of potash felspar, acid plagioclase, quartz, biotite and muscovite. Chlorite, apatite and iron oxide are accessories. Slices 678 and 679 show distinct cataclastic textures with thin zones of granulation parallel to the slightly undulating foliation. The cataclastic nature of the rock is rendered more complex by the development of abundant secondary myrmekite by the replacement of potash felspar by oligoclase.

Potash felspar, usually as microperthite, occurs as irregular masses up to 2 m.m. across, with inclusions of quartz, biotite flakes and laths of oligoclase. The plagioclase is usually oligoclase of composition about An.15 with more albitic rims, and occurs mainly as good crystals 1 m.m. long or minute particles in the granulated zones. Bent crystals occur occasionally. Quartz occurs either as granules in the granulated matrix of the rock, or forms lenticular masses later than the main cataclasis of the rock

and very similar to those in the Glenties Pelites and the Mylonitic Gneiss of Carbane. The lenticles are strained and the twin lamellae are roughly parallel to the foliation of the rock. Biotite occurs as small blades up to ½ m.m. and arranged in undulating bands parallel to the foliation. Its pleochroism is Z = Y = dark chocolate brown to red brown, X = pale yellowish brown to dull yellow. Biotite sometimes occurs as inclusions in the outer rims and outgrowths of plagioclase crystals. Muscovite, in the form of small blades or flaky aggregates, is sieved with minute poikilitic inclusions.

VI. Sheets and Dykes of Microgranodiorite.

A. Occurrence and Description.

The Ardara Granitic pluton contains several minor sheets and dykes of microgranodiorite. These are not restricted to any of the main rock types in the pluton, but seem to be of more frequent occurrence in the coarse tonalite, particularly in the north-eastern sector of the pluton.

The typical microgranodiorite is fine-grained and pale grey in colour. In the Ballyiriston - Maas area, they usually form vertical dyke-like veins, running normal to the contact and varying in thickness between 9" and 8ft. In one place, a microgranodiorite vein 10" thick is seen to have been intruded along the centre of an older vein of pegmatite.

These microgranodiorite veins are slightly poorer in ferromagnesian constituents than the average flat-lying sheets. The orientation of the dark minerals in a vein 3½ft. thick located at Maas, seems to suggest a primary flow structure, and the rock is seen to contain fragments of the tonalite host. The microgranodiorite in this locality is clearly distinct from the fine-grained pegmatites and aplites in the fact that it is seen to cross the outer contacts of the pluton into the hornfelses and the associated metadolerites. At Ballyiriston, the contact of the outer tonalite and contact-altered metadolerite is traversed by a vein of micro-granodiorite. This fine-grained granodiorite also forms an elongated mass 25ft. x 6ft. parallel to the strike at a point 60yds. from the contact W.N.W. of the Maas Hotel. It possesses a feint foliation parallel to the strike direction. The tonalite between Maas and Letterilly contains sheets of microgranodiorite up to 10ft. thick.

The xenolithic quartz-diorite in the centre of the southern shore of Lough Fad contains a large flat-lying sheet of microgranodiorite about 80yds. across. Other important occurrences in the quartz-diorite are at the south-east of Lough Ananima, between Gortnamucklagh and Tullyard and between Loughrillan and Sruhangarve.

Micro-granodiorite sheets in the central granodiorite are of less frequent occurrence. he best example comes from

a large quarried exposure situated about 400yds. along the road to Beagh School.

B. Modal Composition.

	(223)	(538)	(604)	Average.
Plagioclase	45.2	40.6	21.9	42.6
Quarts	24.8	27.6	27.9	26.8
Potash felspar	22.0	20.2	18.9	20.4
Biotite*	7.0	11.4	9.3	9.2
Epidote	1.0	tr.	0.1	0.4
Muscovite	tr.	0.1	1.7	0.6
Total	100.0	99.9	99.8	100.0.

(223) south shore of Lough Fad.

(538) south-east Letterilly.

(604) Beagh school.

* including chloritised biotite.

C. Petrography.

The average microgranodiorite is a fine-grained granitic rock, pale grey to pink in colour with a hypidiomorphic texture. The plagioclase has the composition of oligoclase up to An.26 and occurs as idiomorphic crystals up to 2 m.m. long. It exhibits oscillatory zoning and the crystals have sericitised cores. The potash felspar is

always microcline occurring as large irregular masses and with inclusions of rounded grains of quartz, small crystals of plagioclase, biotite and sphene. The quartz occurs interstitially with few inclusions. Biotite is green to yellowish green and occurs as ragged flakes with pleochroic haloes.

VII. Petrography of Aplite - Pegmatite Veins.

In the study of the Ardara pluton, much emphasis has been laid upon veins of aplite-pegmatite from the structural point of view (p.206). In the present section, only a brief petrographic description of typical veins is given.

A pegmatitic vein from the central granodiorite at Lough Derryduff appears in slice (553) to resemble somewhat its host rock except for the lack of ferro-magnesian constituents, consisting of microcline, quartz and plagioclase.

The plagioclase is oligoclase and occurs in crystals 2 m.m. across which are sometimes broken or bent. It is usually corroded by the quartz. The microcline is in part microperthitic and is actively corroded by quartz. The quartz occurs interstitially or forms rounded grains. It is highly strained and tends to show cataclastic texture.

Another typical pegmatite comes from the xenolithic quartz-diorite, 1/3 mile east of Kilcloney School. It consists mainly of microcline-microperthite in large irregular masses up to 8 m.m. across, a sodic oligoclase and quartz

are subordinate. The quartz is very highly strained and the rock generally possesses distinct zones of granulation.

A typical aplite vein 6" thick, from the xenolithic granodiorite halfway between Lough Killayenna and Lough Fad, is fine-grained and of a dull pink colour. In slice 232 it is seen to consist of microcline and quartz with subordinate oligoclase felspar. Epidote, iron oxide and muscovite are minor accessories. The microcline usually occurs in irregular crystals ½ m.m. across, and exhibits a variety of intergrowths with quartz. These microcline-quartz intergrowths are usually in the form of myrmekite (Fig.3C1) as compared to one or two grains with a granophyric texture. (Fig.3C2). Secondary myrmekite is of very rare occurrence, and in Fig.3C3, it is seen to replace the microcline but only engulfs the primary intergrowths of quartz.

VIII. Summary of Observations.

The Ardara granitic pluton is a granitic complex comprising several rock types and consisting of a circular mass 5 miles in diameter and possessing a 'neck' or protrusion, which is cut across by another member of the Donegal Granite Series. Its outer periphery possesses a strong foliation parallel to the outer margin of the pluton, and the distribution of the rock types also follows the circular structure

The pluton consists mainly of two contrasted components which do not appear to possess a direct genetical relationship.

First, the coarse-grained tonalite, forming an outer 'skin' or mantle to the pluton, makes very sharp contacts with the enveloping country rocks, and contains abundant xenoliths readily ascribed to the lithological groups of the enveloping metasediments and their early basic intrusions. These xenoliths have been practically unaffected by the magma. Other inclusions in the tonalite are drawn out into thin streaks along the strong foliation and their mode shows a convergence to that of the tonalite. The two sets of xenoliths are entirely different and there are no intermediate steps between them.

Second, a main core of the pluton sometimes makes sharp contacts with the outer tonalite mantle. This core is medium-grained and seems to have originally been wholly a biotite-granodiorite at depth. The outer part of this medium-grained core contains abundant dark xenoliths and has acquired the composition of a quartz-diorite - referred to as the xenolithic quartz-diorite. This resulted from the mutual interaction with and assimilation of a considerable part of the amphibolitic complex of Meenalargan, essentially at a lower level. Xenoliths of widely varying amphibolites and calc-amphibolites are seen in all stages of interaction with their quartz-diorite host. As seen at present, the process of assimilation of amphibolitic xenoliths by the already contaminated biotite-hornblende-quartz-diorite takes place

in two stages. First, the minerals of the xenolith are changed to others identical to those in the contaminated quartz diorite, involving mutual exchange of material, mainly a gain of Ca and Mg by the magma, and a loss to the xenoliths of K, Na, Al and Si. Second, the xenolith is gradually dispersed in the magma, as minute clots of ferro-magnesian minerals, by the introduction of quartz, potash felspar and plagioclase into the xenolith. The release of Ca and Mg in the magma would cause a certain degree of desilication, at the same time as the magma is being enriched in the small clots of dark minerals.

Another part of the medium-grained outer part of the core of the pluton consists of an uncontaminated biotite-granodiorite. This type contains only a few dark xenoliths, and in view of its foliated nature and relative position in the pluton seems to correspond to the contaminated xenolithic quartz-diorite in structure and time of emplacement. It represents magma which has only picked up a few dark xenoliths of amphibolite and was not contaminated. It forms a link between the contaminated xenolithic quartz-diorite, which is supposed to be the first part of the magma of the core to reach the present level, and the massive biotite-granodiorite in the centre of the pluton, which apparently represents the final phase in the emplacement of the pluton. This biotite-granodiorite is free from xenoliths as well as

any perceptible foliation.

Veins of aplite, pegmatite and quartz are present in the outer periphery of the pluton.

The xenolithic quartz-diorite in the 'neck' of the pluton was affected by late movements impressing upon it secondary linear structures plunging gently to the south-west and gradually dying out in that direction. While these secondary movements were in operation, probably during their late phase, the pegmatitic fringe of another member of the Donegal Granite Series was emplaced across the 'neck'.

Late granitic activity in the granitic complex is marked by sheets and dykes of fine-grained granodiorite, apparently connected with the later members of the Donegal Granitic Series.

Chapter SEVEN.

STRUCTURE AND EMPLACEMENT OF THE ARDARA PLUTON.

I. Introduction.

As already shown, the Ardara Pluton consists mainly of a circular mass about 5 miles in diameter and possessing a protrusion or 'neck' cut across on the south-eastern side by a member of the Donegal Granite Series.

The diapiric emplacement of the granitic pluton was effected in two stages. First, the contaminated or xenolithic quartz-diorite was intruded, together with the outer foliated tonalite acting as a plastic 'skin' or mantle. This constituted the main phase of emplacement of the pluton. Following a certain degree of cooling of the outer periphery of the then smaller pluton, a further upwelling of magma resulted in the larger part of the central granodiorite forcing its way through the centre of the pluton, which was still in a fluid stage.

The evidence of this presumed mechanism of emplacement is given in the following pages, the structural evidence within the pluton being considered in this present section ; the petrographical and structural evidence in the contact metasediments in the sections dealing with the contact metamorphism of the metasediments and the tectonics of the pluton.

The outer margin of the pluton possesses a strong foliation which exhibits a maximum intensity at the periphery,

gradually decreasing away from the contact over a distance of about one mile, after which it ceases to be perceptible. In the outer part of the foliated zone, that is in the tonalite and in the outer part of the xenolithic quartz-diorite, the foliation runs parallel to the contact metasediments and invariably dips southernly - and is continuous with the foliation of the 'neck'. This is thought to be connected with the emplacement of the first part of the pluton and is here referred to as the 'early foliation'. Meanwhile, in the inner half of the xenolithic quartz-diorite the foliation is vertical and forms a circular structure conforming roughly to the outline of the central granodiorite, and is referred to as the 'late foliation'.

The xenoliths in the pluton are aligned parallel to the foliation, and those xenoliths which have been in a plastic condition are flattened in the plane of foliation. They form ellipsoids with their largest axes lying horizontal and tangential to the arcuate structure, the intermediate axes are vertical and lie in the steep plane of foliation, and the shortest axes are thus normal to the foliation.

It will be shown that the foliation in the granite is mainly the result of distention of the outer cooling periphery of the pluton during its forceful diapiric inflation.

The outer foliated periphery of the pluton was the first to cool and reach a certain degree of rigidity, and

the first fractures formed were essentially radial, normal to the direction of distention ; these were largely occupied with aplitic and pegmatitic residual liquids. The 'neck' was similarly traversed by a set of pegmatite veins trending N.W. - S.E. normal to the foliation.

The formation of radial tension joints was followed by the formation of longitudinal joints parallel to the foliation, apparently later than the hydrothermal phase of the emplacement.

II. The Nature and Significance of the Foliation.

A. General.

The strong foliation in the outer parts of the pluton is a steep platy structure in which lie the biotite and other dark minerals. A central core, some 2½ miles in diameter, is non-foliated and apparently massive. The granite in the 'neck' possesses a strong foliation parallel to its margins and dipping consistently south-east at about 70°.

The outer foliated margin of the pluton has an average width of about 1500yds. and in some places the foliation has been found to persist up to 1900yds. from the outer margin and decreases gradually towards the centre of the pluton, where finally it ceases to be perceptible. Even where the foliation becomes weak and sometimes even imperceptible, xenoliths in the contaminated quartz-diorite still show a strict alignment and are drawn out parallel to

the arcuate structure.

As seen in Map No.2, in the inner part of the foliated zone the foliation is vertical or nearly so, meanwhile all along the southern margin of the pluton, including the neck, the foliation is conformable with the contact and the structures in the country rocks and dips steeply south. In the northern sector, the foliation again dips to the south, and in the north-eastern parts the dip is south-west and south-south-west. Thus the foliation in the outer part of the foliated zone, tends to be concordant with the contacts and the regional dip of the country rocks.

The fundamental cause of this planar foliation in the pluton seems to be that while the gradual feeding and inflation of the diapir produces radial forces divergent from the centre, yet the actual flow is essentially normal to this direction, in other words, tangential with respect to the circular structure. This local flow takes place in a plane steep or vertical, and as the diapir inflates, the surface of the spheroidal mass increases, the local flow becomes essentially a planar distention. This is the plane in which the xenoliths are flattened - the plane of foliation. It will be shown later that the distention in the plane of foliation is not uniform, but that it has a greater horizontal component.

The evidence as a whole indicates that the foliation in

the main body of the pluton is the result of tension, the drawing out of the outer plastic and still cooling mantle together with its compression against the enveloping country-rocks.

Hence the foliation does not represent the actual 'flow' of a slightly viscous magma with the alignment of ferro-magnesian minerals denoting the direction of flow. The 'neck' is the only part of the pluton which apparently has not been under the tension of the inflating diapir, and whose structures would represent the primary flow of the incoming magma. Unfortunately, that part of the pluton has experienced late movements which have progressively obliterated primary structures. The least modified of the primary structures indicate a foliation parallel to the wall rock and conformable with it, and in the plane of foliation, plastic xenoliths have been flattened and drawn out parallel to the structure.

From a general view of foliation in the pluton and its distribution with respect to both the various rock types of the granite and the structure of the metasediment envelope, it is possible to distinguish two structural systems within this foliation. First, a foliation parallel to the margin of the pluton and dipping south or a southernly direction at $70 \pm 80^{\circ}$ and confined to all the tonalite and the outer part of the xenolithic quarts-diorite including all of the 'neck'. Second, a foliation mainly vertical and confined to the inner

portion of the xenolithic quartz-diorite ; its general shape is parallel to the outline of the central granodiorite. It will be shown that this latter foliation is associated with the presumed second upwelling of biotite-granodiorite magma.

Prior to this later upwelling, when the pluton consisted of the xenolithic quartz-diorite with its outer mantle of coarse tonalite, the foliation was most probably dipping south in a manner conformable with the contacts as well as the regional dip of the metasediments, and essentially continuous with that of the 'neck'. Across the pluton from the south to the north, the foliation probably continued to dip south parallel to the main thrust - its southern contact - and gradually faded out towards an apparently massive centre. Towards the northern side the foliation would gradually become perceptible again, dipping towards the south and increases until the northern contact is reached. This is the case in the 'neck', except that this is so narrow that it does not possess an apparently unfoliated central zone.

In the Loon Lake pluton (Cloos 1934), for example, the contact is mainly concordent with the pre-granitic wall-rock structure. The platy foliation dips into the centre of the granite and the latter is thus thought to be a funnel shaped pluton.

The Ardara granite, on the other hand, is supposed

to have come up along a southernly dipping structural break and to have forcibly displaced southernly dipping meta-sediments - it would thus have a foliation structure in the form of a "recumbent arch" as seen along a north-south section of the pluton. The only reasonable explanation for the foliation to steepen to vertical in the southern part of the pluton, to fade out and to appear as vertical for the second time and gradually then attain the southernly dip, would be the late emplacement of a central mass - the central granodiorite.

B. Nature of the Foliation in the Tonalite.

The foliation in the outer tonalite is everywhere parallel to the margin of the pluton and dips south or in a southernly direction at angles of 70 to 80°, less frequently at 85°. Towards the outer margin, the foliation is distinctly gneissic ; such a structure has been noted at distances up to 150yds. from the contact. This gneissic foliation as seen in the field, in oriented specimens and in thin sections, is marked by the ferro-magnesian minerals, mainly biotite, forming strongly curved selveges around augen consisting of large crystals of plagioclase.

It has already been stated that the tonalite formed a plastic envelope or skin to the main granodioritic magma, and as the latter was progressively intruded, the tonalite was

stretched and dilated accordingly. The areal distention near the outer surface of the spheroidal diapir - the contact with the metasediments - is obviously greater than the corresponding dilation near the inner surface of the plastic tonalite - the contact of the tonalite and the quartz-diorite. Thus in the outer part of the tonalite, where the viscosity would also be higher than inside, the greater dilation would cause the relatively large crystals of plagioclase to be rotated and even separated in the plane of foliation, with the ferro-magnesian minerals, especially biotite, 'flowing in' together with the finer-grained components in a type of boudinage structure involving no breaking. The extent of dilation can be judged from the description of the xenoliths in the tonalite (p.126). Microcline usually recrystallises in the shaded areas in the augen (p.118). Cataclastic textures usually associated with the gneissic foliation at the margin of the pluton can be attributed either to the continuation of the process of distention till after the rock had cooled considerably or else to the late movements of the pluton when in a more or less solid state (p.360).

The mode of formation of the platy foliation in the Flammanville massif (Martin, R.N. 1963) is identical in principle to that of the Ardara pluton. Relatively minor differences regarding the uniformity of dilation in the

plane of foliation, and even the foliation pattern seems to depend mainly upon such local circumstances as the ability of the confining country rocks to dilate more easily in a certain direction during the diapiric intrusion or the pre-granite structure of the country rocks. However, the mode of emplacement of the two diapirs is by no means the same.

C. Nature of Foliation in the Xenolithic Quartz-Diorite.

The foliation in the xenolithic quartz-diorite is different in appearance from that in the outer tonalite. It lacks any gneissic structure and the rock is almost devoid of phenocrysts. The foliation is a sharply defined planar element parallel to which the amphibolitic xenoliths are flattened. Owing to its contaminated nature, the ferro-magnesian constituents of the rock partly occur in small clots 1 - 3 m.m. across. These dark clots are flattened in the plane of foliation and the individual flakes of biotite also lie in this plane. On any surface normal to the plane of foliation, these small dark clots and minute particles are elongated and possess a sharp alignment. Not in one single case does the foliation 'flow round' a xenolith that happens not to be flattened. It appears, therefore, that the distending forces in the inflating diapir have merely flattened the small dark clots together with the plastic xenoliths whilst these were in their present situation.

The flattening of the minute clots was apparently effected only where the viscosity of the rock was higher than a certain limit. Thus, in the areas of Ballymackylduff and south of Lough Fad, the xenolithic quartz-diorite gradually looses its perceptible foliation near its contacts with the central granodiorite. Yet, the xenoliths of amphibolite are notably flattened and appear drawn out into spindle-shaped bodies in strict alignment with the arcuate structure. Precisely the same phenomena have been noted in the central granodiorite at Tullycleave, on the southern side of the pluton.

D. Early and Late Foliation.

The second upwelling of magma during the diapiric emplacement of the pluton is believed to have been responsible for the setting up of the 'late foliation' in the inner part of the pluton. This is mainly coplanar with the 'early foliation' in the tonalite and the quartz-diorite marking the early phase of the pluton. Owing to the circular nature of the main body of the pluton, the only places where the two sets of foliation are clearly distinct from one another, are those parts where the outer margin of the pluton does not conform to a circular structure i.e. in the 'neck' of the pluton and in that portion of the pluton projecting outwards as at Ballyiriston and Maas.

At Lough Ananima, the 'late' vertical foliation

conforming to the boundary of the central granodiorite is clearly at variance with the 'early' foliation in the main part of the 'neck', which trends parallel to the wall-rock and dipping to the south-east. A remarkable anomaly in the foliation trends occurs in the district of East Ballyiriston and West Maas. Here the outer margin of the pluton has a right-angled outline, yet the width of the tonalite is more or less uniform. Prior to the second upwelling of magma, when the outer tonalite had already attained its strong foliation, the boundary of the pluton was in the form of the usual smooth arc, though perhaps a slightly obtuse angled projection. Due to the second upwelling of magma, a decrease in the confining pressure of the metasediment envelope was effected in this area by the metasediments sliding outward further along the Maas-Ardlougher Thrust. The plastic tonalite skin was apparently broken in two places, with the xenolithic quartz-diorite flowing in to fill the breaches. The north-western limb of the disrupted tonalite is deflected to the north together with its contact metasediments, while the eastern limb is clearly seen to be deflected aside towards the east. This eastern limb of the tonalite, at a locality due north of Lough Namanlagh, is 600yds. long and about 400yds. wide and appears to have been broken off and moved towards the north as a whole. Where the xenolithic quartz-diorite flows into the breach, west of Maas, the two rocks

interdigitate and possess numerous sharp contacts (Plate 7B). The striking feature is, however, that the xenolithic quartz-diorite is foliated and its usual amphibolitic xenoliths are also drawn out and flattened in the plane of foliation (Plate 7A); while the foliation of the tonalite trends about N. 155° E, that of the xenolithic quartz-diorite is about N.130 - 135° E.

The reason for the tonalite retaining its original foliation is both the advanced stage of development of the latter and the high viscosity of the tonalite itself ; probably it was almost solid. Evidence of this is the breaking apart as just described,

III. Deformation and Shape of Xenoliths.

A. Xenoliths in the Tonalite.

The xenoliths in the outer tonalite have already been described (p.125). The larger part of these are metasediments in slabby form and have not been rendered plastic by their host. They all lie with their longest axes parallel to the foliation of the rock, and platy masses of schist all lie within the plane of foliation i.e. they have been rotated by the distended viscous magma to the position of kinematic-equilibrium. Other semi-digested xenoliths of meta-sedimentary origin, which are drawn out into thin streaks, sometimes retain their original sedimentary banding parallel to their length; thus their present shape and relative

dimensions are of little value as evidence of their deformation. Amphibolitic and dioritic xenoliths are usually rounded, rarely are they flattened parallel to the foliation.

B. Xenoliths in the Xenolithic Quartz-Diorite in the Northern Sector.

The xenolithic quartz-diorite is characterised by abundant xenoliths of amphibolitic nature, flattened and drawn out parallel to the foliation of the rock; these are usually of even distribution. In several localities, xenoliths occur in 'swarms' over small localised patches. The individual xenoliths in the swarms are either rounded or subangular and even sometimes angular (Plate 6B). The granite host in these 'swarms' is also non-foliated. It seems improbable that the xenoliths owe their angular form to their not being in a plastic state, as many of them are in an advanced stage of reaction with the granite and appear as 'ghost' xenoliths, on the verge of disappearing in their contaminated quartz-diorite host. On the other hand, it appears that the quartz-diorite in these small patches has not undergone any considerable deformation, in exactly the same way as it has shown greater shear and deformation over certain zones in the Lough Fad and Burdeck areas (p.153). In these cases the granite has incorporated its xenoliths mainly by mechanical commingling.

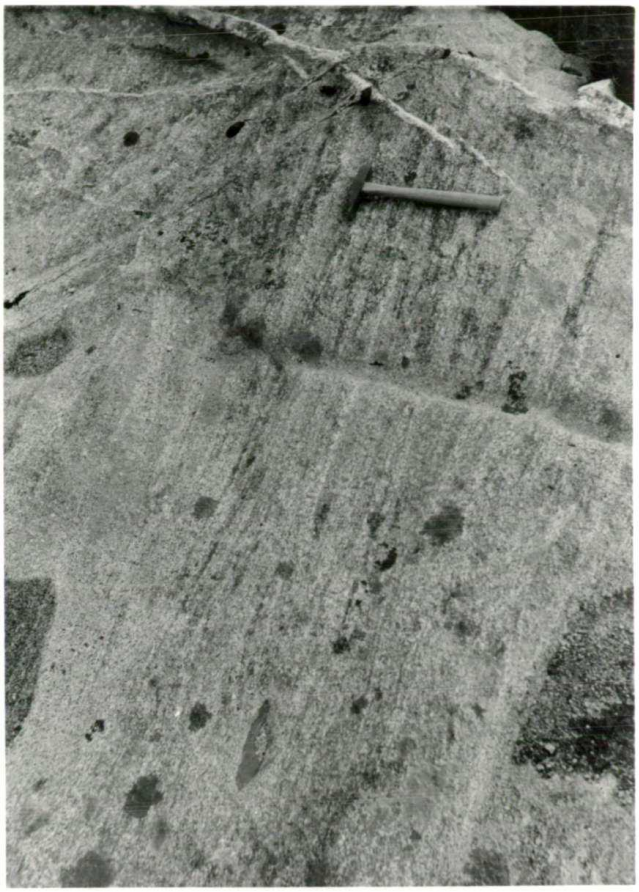
It can thus be inferred that the deformation of the

PLATE 9.

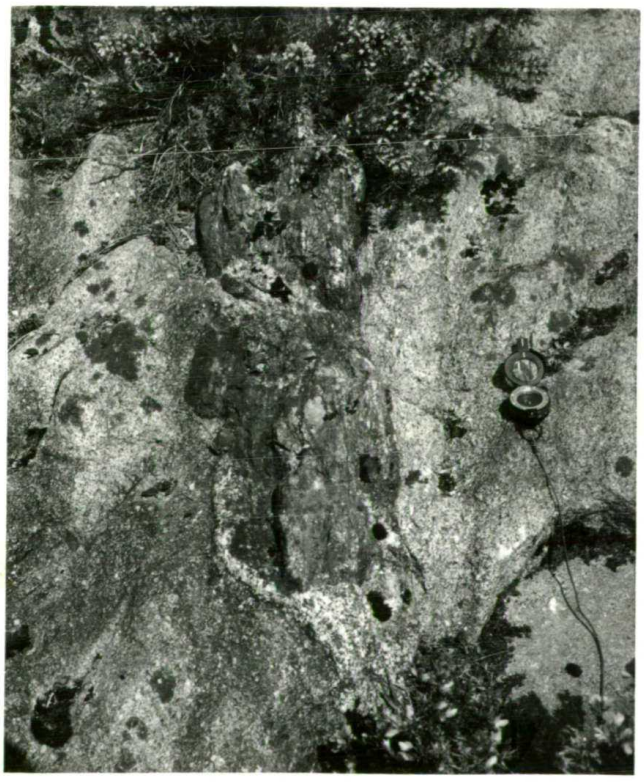
A. Part of the arcuate belt of hornblende-rich schlieren in the quartz-diorite at Burdeck, Lough Fad. The dark schlieren are finer grained than the light coloured granitic bands, they usually taper down and appear to be discontinuous.

B. A large xenolith of calc-amphibolite showing incipient boudinage structure with the foliation of the surrounding quartz-diorite closing in upon the break. Field due south of Parochial house, Kilcleeney.

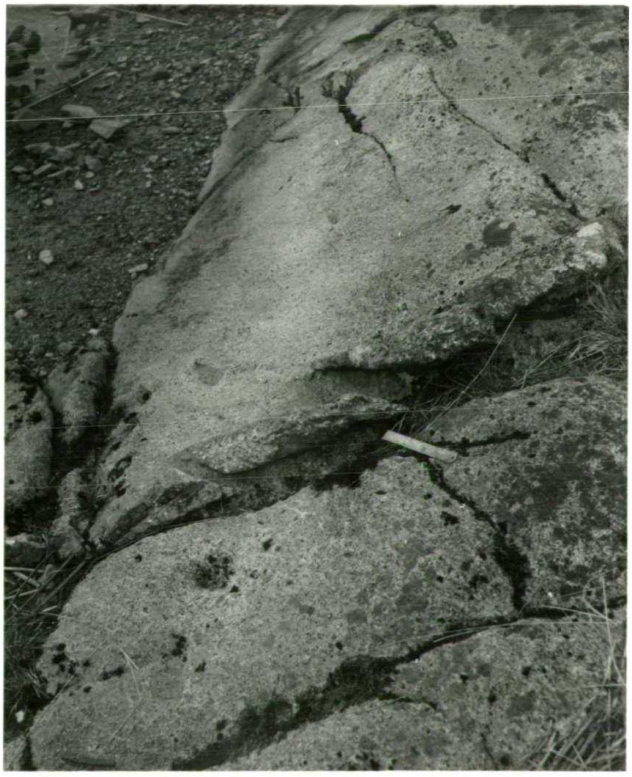
C. One of the 'early' pegmatite veins on the south-eastern shores of Lough Ananima trending N.N.W.- S.S.E. The vein is broken apart during the remobilisation of the surrounding quartz-diorite, and the segments of the vein are slightly rotated in the clockwise direction. The 6" scale is parallel to the foliation of the xenolithic quartz-diorite.



A



B



C

plastic xenoliths is directly related to the formation of the foliation in the granite, and that the relative dimensions of the deformed xenoliths represent the movements in the granite prior to complete consolidation. Xenoliths that have been studied in three dimensions, as in quarried exposures, were all found to be flattened in the plane of foliation to form ellipsoids the longest axes of which were horizontal, the intermediate axes vertical and the shortest axes normal to the foliation. On the flat surfaces of the exposures, the usual spindle shape of the xenoliths parallel to the foliation represents the longest and shortest axes of the flattened ellipsoids. The longest and intermediate axes of a xenolith, as seen in the plane of foliation, represent therefore, the relative distention in that plane.

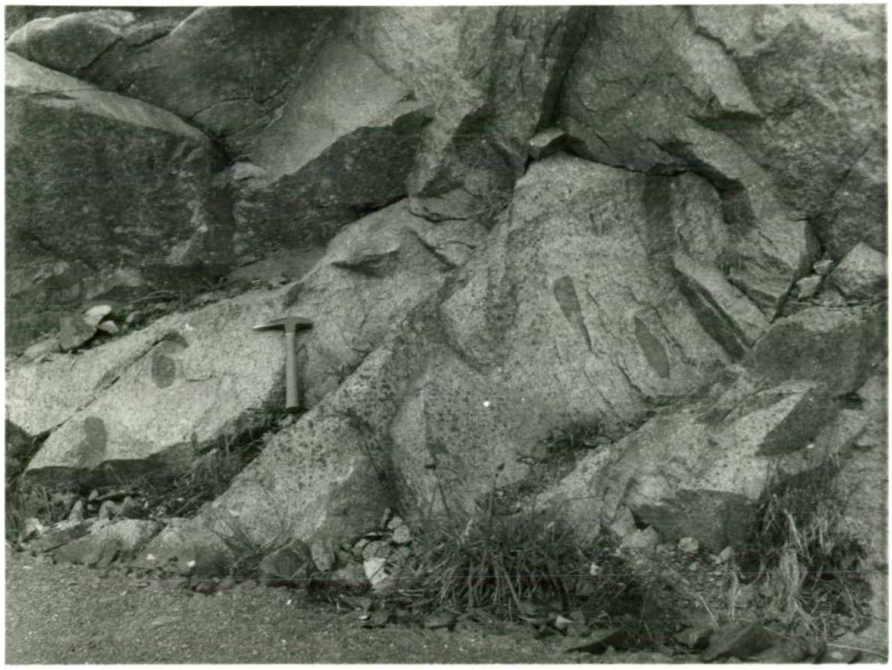
C. Boudiné Xenolith.

In the field due south of the Parochial House, Killcloney, the xenolithic quartz-diorite contains a large xenolith of calc-amphibolite origin (p.155). It measures 9ft. x 1ft, lying parallel to the foliation. The south-western part of the xenolith, about 18" long, shows incipient boudinage structure with the foliation of the rock closing in upon the break (Plate 9B). Not only does this demonstrate the considerable sub-horizontal tension, but also shows that the foliated quartz-biotite was in such a viscous state as to

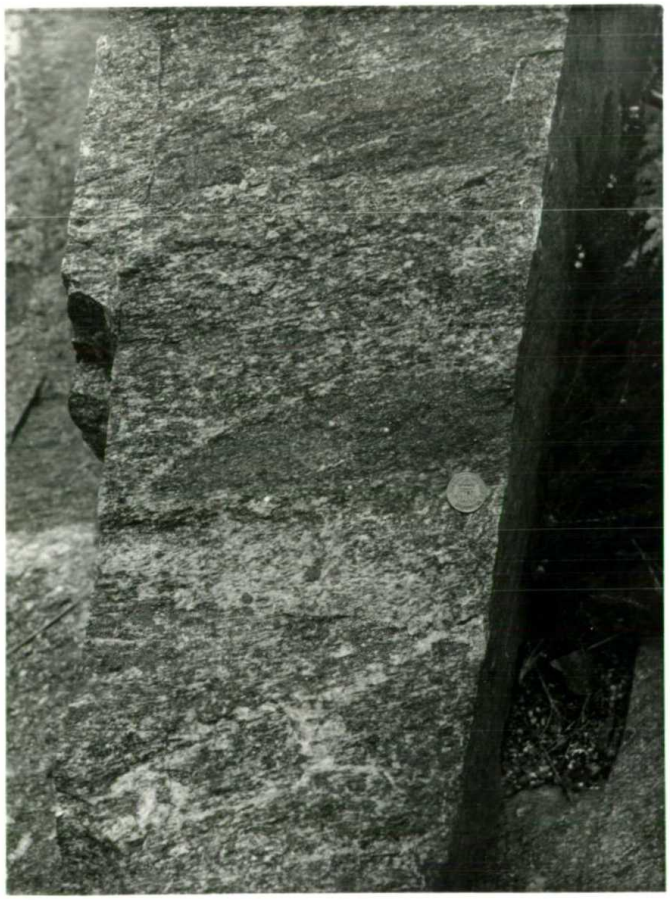
PLATE 10.

A. The quartz-diorite at Sruhangarve Bridge with its amphibolitic xenoliths flattened in the plane of foliation. The intermediate and shortest axes of the roughly ellipsoidal xenoliths are seen on the quarried face of the rock, meanwhile the longest axes lie almost horizontally in the plane of foliation, normal to the plane of the photograph.

B. The flattened amphibolitic xenoliths in the quartz-diorite of the 'neck', Sruhangarve quarry. The quarried face is parallel to the plane of foliation of the granite and shows the longest axes of the flattened ellipsoidal xenoliths to plunge at about 13° to the left (south-west) and that the intermediate axes are almost vertical. The shortest axes are normal to the foliation and the plane of the photograph.



A



B

be able to grip firmly the xenolith and tear it apart.

D. Xenoliths in the 'Neck'.

The late rodding structures superimposed upon the quartz-diorite of the 'neck', decrease gradually towards the south-west, and near Sruhangarve Bridge the primary structures are well preserved. The amphibolitic xenoliths are flattened in the plane of foliation dipping steeply to the south-east (Plate 10A), with the longest axes roughly horizontal. In the Sruhangarve quarry, about 130yds. east of the bridge, the flattened xenoliths have their longest axes plunging about 13° to the south-west (Plate 10B). This south-westernly plunge can be the result of the late movements as the secondary linear element becomes fairly distinct at this place.

IV. Fracture Systems in the Main Pluton.

A. General.

Fracture systems in the pluton, including both pegmatite-aplite veins and 'barren' joints, have been studied in relation to the other structures of the pluton. The statistical study of fracture systems was restricted to the outerparts of the pluton, almost the foliated zone consisting mainly of tonalite and xenolithic quartz-diorite. The outer margins of the pluton contain by far the largest proportion of the pegmatite-aplite veins and the joints in

these two granite types are readily measured. The central granodiorite is relatively poorer in pegmatite-aplite veins and in most places is entirely devoid of them. Also its joints cannot be readily measured owing to the nature of the weathering of the rock.

In the localities containing pegmatite-aplite veins, practically every vein of aplite, pegmatite or quartz has been plotted on an equal area net, with a sufficient number of joints on a separate diagram. Not all parts of the pluton are sufficiently well exposed to permit the statistical study of these structures, and thus in some localities, the generalised trend of the small number of veins has been noted.

All the pegmatite-aplite veins are straight, usually steep and vary in thickness between 2" and 6". In the northern sector, a few veins bifercate repeatedly and taper towards the inner part of the pluton. Pegmatite-aplite veins exhibit a distinct radial arrangement all over the circular body of the pluton. This is particularly evident in the northern sector. The 'neck' possesses a set of pegmatite veins trending N.W. - S.E. across the structure, and a much later set running N.E. - S.W. Radial pegmatite veins do not extend into the country rocks. At Maas, vertical dyke-like veins of micro-granite are radial, and are seen to cross the contact of the granite and metasediments.

There are two main joint systems in the pluton, a

radial system corresponding to the pegmatite-aplite veins, and a vertical system of longitudinal or tangential joints parallel to the foliation of the granite and formed subsequent to the formation of pegmatite-aplite veins.

B. Radial Pegmatite-Aplite Veins.

The arcuate periphery of the north-western, northern and north-eastern parts of the pluton possesses a system of radial veins of pegmatite and aplite. This radial system of veins consists of two distinct parallel-trending sets, one vertical and another dipping 46° - 55° W. In the well exposed south-eastern part of the pluton, radial quarts veins are abundant, dipping 50° W. In other parts of the pluton, pegmatite-aplite veins always exhibit a radial trend.

These veins represent the earliest formed fractures which have been formed during the two periods of cooling of the outer periphery of the pluton as a whole, and they are occupied by the final magmatic residua while the centre of the pluton was still unconsolidated. In this connection, Balk, R(1937) p.41, states that cross joints are formed if the outlying portions of an intrusion have began to consolidate while the interior remains in a partly fluid state.

Some parts of the granite pluton had undoubtedly experienced two periods of cooling associated with the presumed two upwellings of magma in the pluton. During the period

between these two magma upwellings, it seems that the xenolithic quartz-diorite in the outer parts of the pluton had cooled down sufficiently to allow the formation of pegmatite veins at distances over 1300yds. from the margin of the pluton. Such early-formed veins have been disrupted, boudinaged and slightly rotated as a result of the remobilisation of the xenolithic quartz-diorite during the second magma upwelling with its associated wave of heat.

On the south-western shores of Lough Ananima, the xenolithic quartz-diorite contains a few pegmatite veins about 4" thick trending N.N.W - S.S.E., which are members of the set of pegmatite veins crossing the 'neck'. These veins at Lough Ananima are broken apart, with the gaps in between filled with normal foliated granite (Plate 9C). In one or two cases, the spaces between broken segments of the veins reached a maximum length of about 6" giving the impression of a boudinage structure. The broken segments usually appear to have experienced a rotating movement acting horizontally in the clockwise direction. This, however, would be compatible with the development of the late vertical foliation in this area as a result of the compression due to the second upwelling of biotite-granodiorite magma in the centre of the pluton pushing against the 'neck'. Similar structures in pegmatite veins have been noted from the eastern and southern shores of Lough Kipp.

Disruption of early pegmatite veins has also been noted at several other localities particularly at the northern shores of Lough Nagurrah, Ballymackilduff, each at a distance exactly 1 mile from the margin of the pluton. Here the veins are broken obliquely to their length and dislocated sideways from 3" to 6" with the gaps filled with normal foliated granite.

C. The Two Sets of the Radial System of Veins.

The system of radial pegmatite-aplite veins consists of two parallel-trending sets, a vertical set and another set dipping 45 - 55° west or a westerly direction. It seems that the vertical set is later than the set dipping 50° W.

It has just been shown that the set of pegmatite veins trends N.W. - S.E. across the 'neck' dipping about 45° W., is essentially prior to the second upwelling of magma. Moreover this set is roughly normal to the elongation of xenoliths in the 'neck', and to the most probable direction of flow of magma in the 'neck'.

In the southern part of the pluton, between Tullymore and Owenea River, a set of radially trending veins of pegmatite dips 60° W. The joint diagram for the same locality shows the development of the complementary vertical set of radial joints (here 'barren') together with a high development of the usual late system of longitudinal joints. At

Doochill North, south of the above locality, 73 pegmatite veins form a radial set dipping 60° W. Meanwhile out of 23 aplite veins in the same area, 10 veins are radial and vertical and 13 are tangential or longitudinal. These constitute the only case of longitudinal or tangential pegmatite-aplite veins, and thus appear to be of late origin along with the vertical radial aplites.

In view of the following evidence, however, the vertical set of radial veins is thought to be later. First, the vertical veins are normal to the longest axes of the deformed plastic xenoliths, particularly within the xenolithic quartz-diorite - this stretching is undoubtedly related to the very final movements in the granite. Secondly, all radial dyke-like veins of microgranite in the Maas area are vertical. The third point is that the 'neck' which has not been affected by the second upwelling lacks a vertical set of veins parallel to the one dipping 60° W. A similar early system of radial fractures consisting of a vertical set and another dipping at an angle of about 60° has recently been described from the Flamanville massif by Martin N.R. (1951). He states that "The reason for development of only two joints separated by an angle of 30° is not understood".

D. Systems of Joints.

The diagrams of the joints in the pluton show the presence of a radial system of barren joints identical with the system of pegmatite-aplite veins. Some of these have either failed to be intruded with pegmatite-aplite rest-liquids, or were formed subsequent to the hydrothermal phase. The vertical set of radial joints can be appropriately named Cross Joints, in view of their being normal to the longest axes of the flattened xenoliths and the direction of tension in general. These joints as seen in quarried exposures are very smooth and clean cut relative to the other joints.

In the area of Lough Derryduff and Lough Aderry, where there are practically no pegmatite-aplite veins, the same system of radial joints is developed in the central granodiorite.

A comparison between the diagrams of pegmatite-aplite veins and joints clearly shows that a system of joints parallel to the arcuate foliation of the pluton was formed subsequent to the radial fractures. These tangential fractures are essentially Longitudinal Joints, and represent the final shrinking of the granite mass. The rupturing takes advantage of the weak arcuate planes of foliation.

V. Secondary Structures in the 'Neck'.

A. General Statement.

The foregoing has dealt with the detailed structure of the Ardara pluton in relation to its emplacement in the form of two upwellings of magma. Nevertheless, the larger part of the 'neck' of the pluton contains secondary structures impressed upon the granite while the latter was in a more or less solid state. These structures appear to be entirely independent of the emplacement of the main part of the pluton. They seem, however, related to the emplacement of the pegmatitic fringe of the Doocharry Granite.

The secondary movements result in the formation of a lineation, rodding and mullion structures all plunging gently to the south-west. They are particularly distinct in the xenolithic quartz-diorite, and in general show an increase in intensity towards the north-eastern part of the 'neck', progressively obliterating the primary "flow" structures. This linear element is identical to that encountered in all the metasediments in the southern parts of the area as will be considered in detail (p.336).

Fig.4 represents the stereographic projection of the lineations, mullions, rodding and deformed 'early' pegmatite veins and 'late' straight pegmatite veins.

B. Secondary Lineation in the Quartz-Diorite.

The xenolithic quartz-diorite in the 'neck' possesses

FIGURE 4.

Stereographic projection of the structural elements in the 'neck' of the pluton. The foliation in the granite trends N.E.- S.W. parallel to the outer margin and the regional strike of the Glenties Series. 'Early' pegmatite-aplite veins now progressively deformed as in Plate II A, B and C - have a generalised trend running N.W.- S.E. across the foliation. Secondary lineations, rodding and mullion structures plunge at 15 - 20° S.W. A set of 'late' pegmatite veins younger than the late movements run N.E. - S.W. parallel to the foliation in the granite.
(lower hemisphere of equal area net).

PLATE II.

A. The first stages of deformation of 'early' pegmatite-aplite veins in the xenolithic quartz-diorite south-west of Sruhangarve Bridge. Looking towards the north-west and compass parallel to the granite foliation.

B. 'Early' pegmatite-aplite veins south-east of the quarry at Sruhangarve with distinct rodding plunging 20° S.W. Photo looking south-east .

C. Ultimate deformation of 'early' pegmatite veins near Meenalargan Village, the hammer is parallel to the strong secondary lineation in the granite.

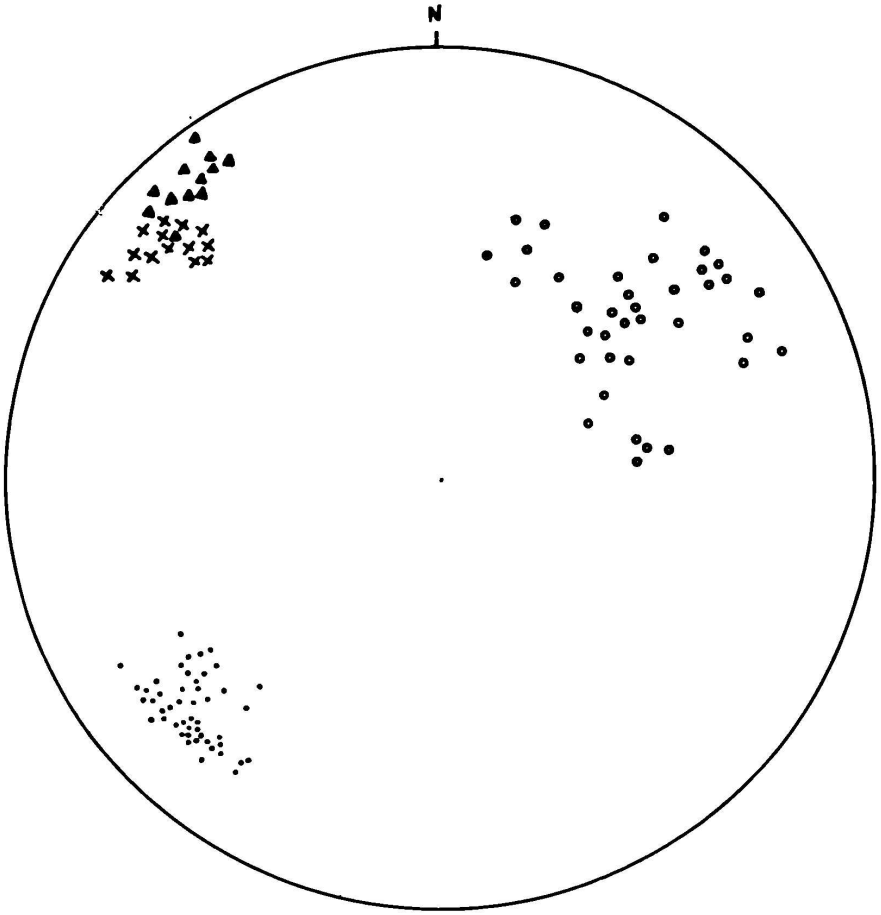
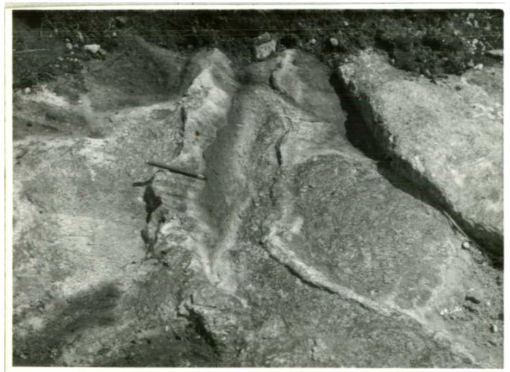


Fig.4 Structural elements in the 'neck'.

- Secondary lineation, rodding and mullions
- Poles of deformed 'early' pegmatite-aplite veins
- Poles of 'late' straight pegmatite-aplite veins
- Poles of foliation



A



B



C

a strong lineation marked by the parallel alignment of the ferro-magnesian minerals in thin lines and streaks, plunging 15° - 19° S.W. Its first appearance can be represented by a line running from Sruhangarve bridge northwards and approximately 100yds. west of the river. The lineation becomes more intense towards the north-west and the primary foliation of the rock decreases accordingly. The two structures vary inversely, and at Meenalargan village, where the secondary linear element reaches a maximum development, the foliation is hardly perceptible. (Spec.792).

C. Mullion Structures.

Mullion structures occur at several places in the well exposed section of the Sruhangarve river, particularly behind Sruhangarve House and at another point about 350yds. up the stream. The granite forms log-like bodies about 1ft. in diameter, and with the same plunge as the lineation.

D. Rodding and Deformation of 'Early' Pegmatite Veins.

The development of the secondary linear elements in the granite of the 'neck' is accompanied by the rodding and deformation of 'early' pegmatite veins trending N.W. - S.E. The first signs of deformation is seen south-west of Sruhangarve Bridge; where a set of parallel pegmatite veins begin to undulate (Plate 11A). These are crossed by a later straight vein of pegmatite. To the south-east of

Sruhangarve quarry, pegmatite veins possess a distinct rodding plunging about 15° S.W. (Plate 11B). Further north-east, these 'early' pegmatite veins are thrown into intricate folds (Plate 11C), but usually their original N.W.- S.E. trend can be inferred.

E. 'Late' Pegmatite Veins in the 'Neck'.

The 'Neck' of the Ardara pluton, with its rodded and deformed 'early' pegmatite veins trending across its length, is cut by a set of straight veins of pegmatite parallel to the foliation N.E.- S.W. They first appear at the western side of Sruhangarve Bridge and extend towards the north-east. They are especially abundant in the tonalite extending from Sheskinatiny Bridge to the north-east of Woodtown, where these are ultimately seen to cut across the interdigitating contacts with the Doocharry Granite.

VI. Structure and Time Relation of the Pegmatite Fringe of the Doocharry Granite.

The pegmatite fringe of the Doocharry Granite, which cuts across the 'neck' of the pluton, contains large rafts of strongly lineated and rodded quartz-diorite with its associated deformed early pegmatite veins.

In thin section, the typical Doocharry Granite, within the present area, exhibits cataclastic textures (p.183). As seen on the map, this granite has a lineation identical to

that in the adjacent xenolithic quartz-diorite. Towards the south-eastern part of the 'neck', a clear foliation trending N.E. - S.W. and dipping steeply to the south-east becomes gradually more distinct in this fine-grained granite towards its south-eastern contact with the Glenties Series.

It is clear, therefore, that this outer part of the Doocharry Granite appears to have been emplaced during the late movements responsible for the secondary structures in the 'neck', and that these movements have proceeded in a mild way to well beyond the cooling of the granite.

The lineation in the pegmatitic fringe of the Doocharry Granite is undoubtedly a secondary structure, similar to that in the other rock types in the 'neck'. Also it can hardly be considered as due to primary flow of liquid magma at a place where the granite is seen to end against the relatively older granite types of the 'neck'.

VII. The Tonalite - Summary of Observations.

The outer foliated tonalite has already been dealt with in detail (pp.111-133), and in general it possesses peculiar properties, and is also in many ways different from the medium-grained core of the pluton including the biotite-granodiorite and the contaminated biotite-hornblende-quartz-diorite. The following are the main points of anomaly :-

1. With regard to its enclaves, the tonalite contains very thin streaks of semi-digested metasediment enclaves

which seem to characterise it as a rock type in the field, and whose minerals show a convergence towards those of the tonalite. The tonalite also contains other types of angular and slabby fragments of metasediments which have been almost entirely unaffected by the magma. No xenoliths occupy an intermediate position both as regards shape and deformation, on one hand, and reaction on the other hand. In exactly the same way, the tonalite contains small size 'ghost' xenoliths of a dioritic nature drawn out parallel to the foliation, and other angular and subangular xenoliths of variable amphibolites and foliated metadolerites almost unaffected by the magma. Again, there are no dark xenoliths in an intermediate stage,

It is rather peculiar that the tonalite magma was contaminated at a low level with the semi-digested enclaves and that it had subsequently picked up the angular and slabby xenoliths at a relatively higher level, because there would still be the usual series of intermediate stages in resorption among those xenoliths picked up at a low level, as in the quartz-diorite.

It seems more probable, however, that the highly deformed bodies in an advanced stage of assimilation are related to its genesis, meanwhile the other angular, slabby and unaffected inclusions are <u>real xenoliths, detached</u> from the envelope of the pluton.

2. The plagioclase in the medium-grained body of the pluton, whether the central biotite-granodiorite or the highly contaminated quartz-diorite, is of uniform composition about An.25 and the crystals are about 2 - 3 m.m. long. The plagioclase in the tonalite has a composition of An.34 and occurs in stout crystals about 10-12 m.m. long.

This latter plagioclase in the tonalite usually contains inclusions of pale green actinolitic hornblende with minute poikilitic inclusions, similar to that in the unreacted dark xenoliths in the tonalite. The plagioclase also occasionally contains inclusions of pale green to colourless diopside, apparently from the calc-rocks of Meenalargan.

3. The indentations and embayments along the northern boundary of the neck and the Meenalargan amphibolitic complex, contain tonalite. The actual contact between the quartz-diorite and this amphibolitic complex is marked by a thin discontinuous screen of variable rock either pertaining to the tonalite or consisting of somewhat modified varieties of the tonalite. The tonalite is seen to be connected with the complex in this area.

4. The following observations are of great interest as regards the physical condition of the tonalite in general and also relative to the corresponding physical condition of the medium-grained main body of the pluton.

(a) What can be readily recognised as real xenoliths in the tonalite do not appear to have ever been rendered plastic by the tonalite magma. Not only do they retain their sharply angular and slabby form, but xenoliths of a semi-pelitic nature retain such very delicate structures as fine fracture cleavage and metadolerite xenoliths their shear. Petrographically, the xenoliths are practically unaffected.

(b) The tonalite is of a remarkably uniform grain size, and does not possess any fine grained chilled margins. Its contacts with the metasediments are very sharp and exhibit no indentations or apparent transfer of material.

(c) Apart from the gneissic foliation in the marginal parts of the tonalite, the nature of the foliation in the tonalite as a whole, suggests that the magma was in a highly plastic condition from the outset. Its foliation appears very different from that in either the quartz-diorite or the biotite-granodiorite in the southern part of the pluton.

(d) The outer tonalite at Maas-Ballyiriston forms a band about 400yds. wide. A part of this band, about 600yds. long, seems to have been actually broken apart while the contaminated quartz-diorite was in a molten condition and has flowed in together with its dark xenoliths to fill the breaches in the outer mantle of the pluton.

(e) The late movements which h ve caused the secondary

linear structures plunging south-west in the quartz-diorite of the neck, in the pegmatitic fringe of the Doocharry Granite and in the metasediments of the Glenties Series, have failed to impress such secondary structures upon the coarse tonalite in the 'neck'. Although the exact reason for this phenomenon is not known, yet the tonalite appears to have been in a different physical state from the other granitic types.

From the foregoing, the following three points can be inferred :-

1. The tonalite is independent in origin from the biotite-granodiorite and its contaminated derivative the xenolithic quartz-diorite.

2. The tonalite was in a relatively colder state since the beginning of its emplacement.

3. The tonalite is closely related to the migmatitic amphibolitic complex of Meenalargan, and most probably is the mobilised derivative of this complex.

VIII. The Second Upwelling of Magma.

It remains now to locate approximately that part of the central biotite-granodiorite which formed the presumed second upwelling of magma. Mainly on structural and field evidence, it seems that the late second upwelling of biotite-granodiorite magma is represented by at least a large part of the northern half of the central granodiorite ;

that part of the latter bounded by the following localities, Lough Makeer, Moolagh, north of the Tullymore drumlin, the northern shores of Lough Mc.Hugh, Lough Derryduff, Loughs Nagurrah and Gunnell and finally Kilclooney Bridge. This area can be referred to as the northern part of the central granodiorite. The following observations about the southern part of the central biotite-granodiorite confirm its close association with the xenolithic-quartz-diorite as regards the time of emplacement.

1. The southern part of the central granodiorite is in contact with the outer tonalite mantle, and in the circular structure of the pluton, it corresponds to the xenolithic quartz-diorite of the northern and north-eastern sectors.

2. It contains occasional dark xenoliths of the same texture as those in the xenolithic quartz-diorite.

3. It possesses a vertical foliation trending in an arc the centre of which lies in the middle of the northern part of the central granodiorite. Dark xenoliths are flattened in the plane of foliation.

4. It contains pegmatite and quartz veins and the systems of barren joints are compatible with the fracture systems developed in the peripheral zone of the main body of the pluton.

5. In the field, it is rather difficult to differentiate between some of the southern part of the central granodiorite and the quartz-diorite.

On the other hand, the northern part of the central granodiorite is entirely free of xenoliths, pegmatite-aplite veins, and of any perceptible foliation. It also shows the maximum contrast with the xenolithic quartz-diorite.

IX. Summary of Emplacement and Structures of the Ardara Pluton.

It has been shown that subsequent to the Main Orogeny and Regional Metamorphism of the area, and also subsequent to the beginning of the activity of the Lamprophyre-felsite suite of dykes, thrust movements of considerable magnitude, associated with a diaphthoresis, have taken place in the southern part of the area. These thrust movements from the south-east have given rise to two major and parallel thrusts trending N.E.- S.W. and dipping to the south-east; first a thrust carrying the Quartzite Group over the Glenties Series and a second thrust by which the whole N.E. - S.W. trending belt of metasediments, including the Glenties Series and Quartzite group, is thrust against the Mulnamin Anticline. The latter thrust, the Glenties Thrust, coincides approximately with the southern contact of the pluton.

The emplacement of the Ardara pluton was first effected by the movement of biotite-granodiorite magma along the Glenties Thrust. At a low level below the present 'neck' and probably to the north-east of it, the incoming magma encountered what is thought to be the mobilised derivative

of the Meenalargan Migmatitic-Amphibolitic Complex - now the outer tonalite, and swept the latter with it in the form of a more plastic skin or mantle. At the same time, the granodiorite magma came into contact with the amphibolites of the complex, resulting in considerable interaction between the amphibolites and the magma. A considerable number of fragments of amphibolites together with their derivatives were detached.

The uprising contaminated magma - now a quartz-diorite in composition and loaded with dark xenoliths - gradually made its way along the major thrust, and with the tonalite skin began to accumulate along the south-western flank of the Mulnamin Anticline to form a small globular body, a nucleus of the diapir. This accumulation of magma inside a plastic skin appears to have taken place at the point of divergence between the Glenties Thrust and the south-western flank of the Mulnamin Anticline. With the further feeding of the inflating diapir with contaminated xenolithic quartz-diorite, the tonalite was finally swept away from part of the northern boundary of the 'neck', and the quartz-diorite came in contact with the altered borders of the Meenalargan amphibolitic complex even at this high level. The incoming magma did not all enter through the 'neck' in the horizontal direction, but also in an upward direction along the Glenties Thrust.

At the south-eastern end of the pluton, the tonalite is in contact with foliated biotite-granodiorite containing a

small number of xenoliths of amphibolitic nature, but the rock is not contaminated and is entirely free of amphibole. This seems to suggest that after all the contaminated quartz-diorite rich in dark xenoliths was exhausted, and the 'neck' probably solidified, further biotite-granodiorite magma essentially uncontaminated but merely containing occasional small xenoliths, was making its way up along the main dislocation. This marked the end of the first and main phase of the emplacement of the pluton.

The swelling of the diapir resulted in the complex thrusting and shouldering of the metasediments, particularly on the northern side of the pluton. At that stage, the outer part of the pluton possessed a foliation running parallel to its margins and dipping everywhere to the south or southernly direction. This structure existed along the northern boundary of the 'neck', extending all around the mass and back again into the 'neck'. The outer margins of the circular body began to cool and radial fractures began to develop, while the centre of the pluton was still in a molten state. These fractures were occupied by pegmatitic residual liquids marking the hydrothermal phase of this cooling.

A second upwelling of uncontaminated biotite-granodiorite magma, entirely free of xenoliths, pierced its way through the still molten centre of the pluton, accompanied by a considerable wave of heat. This marks a vital phase in the

emplacement of the pluton and the history of the contact-altered metasediments. Thus the congealing granite was once more mobilised and the early solidified outer periphery probably attained a plastic condition.

The mechanical effects of dilation were the further shouldering of the metasediment envelope and the further sliding of large blocks upon previous planes of dislocation. In the granite, the original foliation was accentuated by further areal distention along the plane of foliation, causing a wider zone of the xenolithic quartz-diorite to become foliated by merely flattening the minute clots of ferro-magnesian constituents. Plastic amphibolitic xenoliths were also flattened in the plane of foliation and elongated in the horizontal direction.

Pegmatite veins in the inner parts of the xenolithic quartz-diorite are disrupted as their host is rendered plastic and slightly mobile.

Where the confining pressure in the metasediment envelope gave way rather suddenly, the outer tonalite mantle was actually broken apart and the xenolithic quartz-diorite flowed in to fill the breaches.

The final stages of the second upwelling of magma, probably when the outer margins were beginning to cool, is marked by the central granodiorite sending vein-like apophyses into the xenolithic quartz-diorite and outer tonalite.

The second upwelling of magma is separated by the northern part of the central granodiorite, which shows no perceptible foliation, no dark xenoliths and no pegmatite-aplite veins.

The first fractures developed during the second cooling of the pluton were again radial, apparently vertical, and some of these fractures were filled with hydrothermal pegmatite-aplite residual solutions. Longitudinal joints parallel to the foliation of the granite mark the final cooling of the pluton.

At about this stage, or probably before the longitudinal joints were formed in the main body of the pluton, late movements have impressed upon the granite of the 'neck' secondary linear structures plunging gently to the south-west. During these later movements, and essentially subsequent to their climax, the pegmatitic fringe of another member of the Donegal Granite Series, provisionally named the Doocharry Granite, was emplaced across the 'neck'. This was apparently associated with the intrusion of dyke-like veins and flat-lying sheets of microgranodiorite in the main body of the pluton.

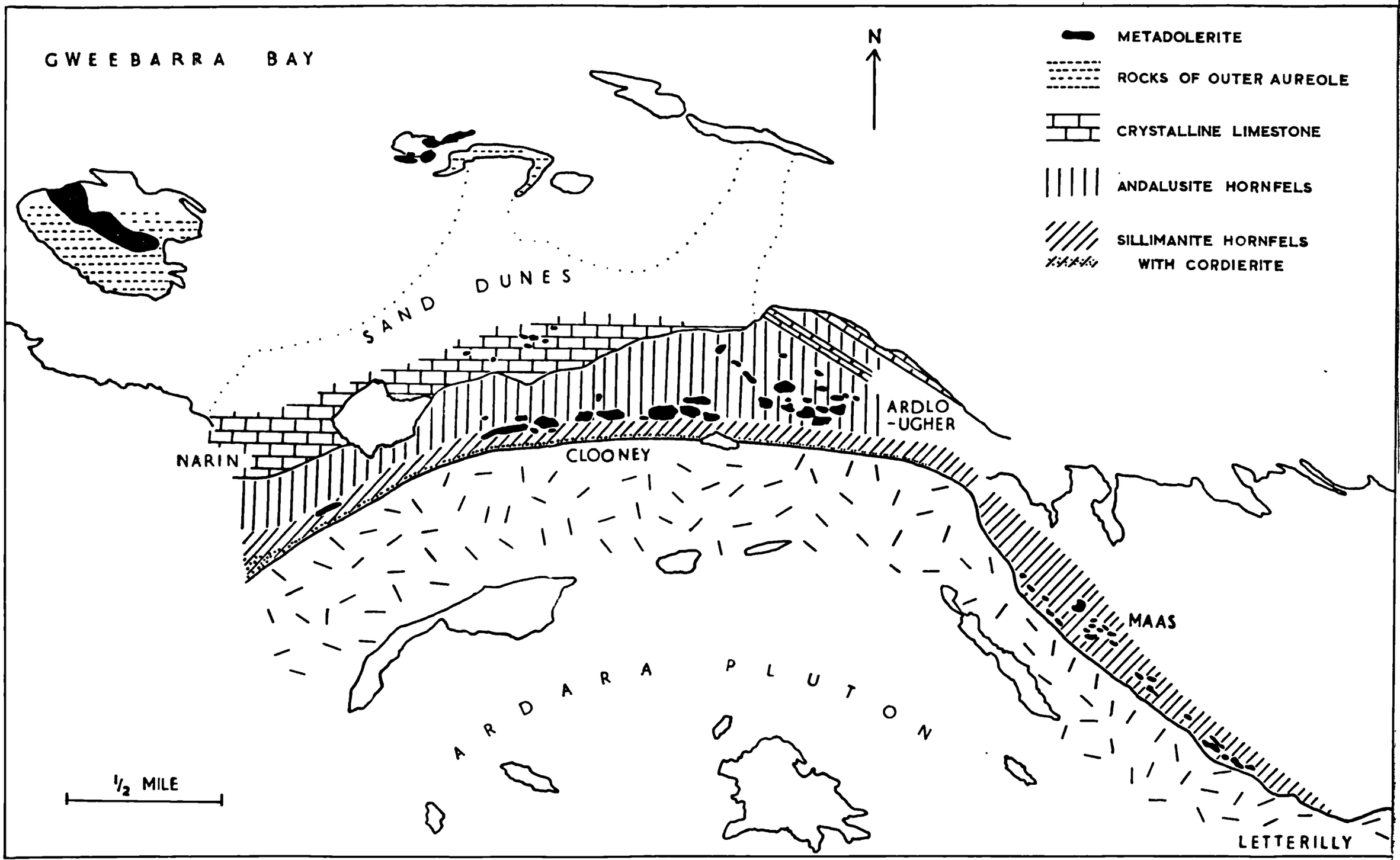
Chapter EIGHT.

THE NORTHERN AUREOLE - THERMAL METAMORPHISM OF METASEDIMENTS.

I. Introduction.

The Ardara pluton is bounded on its northern and north-eastern sides by a wide aureole of thermal metamorphism. This thermal or contact metamorphism has been impressed upon rocks which have undergone two main metamorphisms. This third metamorphism tends to obliterate the records of the two previous meta-morphisms progressively from outside the aureole towards the granite pluton.

The aureole is divided into an 'Inner Aureole' and an 'Outer Aureole' by a thick 'Limestone Barrier', which is itself almost unaffected by contact metamorphism. The rocks of the inner aureole are of pelitic composition, exhibit high grade thermal metamorphism and have a width of half a mile on the northern side. The most important features characterising the inner aureole are, first, that it possesses distinct 'metamorphic zones' each of which is characterised by an 'index mineral' and, secondly, that it consists of an inner moved part or 'Zone of Mobilisation' and an outer relatively unmoved part. The outer aureole is largely covered by drifting sand, and the exposed rocks along the shores of Gweebarra Bay at Inishkeel, Carrickfad and Grabbindoo, are at distances of about one mile and one and a half miles


GWEEBARRA BAY
N
METADOLERITE
ROCKS OF OUTER AUREOLE
CRYSTALLINE LIMESTONE
ANDALUSITE HORNFELS
SILLIMANITE HORNFELS WITH CORDIERITE
SAND DUNES
NARIN
CLOONEY
ARDLO-UGHER
MAAS
LETTERILLY
ARDARA PLUTON
½ MILE

from the granite contact. These do not show complete re-crystallisation due to contact effects, but exhibit notable mineralogical rearrangements.

The area covered by this thesis includes only a thin strip of contact altered metasediments on the north-eastern side of the granite, lying west of the main Maas-Glenties road and stretching from Ballyiriston to near Letterilly House. These metasediments consist of sillimanite hornfelses.

The main rock types found in the aureole are of pelitic and semi-pelitic composition, a few calc silicate bands and associated metadolerites. Limestones with intercalated pelitic and semi-pelitic bands form an important group. A few older lamprophyre dykes are also present in the northern part of the aureole.

The pelitic and semi-pelitic rocks, together with the thin calc-silicate bands show marked mineralogical recon-stitution, with the development of contact minerals such as andalusite, sillimanite, staurolite, cordierite, garnet and biotite in the pelites and semi-pelites. Grossular, idocrase, zoisite, clinozoisite, epidote, sphene, diopside and tremolite develope in the calc-silicate bands. On the other hand, the limestones, metadolerites and lamprophyres are affected to a far less degree, and exhibit a considerable 'metamorphic lag' behind the other rock types.

In the field, it is clear that the pelites and semi-

pelites, as well a the metadolerites, have recrystallised in a different manner in the Clooney area from that of the Maas area.

Vein-like exudations or 'sweats' of quartz and andalusite have developed in the hornfelses at Clooney.

The most salient feature of the whole contact aureole of the Ardara pluton is, no doubt, the thick belt of pelitic hornfelses bounding the granite on the north - the Clooney Hornfelses. This belt of hornfels is of considerable interest due to its zoned nature as well as the excellent development of the mineral andalusite. It is very well exposed. It is on this account that the lithological division is named the Clooney Pelitic Group.

Near the north-western corner of the writer's area, the pelitic hornfelses form the eastern foot of Narin Hill, and the block bounded by the bifercation of the road from Ardara. At this spot, the hornfelses are in contact with the granite. They proceed towards the east for a short distance before they disappear in the lowlands south of Clooney Lough. The main mass of hornfels begins from the road along the eastern shore of Clooney Lough, and quickly ascends to form the high ground towards Clooney Hill (250') and further east Cashelgolan Hill (304'). From hence, it gradually descends towards Ardlougher. This single well exposed mass consisting mainly of andalusite hornfels stretches for one-and-a-half-miles east-west, and its breadth varies from 350yds. at

Clooney Hill to about 650yds. at Cashelgolan Hill. At Ardlougher, the hornfelses of this group end adruptly against a major structural break - the Ardlougher Thrust.

The strike of the contact metasediments in the aureole together with their associated metadolerites swings round forming an arcuate structure parallel to the contact of the granite, from N.E. - S.W. at Narin to E.-W. at Clooney, and finally E.S.E. - W.N.W. at Ardlougher. In the main part of the hornfelses the dip remains fairly constant at about 60° S. The dip of the bedding plane is always towards the granite, and in a zone about 80yds. wide surrounding the granite, the metasediments together with their metadolerite masses, stand vertical or nearly so. All along the contact zone, steeply dipping and vertical structures are developed. The more competent bands in the metasediments as well as the thinner members of the sill-like metadolerites and early quartz veins show marked boudinage structures. Where the boudins are not vertical, their direction always plunges steeply towards the granite contact. Only a few boudins lie horizontal and tangential to the contact.

The contact of the granite and the metasediments is well exposed in several places, the best of which is near the Ardara road. The contact between the gneissic margin of the tonalite and the highly mobilised and massive hornfels

is distinct and sharp, and is usually marked by the presence of tourmaline. Excellent contacts are seen all the way from Ballyiriston through Maas towards Letterilly, where the granite forms a long ledge some 20 or 30ft. above the hornfels. Thin layers or 'crusts' of the mobilised hornfels still adhere to the vertical wall of the tonalite. The hornfelses in the Clooney area are traversed by a dislocation running parallel with the contact and followed by the main Portnoo-Maas road.

II. The Inner Aureole - the Clooney Pelitic Group.

A. Introduction and General Description.

In general terms, the inner aureole includes all the metasediments lying between the 'Limestone Barrier' - Lower Portnoo Limestone - and the northern and north-eastern contacts of the Ardara pluton. This comprises the metasediments of the Clooney Pelitic Group stretching from the north-eastern foot of Narin Hill in the west to Ardlougher in the east, as well as the strip of contact metasediments bounding the granite from Maas to near Letterilly. The Upper Portnoo Limestone, forming the structural block at Ardlougher and Drumshantony, also falls within the inner aureole and some of its horizons consist of andalusite hornfels, identical with the Clooney hornfelses. But in view of the fact that other members of the Upper Portnoo Limestone show a different type of metamorphism, and that the study of this throws more

light upon the thermal metamorphism in the aureole in general, the Upper Portnoo Limestone is dealt with separately from the Clooney and Maas hornfelses.

The metasediments of the Clooney Pelitic Group, as seen in the inner aureole, consist of pelites with minor semi-pelites and thin calc-silicate bands and include a notable series of metadolerite bodies. The best example of a semi-pelitic horizon is found where the Clooney road ascends and joins with the Ardara road. At that point, the sub-vertical and steeply dipping hornfelses are grey in colour with a granulitic appearance, and are particularly well exposed in two small road-side quarries. Due to their semi-pelitic nature, they are strongly affected by late shear, more obviously so than the pelites.

The pelites, which form the larger part of the group, show varied types of banding produced by the alteration of pelitic and semi-pelitic bands. Sometimes the pelites show graded bedding, but more often it is a rhythmic banding. The thickness of the individual alternating bands varies rather widely. Generally the upper part of this group is less pelitic than the lower part, and lacks the alternately banded nature. The pelitic bands are crammed with crystals of andalusite.

B. <u>Sub-division into Metamorphic Zones</u>.

It has been stated earlier that andalusite shows a

rather high degree of development in a large part of the Clooney hornfels. Nevertheless, the hornfelses nearer to the granite are devoid of andalusite, and in the field, it has been possible to classify the hornfelses into two distinct and mappable zones; an inner Sillimanite Zone and an outer and much wider Andalusite Zone. This field classification has been confirmed petrographically.

Also on a petrographic basis, the sillimanite zone was found to include a Cordierite Sub-Zone marking the immediate contact of the granite pluton. It will be best, however, to describe the widespread sillimanite-hornfels first.

C. The Sillimanite Zone.

1. The Sillimanite Hornfelses of Clooney. The sillimanite zone in the Clooney hornfelses is of remarkable uniform width, varying only between 120yds. and 140yds. from the granite contact outwards. In the north-west, it begins at the Narin crossroads, and extends through Clogher, Clooney and south of Ardlougher to Ballyiriston Bridge. The whole of the strip of contact metasediments at Maas is in the 'sillimanite grade'.

In the Clooney area, the sillimanite hornfelses are usually fine grained, dark grey to brownish grey in colour, and of a massive nature. No minerals are readily discernible in the hand specimen, except occasionally some pink garnet, biotite and even more rarely web-like aggregates of

sillimanite. The sillimanite hornfelses can be studied particularly well from fresh specimens gathered in a series of small quarries north of the main Clooney-Maas road.

2. Petrography of the Sillimanite Hornfelses of Clooney. The greater part of the sillimanite hornfelses are affected by strong shearing - the cause of a late local retrograde metamorphism. Sillimanite and staurolite change to sericite and the biotite to chlorite.

Typical representatives of the sillimanite hornfelses that have escaped late shearing consist of sillimanite, biotite, cordierite, staurolite, garnet, quartz and plagioclase.

Sillimanite occurs in the form of felt-like aggregates and nests of fibrolite enveloping spindle-shaped flakes of biotite along the foliation plane. Only rarely does it appear as slender crystals. At Marin crossroads, the sheared crystals of sillimanite stand out on the weathered surfaces. The recrystallised quartz is crammed with needles of fibrolite Garnet occurs either in small corroded grains or larger broken crystals and irregular masses, but is sometimes of limited occurrence. Staurolite is of very restricted and sporadic occurrence.

Cordierite is of special interest, as its occurrence is restricted to the immediate contact of the granite; it has been found to occur at up to a maximum distance of

40yds. from the contact of the granite.

Elongated poikiloblasts of andesine plagioclase about An.40 lie parallel to the schistosity of the rock. Well developed albite twinning is usually at a high angle to the schistosity. Trails of fine inclusions and blebs of quartz pass through the poikiloblasts unhindered.

In addition to retrograde mineralogical changes, the most important of which are the sericitisation of sillimanite and staurolite, and the development of large plates of muscovite, the rocks show mild cataclastic textures (slices 62 and 91).

3. The Sillimanite Hornfelses of Maas. The contact metasediments at Maas, within the writer's area, form a thin strip trending N.W. - S.E., from Ballyiriston Bridge to Letterilly House and lying between the main Maas - Glenties road and the north-eastern boundary of the Ardara pluton.

These metasediments are pelites, lacking semi-pelitic horizons, and belong to the Clooney Pelitic Group. In general appearance, these hornfelses are brownish grey in colour, medium grained, and usually of a non-schistose massive nature. Index minerals are never seen in the hand specimens, though occasionally small crystals of staurolite occur. They differ from the Clooney hornfelses in several points. One point of difference, between the hornfelses at Clooney and those of Maas, lies in the fact that the latter are intimately

associated with a large amount of quartz in the form of veins, stringers and small irregular masses. These are particularly abundant where the rock shows evidence of mobility and swirling when in a plastic condition (Plate 12D). The larger part of the quartzose material appears along the original bedding of the rock, where this still survives. In many places the bedding is found to be continuous only over a distance of a few inches.

As to the origin of the quartz occurring in the hornfelses at Maas, the writer is inclined to ascribe a large part of it to endogenous secretion by the rock in which it occurs. No faser - kiesel has so far been observed in these veins. On the other hand, quartz occurring as well formed quartz veins, including two or three ptygmatic quartz veins, are most probably of igneous origin.

The hornfelses at Maas are also associated with granitic material in the form of veins or lens-shaped bodies, varying in width from ¼" up to 6". They are of a discontinuous nature, the veins are usually very short. Their general characters indicate that these have been intruded into the hornfelses during a late stage in the formation of the latter. They also appear to be independent of the dyke-like veins associated with the late micro-granite sheets within the granite pluton, and which are seen cutting the contact of the granite and metasediments along the radial joints.

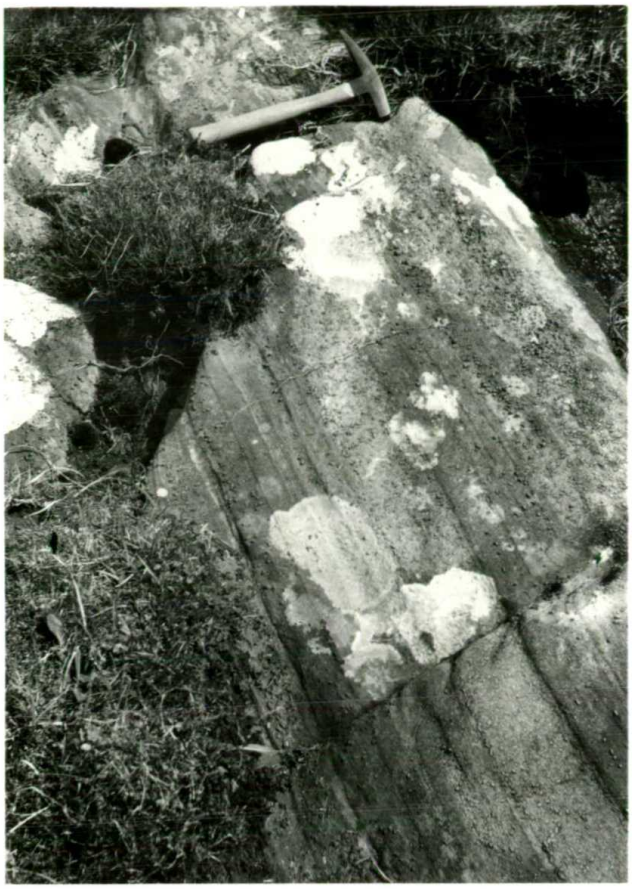
PLATE 12.

A. One of the types of graded bedding preserved in totally recrystallised high grade hornfelses. The two graded units show a relative abundance in andalusite crystals in their upper parts, the steeply dipping hornfelses are thus 'right way up'.

B. An andalusite-rich band brings out the folding in the inner part of the andalusite zone, N.E. Clooney. Note the sharp inner boundary of the folded andalusite-rich band and its less defined outer boundary.

C. Typical sillimanite hornfels at Maas - the Maas Hornfelses - exhibiting a high degree of mobility when in a plastic condition and is intimately associated with quartz in the form of veins, stringers and small irregular clots.

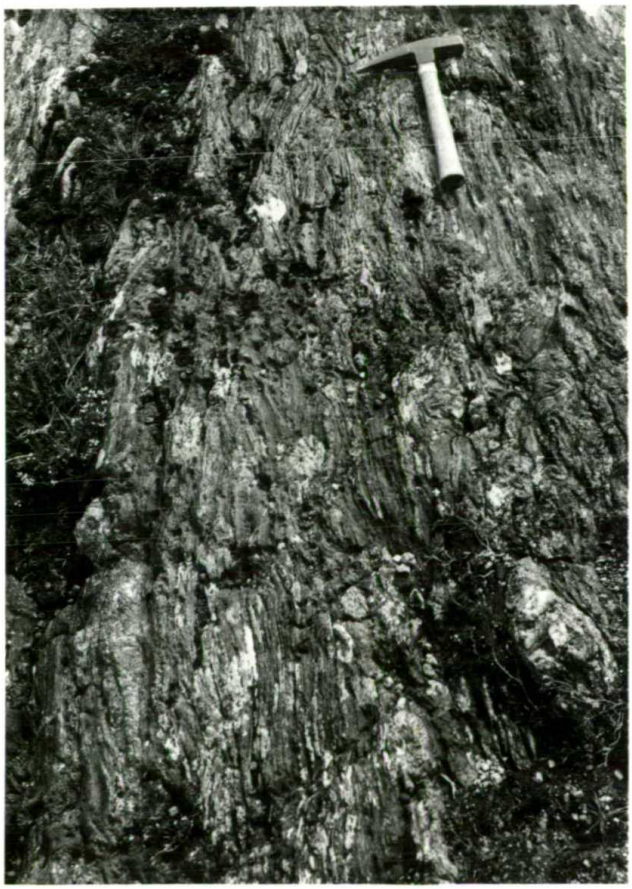
D. Sillimanite hornfels at Maas showing irregular swirling and crinkling.



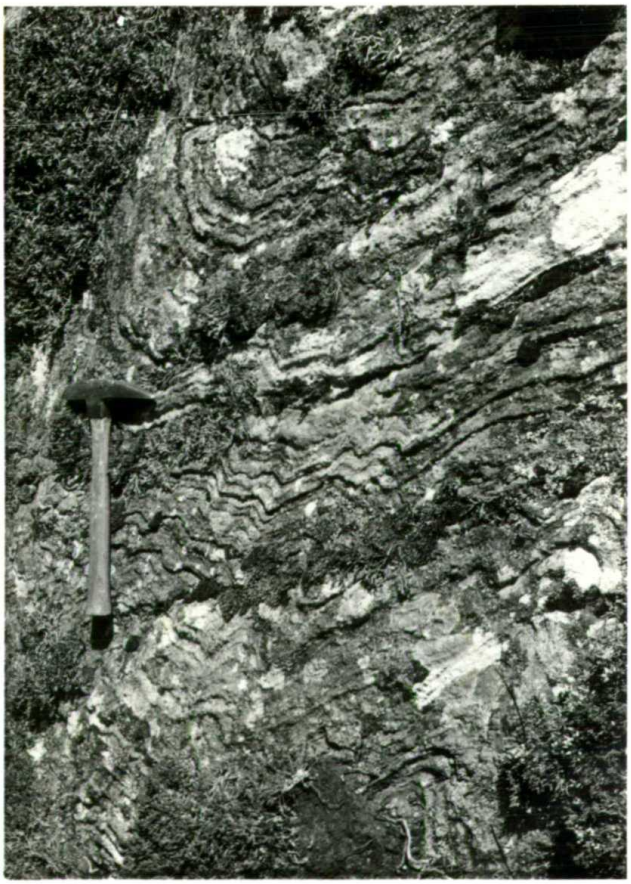
A



B



C



D

4. Petrography of the Sillimanite Hornfelses of Maas.

In thin section, the hornfelses consist mainly of sillimanite, biotite, staurolite and quartz.

Sillimanite occurs as felt like aggregates of fibrolite, closely associated with the biotite which it replaces. The fibrolite forms bundles interleaved with the biotite, as well as channel-like patches in the biotite rich bands of the rock. The fibrolite is almost all changed to sericite, but the latter preserves the form of the fibrous and felty aggregates. Large flakes of biotite are seen to be replaced by fibrolite in curved bundles of fibrolite, the latter in its turn being largely replaced by sericite. Sometimes the sericitic aggregates at the boundaries of biotite and quartz still retain the form of the original fibrolite rosettes. The fibrolite patches and nests include abundant iron-oxide shed during the alteration of biotite to fibrolite. Biotite is of a honey-brown colour and is largely altered to fibrolite. Staurolite is not abundant and is present in ragged grains. Quartz is recrystallised into large grains, part of it is crammed with fibrolite needles.

D. The Cordierite Sub-Zone.

The rocks of the innermost part of the sillimanite zone, in immediate contact with the granite, are characterised by the presence of cordierite. The persistence of this mineral all along the contact, and its absence in any of the other hornfelses, has led to the initiation of

of a cordierite sub-zone within the sillimanite zone.

Cordierite is particularly abundant along the granite contact towards the north-western part of the writer's area, and most probably extends in the area towards the west. Slice (53) from this area, near the bifercation of the road from Ardara, contains cordierite, sillimanite, staurolite, garnet and biotite.

The cordierite bearing rocks extend towards the east, where at the granite contact at Clooney, the rock is a typical cordierite-biotite hornfels. It is medium-grained and brownish grey with a granulitic appearance. In slice (253) the cordierite crystals are 2 m.m. across with poikilitic inclusions of quartz. It is rarely sericitised, and has yellow pleochroic haloes around minute inclusions, including epidote. The biotite is in large red-brown flakes, some of which are bent. Andesine (An.37-40) in small stout crystals or equant grains is rather subordinate.

The hornfels at the granite contact oppisite the drive leading to Ardlougher, contains sericitised cordierite. The rock is highly sheared, and even late muscovite - belonging to the late retrograde metamorphism - is bent and broken. Nearly all the biotite is altered to chlorite.

Such late cataclastic effects are comparable to those found in the Maas metadolerites. They have probably been caused by the late movement of granite blocks along joint planes.

E. The Andalusite Zone.

1. General Description. The larger part of the Clooney hornfelses, stretching between Clooney Lough and Ardlougher, are in the 'andalusite grade', as well as the larger part of the pelitic hornfelses near the Ardara road.

In passing from the sillimanite zone outwards, andalusite makes its appearance fairly gradually, and in the field a boundary between the two zones can be mapped without difficulty.

In the inner part of the andalusite zone, for a distance of about 50yds. from the boundary of the sillimanite zone, the andalusite hornfelses are still mobilised. This marks a zone of mobilisation around the granite, measuring about 190-200yds. in width. Near the summit of Cashelgolan Hill, the andalusite hornfelses also show a marked swirling and free mobility, and innumerable quartz veins are broken and rarely folded.

Andalusite-rich bands bring out the folding and swirling of the hornfelses (Plate 12B). In the sillimanite zone, on the other hand, because of the lack of these purely pelitic bands, the very high degree of mobilisation together with the higher degree of compression of the metasediments normal to the strike, have all helped to obliterate the original bedding. Late shear imparts a planar element to these otherwise massive hornfelses.

Outside the zone of mobilisation, the hornfelses have a uniform dip of about 60° S. The rocks on the high ground of Clooney and Cashelgolan Hills are traversed by long and straight lines of thrust and shear, parallel to the arcuate structure of the metasediments.

2. Occurrence of Andalusite and Graded Bedding.

Andalusite is very abundant in the andalusite zone, much more so than is usual for an index mineral, and in addition to its high degree of development over the larger part of the Clooney hornfelses, it exhibits a variety of types and occurrences.

Andalusite crystals usually occur in bands varying in thickness from a fraction of an inch to one foot or more. Some of these bands consist almost wholly of andalusite crystals with a small amount of micaceous material between them. These bands represent highly aluminous shales and alternate with less clayey bands in which andalusite crystals might occur sparingly or might even appear to be absent. Read (1923, p.56) stated that andalusite rich bands at Boyndie Bay, Banffshire, represent original sedimentary bands.

The transition from a pelitic, andalusite-rich band to a more sandy one is usually abrupt and rather sharp, bringing out the rhythmic banding of the original sediment, (Plate 24B). This rhythmic banding is very

inconsistent, as the bands or 'couples of bands', trend to vary considerably in thickness over a very short vertical distance.

However, the transition between the andalusite-rich or pelitic bands and the more sandy bands shows, at times, different degrees of gradation ranging from cases that are hardly called graded, to cases of typical graded bedding in totally recrystallised rocks. Sometimes the graded bedding takes the form of a mere decrease in the andalusite crystals along one margin of the andalusite-rich bands, the gradual decrease being over a very short distance compared to the width of the band (Plate 24B). Again the inconsistent and capricious nature of the conditions of sedimentation of the original sediments is reflected in the fact that among rhythmic bands, as described above, there may occur one or two 'graded units' exhibiting a distinct gradation in the decrease in andalusite crystals towards one of the margins of the 'couplets'. Or, vice versa, among graded units, there may be an odd couple with very sharp margins and exhibiting no gradation at all. In this type of banding, where the andalusite-rich bands consist almost totally of crystals of andalusite, the sandy layer always appears to be devoid of andalusite. This characterises the first type of graded bedding.

Another type of graded bedding (Plate 12A), lacks the very strong contrast in composition between the pelitic

sandy layers constituting a 'graded unit' or 'couple'. The pelitic layers contain abundant crystals of andalusite, whilst the sandy layer is only relatively poorer in andalusite. This type of graded bedding is very similar to that described by Read (1936, p.473) from the andalusite schists of Boyndie Bay, Banffshire.

An interesting feature in the second type of graded bedding described here is a second grading within the less pelitic layer itself. In the more sandy or andalusite-poor layer, there is sometimes a gradual lightening in the colour of the layer towards the base, probably due to a graded decrease in biotite towards the base of the layer or sandy component of the graded couplet.

Andalusite crystals usually grow along the schistosity plane, which is commonly also the bedding plane. This is very clear on the fresh surfaces, but on weathered joint surfaces of the sheared hornfelses, andalusite crystals appear to grow oblique to the bedding plane due to the fact that the individual crystals are 'sliced' by late shear in that direction. This phenomenon is particularly well shown in (Plate 24B).

The individual crystals reach a maximum length of about 6" with a cross-section about ½" across. These are seen to push aside the schistosity of the more fissile andalusite hornfelses, and cause elongated bulgings on the fresh

surfaces. This is very well seen in the large quarry east of Clooney. In this quarry, the andalusite which is dark pink to wine in colour, is either totally changed to schimmer aggregate pseudomorphs, or else the crystal is fringed by muscovite blades which grew from the crystal inwards, leaving an unaltered core.

It is important to emphasize the fact that the crystals of andalusite grow at random in the earlier planes of schistosity of the rock.

Andalusite may also occur in the form of pink chiastolite with square cross-section, and the usual black cross of swept inclusions. Chiastolite crystals about 4" long and ½" across occur abundantly at the spot where the road from Narin bifercates into the 'top' and 'bottom' roads. Beautiful crystals of chiastolite stand out on the weathered joint surfaces, and possesses very clear crosses. Other pink chiastolite, usually smaller in size, is of abundant occurrence in many parts of the western half of the andalusite zone.

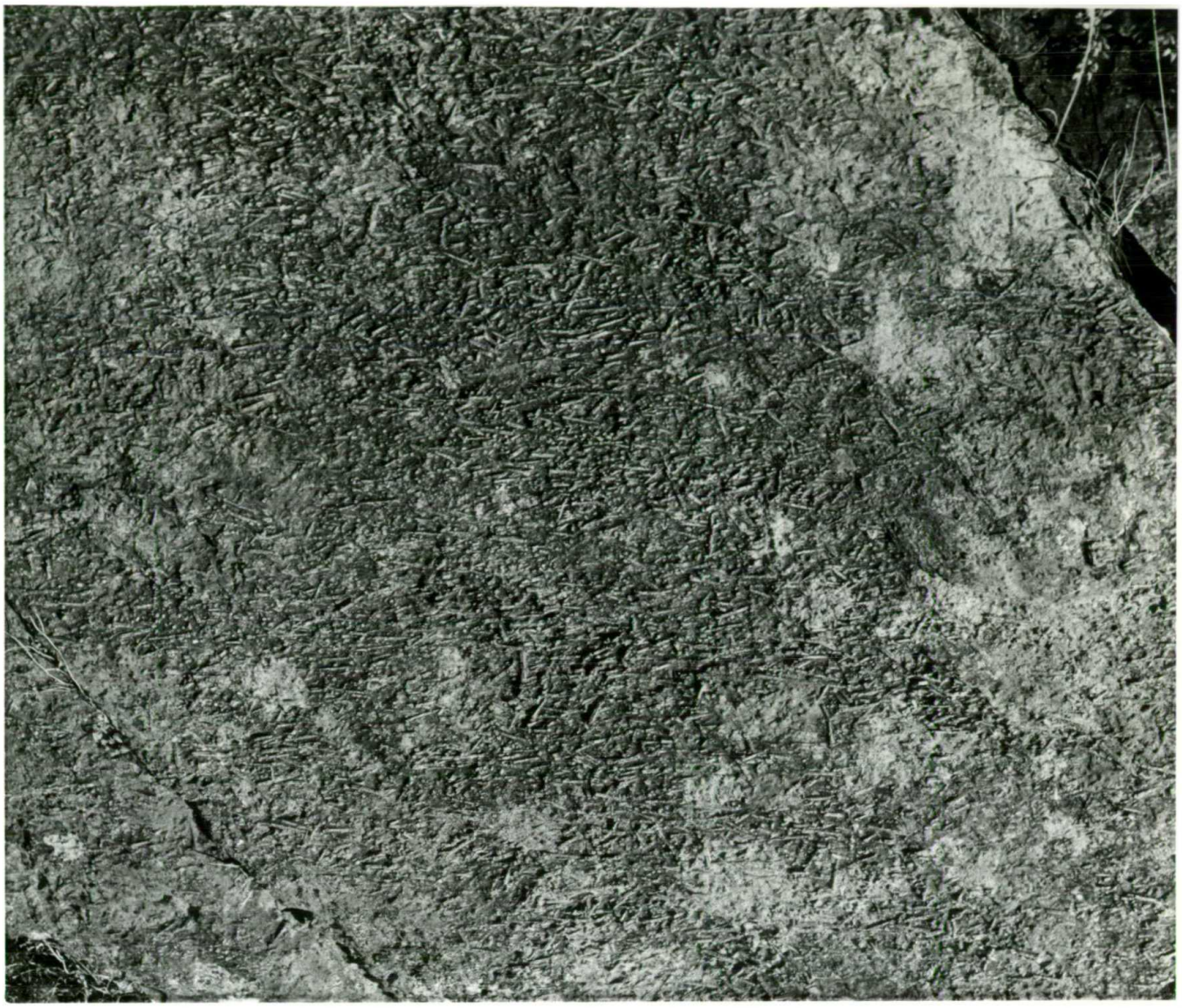
Chiastolite, unlike the usual variety of andalusite, always tends to preserve its sharp square edges on the weathered surfaces of the rock. The other andalusite crystals have rounded edges.

The most peculiar occurrence of chiastolite in the whole aureole is at a point between Clooney and Cashelgolan Hills, situated 140yds. from the main road, and 110yds. west

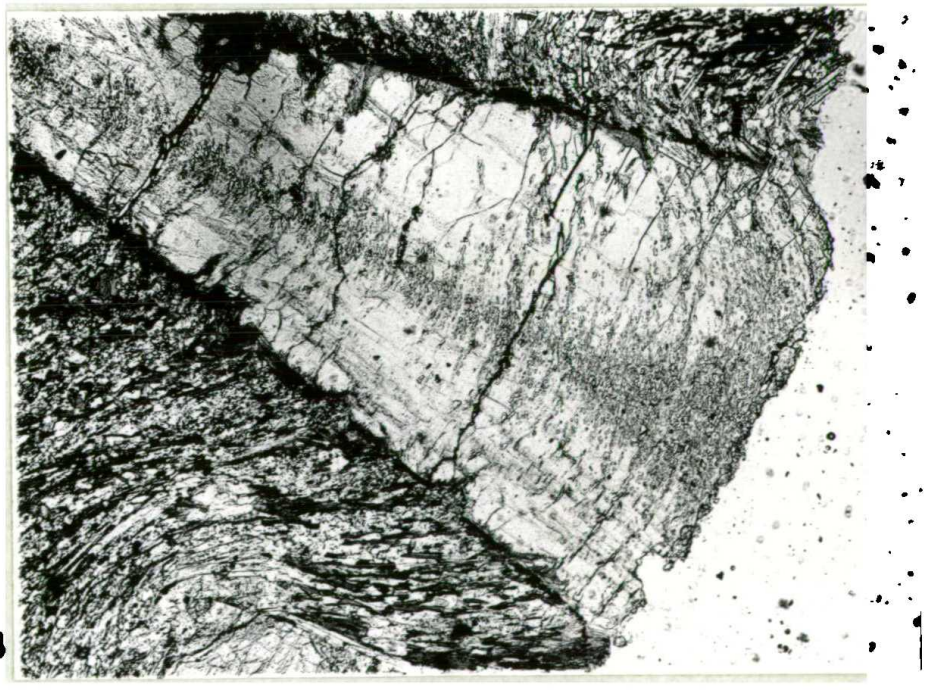
PLATE 13.

A. Porphyroblastic crystals of chiastolite 1" to 2½" long showing a remarkable degree of preferred orientation. The surface of the exposure is the bedding plane and the chiastolite crystals are aligned horizontally E. -W. parallel to the strike, between Clooney and Cashelgolan Hills.

B. Photomicrograph of one of the above porphyroblasts of chiastolite with trails of inclusions from the groundmass passing through it, showing the continuity of the original folded schistosity of the rock. Ordinary Light, X 25.



A



B

of the parish boundary of Cashelgolan. The chiastolite appears on a bedding plane dipping about 60° S, and forming one single exposure about 50ft. along the E. -W. strike, and 8ft. wide. This exposure lies between two lines of thrust, and unfortunately the ground is not well exposed on either side of it. Pink crystals of chiastolite with sharp edges and from 1" to 2½" long, show a remarkable degree of preferred orientation parallel to the strike direction (Plate 13A) Poor exposures on either side show a lower degree of preferred orientation over a total distance of about 50yds.

3. Petrography of the Andalusite Hornfels. The important constituents of the andalusite hornfels, apart from andalusite, are biotite, garnet, fibrolite, staurolite, quartz and plagioclase together with accessory iron-oxide and the late muscovite. The latter will be dealt with in a later part of this work.

Biotite occurs as large flakes red-brown in colour, and is usually interleaved with chlorite. The biotite flakes are usually deflected by the growth of the andalusite crystals. Garnet appears as irregular masses or broken grains and never shows good form. Staurolite is of sporadic occurrence, usually in small grains of irregular shape. Andesine felspar of composition about An.40 sometimes forms elongated poikiloblasts along the plane of schistosity of the rock.

Fibrolite occurs either as inclusions in the quartz and late muscovite or else taking the place of andalusite. Its occurrence is, however, restricted to the innermost part of the andalusite zone.

4. Andalusite in thin section. The occurrence of andalusite in the field has already been summarised. The study of several thin sections of the andalusite hornfelses has shown the mineral andalusite to be of considerable interest and of notable petrogenetic significance. It exhibits different types of occurrence and merits separate treatment.

Andalusite usually occurs as large crystals which are pale grey or colourless; less often it is coloured a pink of variable intensity. Representatives of this mineral are commonly sheared and appear in thin section to be sliced by the shear planes into separate parts. The latter now appear as aggregates of fine sericite, but the unaltered cores are in perfect optical continuity as seen in slice (100A). This type of andalusite is present as large crystals with no inclusions ascribed to the groundmass of the rock, and is usually colourless to grey and pale pink in colour. It represents by far the largest part of all the andalusite present in the aureole and is the most essential mineral in these hornfelses.

The second type of andalusite is of relatively

limited occurrence. This is the chiastolite with the preferred orientation from N.E. Cleoney (p.244). In thin section, the chiastolite is seen to consist of two different types representing two different generations. Thin section (101) is cut normal to the length of the oriented chiastolite crystals i.e. in a vertical N.-S. plane, and contain mainly basal sections of chiastolite in a schistose matrix of red brown biotite, quartz and iron-ore. Basal sections of the chiastolite show the characteristic cross of inclusions ; the latter consist of quartz, biotite, graphite and iron-oxide from the groundmass of the rock. The inclusions, in spite of their being swept inside the cross, still retain their original orientation with their longest axes parallel to the foliation of the rock. They are seen to be oriented parallel to the foliation of the rock, and the latter is curved due to the growth of the chiastolite crystal. In plate 13B, the inclusions in an oblique section of the chiastolite are continuous with the folded groundmass of the rock on either side.

Several sections of this anhedral colourless chiastolite are seen to possess cores of andalusite, pleochroic in pale to deep pinks. The andalusite cores usually have trails of very fine inclusions - graphite or iron-oxide - the trend of which is nearly normal to the schistosity of the rock and at the same time to the inclusions in the outer chiastolite.

This is not a case of a 'zoned andalusite' in which an inner kernel of deep violet colour is surrounded by a much paler rim, as reported by many writers from the Scala Pass, Switzerland.

In the present case, the two andalusites are totally independent of each other ; the inner core has apparently undergone some degree of movement before it has been enveloped by the chiastolite mantle. The core and mantle aremot in perfect optical continuity. The second type of chiastolite, whether it is present as mantles to older andalusite or forms individual crystals, contains the trends from the groundmass of the rock, and seems to have been formed while the latter was rigid.

How much time has elapsed between the two generations of andalusite is unknown, but it is certain that the older andalusite has undergone some movement before the chiastolite border was formed. Secondly, the orientation of the chiastolite crystals as described on page 24- can be explained as having been formed under the conditions while forces were still acting in the vertical N.S. plane, normal to the length of the oriented chiastolites, in other words, while the granite pluton was still shouldering its enveloping metasediments in the north.

The third type or variety of andalusite is seen in the hand specimen as small rounded knots in the inner part of the andalusite hornfelses, which are r ther massive in nature.

In slice 103 A.S., of an unsheared andalusite-rich band from S.Ardlougher, andalusite constitutes over 50% of the rock, and is present as rounded poikilitic masses about 2 m.m. across. The poikilitic inclusions are relatively large compared to the size of the andalusite host, and consist of grains of quartz, flakes of biotite and pellets of iron oxide. Among the inclusions are grains of weakly pleochroic staurolite and small fragments of garnet. This andalusite is very fresh especially when compared with the first type. This third type of andalusite seems to be of a slightly later age.

5. Note on Fibrolite after Chiastolite.

Generally the andalusite hornfelses, near the boundary of the sillimanite and andalusite zones, contain pseudomorphs of fibrolite after chiastolite and andalusite. The best example is slice (99) from near the boundary of the two zones. It shows pseudomorphs after chiastolite about 2½m.m. in cross section and containing fibrolite in four triangular patches with the characteristic cross of inclusions passing diagonally between the fibrolite triangles. A large part of the fibrolite is altered to very fine sericitic aggregates, which retain the precise form of the fibrolite. Apart from pseudomorphs after chiastolite, there are elliptical masses of fibrolite in the centre of which are large flakes of late muscovite. In the same slice, the majority of the biotite is altered to fibrolite, the latter forming thick felts

around remnant flakes of the red brown biotite. Fibrolite also forms rosettes of slender needles inside the quartz.

Another clear case of secondary fibrolite after chiastolite is seen in slice (101) of the oriented chiastolite already described, chiastolite of the later generation gives rise to secondary fibrolite at the edges of the crystals.

It can thus be inferred that the development of fibrolite after andalusite was among the late manifestations in the hornfels. It is also necessary to state that this is not the formation of secondary fibrolite by some metasomatic process connected with late pneumatolytic or hydrothermal stage of the granite, but the result of changes in the physical conditions of progressive thermal metamorphism consequent on a further uprise of the pluton.

6. Veins of Quartz-Andalusite. Veins and vein-like masses of quartz and andalusite occur occasionally in the andalusite zone of the Clooney hornfelses. The rocks of these veins consist of quartz and andalusite, and in those types found near the granite contact, thick books of muscovite are also present. These veins show a variation both in the form and in the relative proportion of the two main components.

The most common type of quartz-andalusite veins take the form of thin veins and stringers which vary in thickness

between ¼" to 6", and are usually mistaken for veins of pure quartz. The latter veins are very common in the hornfelses. However, the quartz-andalusite veins are sometimes readily distinguishable from the older quartz veins, by their fresh appearance and the presence of pink andalusite.

With regard to the relation of the quartz-andalusite veins and the bedding plane of the hornfelses, the veins were found to occur in the following forms :-

(a) Very steep veins running across the strike.

(b) Veins along the bedding plane, and sometimes folded together with the latter.

(c) Veins parallel to the strike and at a high angle to the schistosity (bedding ?) of the andalusite hornfels.

(d) Irregular masses of quartz in association with andalusite crystals along irregular steep planes roughly parallel to the strike.

From the field occurrences of the quartz-andalusite veins, and particularly that type which is always seen to run steeply across the strike, whether straight or in a rather sinuous and irregular manner, the writer is inclined to believe that these veins have taken advantage of older joint planes, before these had been completely obliterated by hornfelsing. Some of these quartz-andalusite veins are only ¼" thick and have their generalised trend running roughly N. - S., across the strike and are seen to cut

through the andalusite-rich bands. A clear demonstration of this type comes from N.W. Ardlougher. A vein about 2½" thick is seen to run straight across the strike. It consists of quartz with only a few crystals of pink andalusite, about 4 m.m. across. The contact of the vein with the hornfels is marked by thick clusterings of andalusite crystals growing from the hornfels into the quartz-andalusite vein. The vein is broken and shows evidence of movement after it had congealed.

The second type which follows the folded bedding of the hornfels is seen very clearly in a large flat and glaciated exposure at N.W. Ardlougher, about 100yds. from the major dislocation. The vein is about 1½" thick to 2" in places, and follows the gently folded bedding plane for about 12 to 15 feet. It contains abundant stout crystals of pink andalusite.

In the large quarry N.E. of Clooney, are very well developed quartz-andalusite rocks. These are not easily seen on the walls of the quarry due to the thick staining of iron oxide on the joint and bedding planes, but very good masses of quartz-andalusite rock in contact with the hornfels are found among the quarried rock. From the study of numerous such masses in the quarry itself, the writer has inferred with confidence that they are in the form of elongated vein-like or lenticular bodies averaging 9" across, and trending

parallel to the strike. The veins (plane) are usually at a high angle to the schistosity of the hornfels (bedding), and in many cases normal to it. A typical mass of this rock collected from the quarry, shows the strongly ribbed crystals of pink andalusite embedded in the quartz. The contact of the vein-like body is usually marked by a thick layer of closely packed andalusite crystals, which appear to grwo from the contact into the vein. Small but thick books of muscovite are also present and are locally, rather abundant.

In a large thin section across the contact of one of these quartz-andalusite-muscovite veins within the hornfels, parts of the latter are seen to be much poorer in quartz than the average andalusite hornfels. Some parts are even almost lacking in quartz, and contain beautiful porphyroblasts of muscovite. The latter form perfect rectangles about 2 m.m. x 1 m.m. and are traversed by abundant trails of opaque inclusions, hence their dark colour in the hand specimen. The muscovite porphyroblasts are sometimes intergrown with biotite along the cleavages and the crystal borders. This muscovite is closely associated with the formation of the quartz andalusite vein and is almost certainly of much earlier age than the late muscovite in the hornfels. Large crystals of andalusite at the contact of the vein with the schist are traversed by thin cracks along which

the mineral is altering to sericite. Also at the boundaries of the andalusite, red brown biotite and some muscovite are seen to be growing within the boundaries of the andalusite. Parts of the andalusite have patchy pleochroism, and a very faint difference in birefringence. The quartz is full of thin fine trails of bubble-like inclusions, these are usually oriented at a high angle to the contact of the vein. Also a the contact are small detached pieces of the turbid groundmass of the schist lying a short distance in the quartz. The trend of the groundmass of the schist passes into the quartz without deviation.

An interesting case of a quartz-andalusite vein in contact with an older quartz vein - probably of earlier age than the Ardara granite - comes from half way between Cashelgolan Hill and Ardlougher. The quartz-andalusite vein is about 1½" thick and contains abundant crystals of pink andalusite. The two veins are separated from each other by a parting or schist, and the andalusite crystals pierce the latter and tend to grow into the older quartz vein. The andalusite bearing vein also has fragments of schist included in it.

In thin section (616) the andalusite crystals have rare inclusions and thin linings of sericite along cracks. It is generally colourless except for a few crystals with a patchy pleochroism of pale pink, together with patchy

and irregular extinction. Macdonald and Merriam (1933), have found similar phenomena in andalusite from pegmatite. They concluded that it was due to a variation in ferric iron content present in the andalusite as impurity. It affected the indices of refraction, birefringence as well as the optic-axial angle.

Another phenomenon probably associated with the quartz-andalusite veins is the presence of irregular but flattened masses of quartz on steep irregular planes of fracture, roughly parallel to the strike. Close to these quartz masses are andalusite crystals which appear much more frequent and of notably larger size than those in the normal hornfels a short distance away.

Regarding the origin of these quartz-andalusite veins, at least the andalusite alone has been found as 'sweats' or exudations from the andalusite hornfels by some process of metamorphic differentiation. In the literature, there are innumerable instances of quartz and pegmatite veins and lenticular bodies, practically on every scale, containing aluminium silicate minerals. The latter have been formed, it is believed in many cases, by processes of metamorphic differentiation from highly aluminuous rocks, either metasediments or rocks of a tuffaceous nature.

(Read (1933) showed how kyanite-chlorite-muscovite-quartz-schists, by a process of 'indogenous secretion' during

the period of metamorphism, have formed quartz-kyanite rocks. He states that "the quartz and kyanite are of contemporaneous formation" and are complementary to the intimate wall rock of the veins.

Karpoff (1946), in accounting for the presence of kyanite only in those parts of a pegmatite vein where the latter cut kyanite-bearing schists, postulates the washing or 'lessivage' of kyanite by the pegmatitic solutions, involving molecular displacement and reconstitution.

Thus as regards the quartz-andalusite rocks of Clooney, the precise origin of the quartz remains uncertain. Even a defficiency in the quartz content in the hornfels in immediate contact with the veins, as compared with the average hornfels, is no proof that the quartz has all been 'sweated' together with the andalusite. Ptygmatic veins of quartz together with several thicker quartz veins of a pegmatitic nature, are sufficient evidence of the introduction of quartz, of probable igneous origin, during the main and final phases of the emplacement of the granite pluton. Also the presence of muscovite in some of the quartz-andalusite veins as well as in the hornfelses at their contact may suggest a foreign origin for some quartz accompanying the muscovite.

F. Calc-Silicate bands in the Inner Aureole.

1. Introduction. Interbanded with the pelites of the Clooney Pelitic group are occasional calc-silicate bands.

These show a wide variety in their composition from calcareous shales to impure limestones. The calc-silicate bands vary in thickness between ½" to about 3ft.

Unlike the pure limestone horizons present in the aureole, the calc-silicate bands respond readily to the contact effects of the granite. Nearly all the calc-silicate bands within the Clooney Pelitic group were found to occur within the sillimanite zone, some in the cordierite bearing hornfelses at the contact.

These bands show varied assemblages of calc-silicates, such as grossular, idocrase, diopside, zoisite, clinozoisite, epidote, tremolite, together with calcite, quartz, potash felspar and plagioclase.

The calc-silicate bands are torn apart to form both sub-vertical and sub-horizontal boudins. These boudins are useful from the structural point of view and will be the subject of further comment.

2. Distribution. In the Maas hornfelses, calc-silicate bands are very common, and have a uniform appearance. They are usually 1" to 2½" thick, and all have an unfailing greasy lustre, mainly green in colour.

In the Ardlougher area, several calc-silicate bands occur within a few yards of the major dislocation. These are about 1 - 1½ft. thick and show incipient boudinage structures. They lack the characteristic pink garnet.

A rather important calc-silicate band exists in the face of the road-side quarry, situated ¼ to the east of Cleoney and facing the road from Killayenna Lough. It is about 3ft. thick and is horizontally boudinaged (Plate 19B).

Another important calc-silicate band about 4ft. thick is found at Ballyiriston situated at a point 85yds. due S.E. of B.M. 59.4 and about 50yds. from the granite contact.

Several minor bands occur at the immediate contact of the granite.

3. Petrography. The calc-silicate band at Ballyiriston is of a dull buff colour, slightly banded, and contains small garnets of a light tan colour. Slice (1468) shows the rock to consist mainly of grossular, idocrase, diopside, zoisite, epidote, calcite, quartz and potash felspar. The grossular is either in irregular poikiloblastic masses 3 m.m. across, or else as fine aggregates and minute patches. Idocrase is the best formed among this assemblage. It is usually in roughly rectangular crystals with a variable amount of inclusions. Diopside in minute equant grains about 0.1 m.m., occurs sometimes as inclusions in the grossular or else associated with the calcite. Epidote and clino-zoisite occur together as fine aggregates. Zoisite also lacks good crystal form. Calcite is in excess over the quartz and felspar, and its rounded grains have abundant inclusions of diopside and epidote. Potash felspar occurs as orthoclase

changing to microcline. Quartz occurs as recrystallised grains.

The calc-silicate band in the road-side quarry at Clooney is dark green in colour, medium grained with a weak foliation. It has a marked resemblance to the metadolerites. In thin section (546) the rock appears to consist of plagioclase, actinolite, biotite and quartz, with the amphibole and biotite roughly aligned. Oligoclase about An.25 occurs in irregular plates and poikiloblasts. It is highly sericitised. Actinolite is in excess of the biotite, as small slender prisms with pleochroism: Z' = lavender green Y' = light olive green and X' = pale yellow. The biotite which is reddish brown, resembles in part the 'hornfels type', and is sometimes interleaved with penninite. The biotite flakes are bent. The quartz shows undulose extinction, and has inclusions of minute needles of tremolite. It is roughly equivalent in quantity to the plagioclase.

Slice (252) of a thin calc-silicate band from the cordierite-bearing hornfelses at Clooney consists of tremolite, cordierite and quartz. The tremolite occurs as poikilitic patches and prisms with pleochroism Z' =. pale yellow green, Y' = pale yellow, X' = colourless. A mineral which has been converted to pinite is thought to have been cordierite.

G. Ptygmatic Quartz Veins in the Inner Aureole.

Closely associated with the final phase in the forma-

tion of the hornfelses are the ptygmatic quartz veins found in the inner part of the aureole. The scrupulous examination in the field of innumerable veins of quartz, has revealed only about seven or eight ptygmatic quartz veins. Scores of folded and disrupted veins of quartz have also been encountered.

The ptygmatic veins are confined to the sillimanite and andalusite zones in the Clooney and Maas hornfelses. The thickness of these veins vary between 2" and 4", and the maximum length observed for a single vein never exceeded 5ft. They are of a sinuous and buckled nature, and usually trend oblique to the bedding of the hornfels.

This is very clear in a ptygmatic quartz vein in the andalusite hornfels at the N.E. foot of Cashelgolan Hill. The vein is about 4" thick and forms thick and close buckles. The bedding plane, marked by andalusite-rich bands about 3" thick, is continuous on either side of the vein, as seen in the lower left hand side of (Plate 14A).

In other cases, the bedding of the hornfels is not so well preserved as that in the case described. Even so, where the rock has experienced a certain degree of mobilisation and free swirling, as is usually the case in the inner part of the aureole, the hornfelses do not show folding compatible with the sinuous nature of the ptygmatic vein.

A good ptygmatic vein of this type occurs in the mobilised hornfels at a distance of about 200yds. S.W. of the

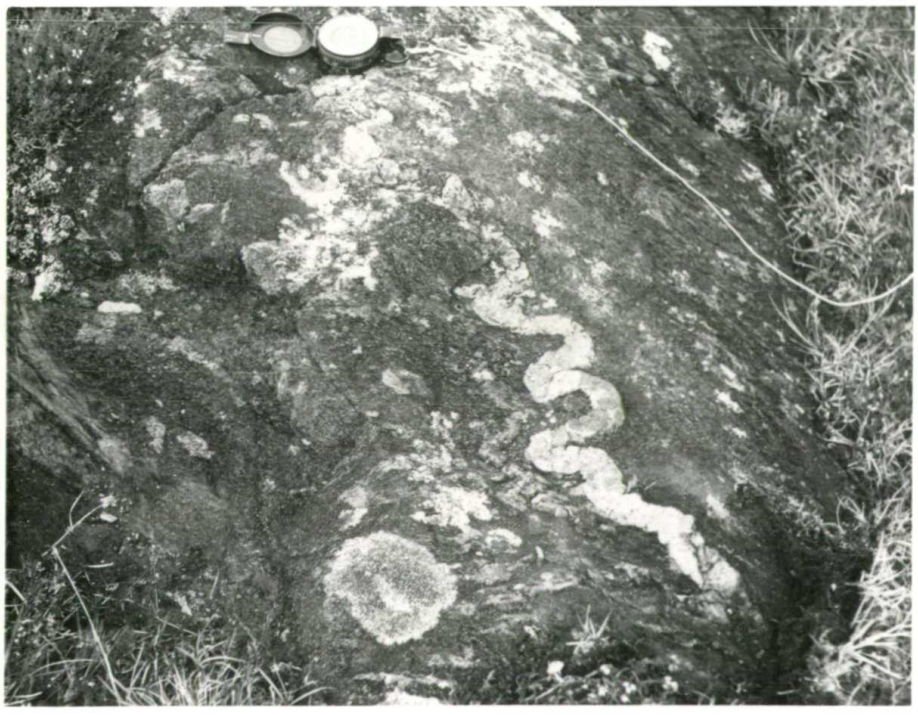
PLATE 14.

A. Ptygmatic quartz vein in the andalusite hornfels to the north-east of Cashelgolan Hill. Andalusite-rich bands marking the bedding plane of the rock are continuous on either side of the vein.

B. Ptygmatic quartz vein in the mobilised sillimanite hornfelse at Maas. The compass is parallel to the strike.



A



B

hotel at Maas (Plate 143). There is perfect agreement in form and structure between these types and the ptygmatic veins in Sutherland (Read 1927), in spite of the difference in general set up, and the composition of the veins themselves. The writer would use some of Read's own words to describe the ptygmatic veins in Clooney: When the host metasediments are folded "there is no agreement between the vein-folding and the host-folding" (op.cit.p.74).

All the field relations of these few ptygmatic veins of quartz indicate that they had not been originally intruded as straight quartz veins and subsequently folded. They have been intruded into the hornfels while the latter was in a plastic condition, hence the buckling of the quartz on itself, their structures are primary according to Wilson (1952).

The origin of these quartz veins seems, in all probability, to be igneous. There is no evidence to consider them otherwise.

Numerous quartz veins essentially earlier than the emplacement of the granite pluton, are simply folded. Again in strong support for Read's suggestion of the improbability of demonstrating "ptygmatically folded" veins, the older veins of quartz are usually broken and discontinuous due to the marked difference in competence between the quartz veins and the pelites and semi-pelites. They have never been seen to resemble the ptygmatic veins in occurrence.

III. The Inner Aureole - Upper Portnoo Limestone.

A. Introduction.

The Cloney Pelitic group, forming the largest part of the inner aureole, ends abruptly at Ardlougher against a major dislocation - the Ardlougher Thrust. The latter brings the pelitic group structurally against the upper part of the other lithological group within the inner aureole, the Upper Portnoo Limestone. The thermal metamorphism of the latter is now to be considered.

As stated on page 19, the Upper Portnoo Limestone forms the upper part of the Portnoo Limestone Group, and consists of limestones, pelitic and semi-pelitic bands, black graphitic phyllites and flags. The following succession has been given together with a detailed description of the different members :-

---------- Ardlougher Thrust

Youngest) Upper Pelite.

Upper banded Calc-phyllite.

Upper Limestone.

Inter-banded Limestone and Flags.

Middle Pelite.

Banded Semi-pelite.

Middle Limestone.

(Oldest) Lower banded Limestone.

The different members of this succession are affected in different ways according to their nature. The Middle Pelite, for instance, is an andalusite hornfels precisely similar to the andalusite hornfels in the Clooney Pelitic Group, and the limestone horizons, such as the Upper Limestone, the Middle Limestone and the Lower banded Limestone, are also unaffected as is the Lower Portnoo Limestone (p.267). The horizons of dense phyllite and graphitic flags do not show much response; how much of their metamorphism can be attributed to each of the Regional Metamorphism or the later Thermal Metamorphism due to the emplacement of the Ardara pluton is a matter of great uncertainty.

On the other hand, the calcareous semi-pelitic members such as the Upper Pelite and the Banded Semi-pelite show notable contact effects which throw further light upon the general thermal metamorphism in the aureole. Hence the metamorphism of these two members only will be considered in detail here.

B. The Upper Pelite.

1. General Description. To the north-east of the Ardlougher Thrust, is a band of silvery pelite about 40ft. thick, standing vertical and trending N.W. - S.E. The pelitic schist is fissile, with a salient knotting on the dark silvery-grey bedding plane. Several beds of calc-silicate form intercalations ; these are greyish green with a greasy appearance.

At the south-east end of this pelitic member, the rock is very well exposed in a quarried outcrop a few yards from the winding track to Ardlougher House. On the weathered surfaces the knotting appears as distinct white spots.

2. Petrography of the Upper Pelite. In thin section, the rock appears as a muscovite-plagioclase-zoisite-schist with subordinate biotite and quartz. The muscovite, in the form of slender blades of a pale greenish colour, marks the undulating foliation of the rock, and is crammed with opaque dust. Porphyroblasts of andesine felspar about An.40, either rounded or slightly elongated, usually stand with their longer axis at an angle of about 60° to the foliation and give rise to the knotting. The porphyroblasts push aside the muscovite, and include only a very small proportion of it. Inclusions of quartz, zoisite, muscovite, biotite and apatite are seen to pass in trails through the porphyroblasts of andesine, and usually oblique to its albite twinning. These trails of inclusions mark the original foliation of the rock prior to the growth of the plagioclase porphyroblasts. However, these porphyroblasts show positive evidence of movement at a time before they had attained their present size. A number of elongated porphyroblasts have trails of inclusions parallel to their length over the greater part of the crystals. Towards either end, the trails turn in opposite direction and pass from the porphyroblast into

the goundmass of the rock. During the larger part of its growth, the porphyroblast was lying parallel to the foliation of the rock. Movement of the rock during the latter part of the growth of the porphyroblast caused it to rotate slowly through an angle of about 60° - thereby recording a paracrystalline deformation.

In the areas 'sheltered' by the porphyroblasts, quartz has recrystallised.

C. The Banded Semi-pelite.

1. General description. The banded semi-pelite is a closely folded and banded member, the folds being slightly overturned. It consists of/medium grey micaceous schist bands of 1" to 1½" thick, alternating with slightly thicker bands rich in porphyroblasts of plagioclase. The plagioclase-rich bands tend to weather out more readily than the more schistose bands, and the distribution of the plagioclase crystals relative to a pair of these bands suggests a certain degree of graded bedding.

An important point about this phenomenon lies in the fact that it affords further confirmation for the sedimentary origin of the so called "igneous looking" bands reported by other members of the Donegal Research Team. This has been dealt with (p.22).

2. Petrography of the Banded Semi-pelite.

Thin sections 134, 135, 136 and 137 are of specimens

collected over a few feet across the strike; 134 and 136 represent typical plagioclase rich bands, 137 represents a pelitic band and 135 the transition.

The plagioclase-rich bands consist of andesine plagioclase, biotite, garnet and quartz, with minor amounts of muscovite, clinozoisite, iron oxide and apatite.

Andesine (about An.40) constitutes the larger part of the rock and is present as porphyroblasts up to 3 m.m. across, which are full of trails of inclusions indicating the original folded nature of the rock. They occur either inside the small folds in the foliation or else along the foliation. They exhibit good twinning generally oblique to the trails of inclusions (original foliation). The inclusions inside the porphyroblasts are mainly elongated and spindle shaped grains of quartz and prisms of clinozoisite, some of which are thought to be idocrase. Iron oxide and apatite are also included in these trails, as well as ragged flakes of biotite. These trails of inclusions sometimes show a single or double fold within one individual porphyroblast of plagioclase (plate 15C). The plagioclase may also grow along the folded schistosity in the form of a thin undulating band with albite twinning and perfectly uniform optical extinction. No movement of the plagioclase porphyroblasts has been noted.

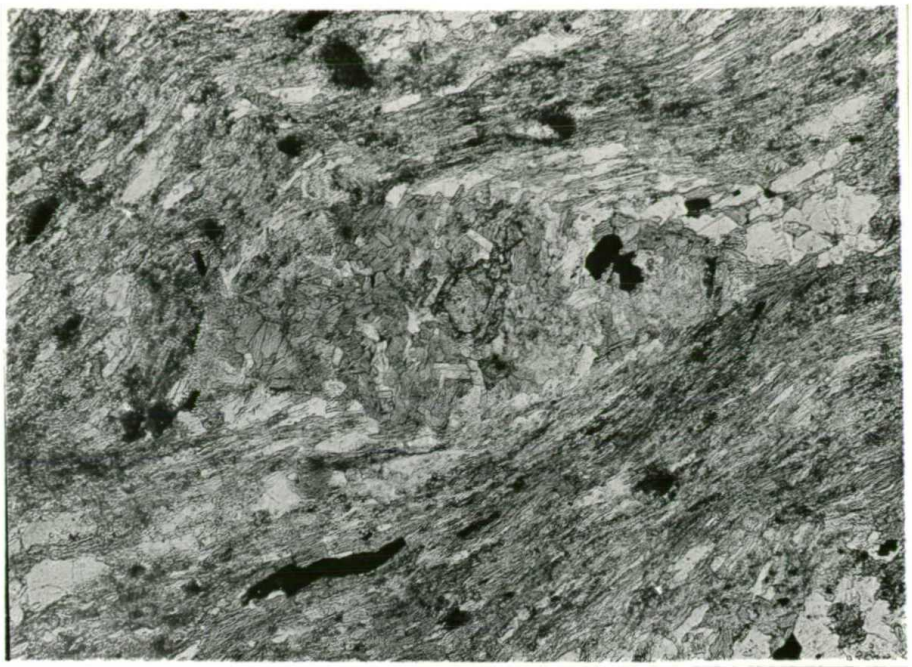
It is necessary, at this stage, to introduce the term 'New Garnet' to distinguish the garnet of thermal metamorphism

PLATE 15.

A. Pseudomorphic biotite after the pseudomorphic 'Old Chlorite' this in its turn being after the regional or 'Old Garnet', a remnant fragment of which still survives in the middle of the biotite aggregate. The structure of the groundmass indicates the rolling movement (anticlockwide direction) of the original garnet in the Banded Semi-pelite, Upper Portnoe Limestone. Ordinary Light X 35.

B. 'New Garnet' in the Banded Semi-pelite is broken and corroded only in one direction, leaving behind some particles which together with other particles from the groundmass form a 'tail'. On the opposite side of the garnet crystal where its edge is flattened, porphyroblastic plagioclase (with distinct cleavage) has been moulded upon it. Ordinary light X 35.

C. Porphyroblast of andesine-labradorite with trails of inclusions of the groundmass showing a complete fold. The plagioclase porphyroblast is distinctly later than the folding of the schistosity or bedding. Crossed nicols X 30.



A



B



C

from the regional or Old Garnet.

New Garnet crystals, euhedral to sub-euhedral, are sometimes broken and contain inclusions of quartz. These garnets show a remarkable feature in that nearly all the crystals show good crystal faces in one direction in the thin section, though in the opposite direction/they are broken and possess a 'tail' of iron oxide, biotite flakes, clinozoisite and broken fragments of the garnet (Plate 15B). This seems to be due to movement after the new garnet has developed but prior to the plagioclase porphyroblasts.

Aggregates of biotite flakes after the 'old garnet' are rare and contain some remnant fragments of the garnet. Biotite is reddish honey brown with strong pleochroic haloes. Tourmaline is an important accessory.

Towards the more pelitic bands, the rock becomes finer in grain and has a larger content of fine opaque dust. The plagioclase porphyroblasts are crammed with fine inclusions, and the twinning, when present, becomes less distinct. Biotite aggregates after the chlorite pseudomorphs replacing 'old garnet' are much more abundant in the pelitic bands. The rolling movement of the original garnet is still recorded, as in slide 137 (Plate 15A). The foliation of the rock shows this phenomenon clearly. Also the fine trails of iron oxide can be seen under high power to have a curved trend inside the biotite flakes in these 'double pseudomorphs'. The pelitic bands are also rich in ilmenite; The latter some-

times has a coating of sphene.

A thin band of dark silvery schist with slight knotting on the bedding plane and distinct 'New Chlorite' on the fresh surfaces, forms a transition between the described Banded Semi-pelite and the overlying andalusite hornfels of the Middle Pelite member. In thin section (141) it is muscovite-garnet-plagioclase-schist with a few pseudomorphs of sericite after euhedral andalusite, and subordinate quartz and biotite. Muscovite, in thin slender blades, is predominant and includes much opaque dust. The muscovite blades are pushed aside by the porphyroblasts of garnet, plagioclase and andalusite. Quartz in spindle shaped grains occurs with the muscovite. New Garnet occurs as euhedral crystals 0.2 m.m. across, which are partly broken down along their borders to a sub-transparent chlorite, except where they are included in the porphyroblasts of plagioclase, in which case, they are preserved as perfect euhedra. Porphyroblasts of andesine, either sub-rounded or augen-shaped, have trails of inclusions of quartz and iron oxide, but not muscovite. Andalusite is replaced by shimmer aggregates. Muscovite and chlorite grow from the periphery of the pseudomorphs inwards.

IV. The Limestone Barrier - Lower Portnoo Limestone.

A. Occurrence and Morphology. The Lower Portnoo Limestone comprises the larger part of the Portnoo Limestone

group, and consists of a thick marble in contrasting with the Upper Portnoo Limestone. This thick crystalline marble is overridden by the high grade andalusite hornfels of the Clooney Pelitic group, and the contact marks a major thrust - the Cashelgolan Thrust - responsible for the shearing out of the Upper Portnoo Limestone. The maximum exposed thickness is about 750ft., including a certain amount of folding, and its base is concealed below drifting sand. This thick limestone running parallel to the arcuate structure of the aureole occurs, at places, as near as 300yds. from the granite contact. Nevertheless, the thermal effect of the granite pluton on this limestone did not involve much reaction or the development of new 'contact' minerals. However, it is highly mobilised by heating up by the granite, the shaly partings serving to record all folding movements in the otherwise homogeneous marble. Not only does it shield itself against contact effects, but it also forms a barrier, so that only mild contact effects are found in the rocks to the north of it, in marked contrast to the high grade andalusite hornfelses above it.

B. Petrography of the Lower Portnoo Limestone. In hand specimen, the limestone is rather coarse grained with a sugary appearance, light grey in colour with a tinge of blue and rarely brown. The study of several thin sec ions of representative types shows the rock to consist mainly of

calcite, with minor amounts of quartz, muscovite and graphite, and accessory plagioclase rutile, epidote, iron oxide and orthite.

The calcite occurs as coarse elongated grains about 1 m.m. by $^1/_3$ m.m. with their longer axes parallel to each other, and usually show glide planes. The rock seems to possess a strong fabric. Calcite has inclusions of rounded grains of quartz and graphitic dust, less frequent muscovite flakes. Graphite, either in trails or haphazardly dispersed, is included in the calcite, and such trails have been noted to pass through adjacent grains. The inclusions of quartz also contain graphite. The rock appears to be entirely recrystallised. Planes of late shear and cataclasis are clearly seen in thin section.

Quartz, as rounded and rarely subangular grains is fairly common both as inclusions inside the recrystallised calcite or else at their boundaries. The quartz usually contains a variable amount of graphite, and is sometimes associated with epidote.

The relative amount of quartz in the rock is variable. Sometimes it is more abundant in bands as seen in slice (27) from W.Boleymore near the outlet of Clooney Lough. In the more sandy layers, the quartz contains more graphite than usual and is also associated with more epidote. In these bands the calcite is finer grained.

Muscovite in thin bands occurs usually along the

boundaries of calcite grains, less often as inclusions. Muscovite also contains trails of graphite.

Aggregates and grains of epidote are distributed along the boundaries of the calcite or else associated with the quartz.

Plagioclase, rutile, iron oxide and orthite are accessories.

V. The Outer Aureole.

A. Introduction. It has already been stated that the aureole on the northern side of the Ardara pluton has a width of over one-and-a-half miles. Certain mineralogical changes characteristic of thermal metamorphism have been noted in the island of Inishkeel and the group of isolated rocks known as Carrickfad, constituting the Outer Aureole.

The rocks under consideration at Carrickfad and Inishkeel are pelites and semi-pelites belonging to the Maas Semi-pelitic group. At Grabbindoo and Auninish other semi-pelitic rocks are of special interest and, as they also belong to the base of this group, which is different from its upper part, they will be considered separately.

The present pelites and semi-pelites are totally different from those of the Inner Aureole, mainly in the fact that they have not undergone high-grade thermal metamorphism, but have experienced only some mineralogical readjustments. The present rocks retain all their textures as well as the larger

part of their mineral assemblages ascribed to the two regional metamorphisms prior to the emplacement of the Ardara pluton.

It is intended now to show the type of contact effects produced at these distances from the granite. For the sake of simplicity, only the actual mineralogical changes and the minerals involved therein will be mentioned, and the reader is referred to the description and history of these rocks (p.44).

B. Contact Effects at Carrickfad.

The alternately banded semi-pelites of the thrust block at Carrickfad (p.40) are of great interest as they are the only rocks to provide clear and positive imprints of the three main metamorphisms viz. the regional metamorphism associated with the main orogeny, the regional diaphthoresis and thirdly the thermal metamorphism due to the emplacement of the Ardara granite.

Slice (157) is taken from Maddybunlina S.E. Carrickfad, exactly one mile away from the granite contact. The porphyroblasts of 'New Chlorite' are bent and rarely broken and show alteration to biotite, sometimes along their boundaries, sometimes as interleavings within them. The quartz is totally recrystallised into larger grains, and all cataclasis has been completely healed.

In slice (177) from N.Carrickfad, about 1850yds. from the granite, 'New Chlorite' again shows marked alteration to

biotite along the edges of the porphyroblasts. 'Old Chlorite' (after garnet) likewise shows all phases of alteration to biotite. These now occur as rounded or augen shaped pseudomorphs of chlorite, biotite and iron oxide.

C. Contact Effects at Inishkeel.

Changes similar to those described from Carrickfad have been noted in Inishkeel more than one-and-a-half miles from the granite contact. Only the 'Old Chlorite' after garnet shows alteration to biotite to a variable extent. 'New Chlorite' is entirely unaffected. This is best seen in slice (413) from a band of horizon 1, north of Porter's Rock. In slice (447) also 'Old Chlorite' alters to biotite.

At Grabbindoo, the presence of schimmer aggregates after chiastolite is not attributed to the extension of the andalusite zone towards Grabbindoo, but only to the localised effect of the minor granite body in that area.

VI. Summary and Conclusions.

Prior to the emplacement of the Ardara pluton, the metasediments of the area can be described in general terms as low grade phyllonites composed of biotite, muscovite, with the following two distinct types of chlorite. Pseudomorphs of 'Old Chlorite' after the regional or 'Old Garnet', remnants of which still survive in some of the pseudomorphs, and porphyroblasts of 'New Chlorite', the product of the regional retrograde metamorphism.

Thus the thermal metamorphism in the aureole of the Ardara granite, due to its emplacement, forms a third metamorphism impressed upon rocks already containing the imprints of the two earlier metamorphisms. In the outer parts of the aureole, where the thermal metamorphism is of a milder nature, the three metamorphisms aredistinctly preserved in the rocks.

The thermal or contact metamorphism in the aureole was found to have been effected in two stages closely associated with the main emplacement of the Ardara granite and the subsequent 'diapiric swelling' of the latter. These two main stages in the formation of the hornfelses do not seem to have been separated by any lapse of time, but only embrace certain movements between them. Most probably, they are only two phases of one and the same continuous process - the diapiric emplacement of the granite pluton. The late phase is certainly minor and subordinate to the main and earlier one.

The emplacement of the granite pluton resulted in the formation of a wide thermal aureole on its northern side, referred to as the Northern Aureole. This aureole has an arcuate structure parallel to the contact of the pluton, with the different lithological groups distributed accordingly. This has initiated its subdivision into an inner part, or Inner Aureole, and an outer part where contact effects are of a milder nature - the Outer Aureole. These two parts of the aureole are separated by a thick marble which is comparatively

unaffected and which forms a kind of barrier shielding the outer aureole. It is referred to as the Limestone Barrier.

The rocks in the inner aureole, consisting mainly of pelites and semi-pelites of the Clooney Pelitic group and the Upper Portnoo Limestone, were completely recrystallised with the formation of new minerals typical of thermal metamorphism such as sillimanite, andalusite, cordierite, staurolite, garnet and biotite. It is necessary, here, first to introduce the term 'New Garnet' to distinguish the garnet of thermal metamorphism from the regional or 'Old Garnet', and secondly, to emphasize the fact that staurolite and 'New Garnet' appear to have been more stable during the earlier stage of the formation of the hornfelses. This recrystallisation of the pelites and semi-pelites was effected in metamorphic zones, each characterised by an index mineral. Thus a sillimanite zone forms the innermost part of the aureole, and comprises a cordierite sub-zone marking the immediate contact of the granite. Cordierite does not appear in other parts of the aureole. The sillimanite hornfelses consist of sillimanite (mainly fibrolite), biotite, garnet and staurolite. Andalusite is lacking in the sillimanite zone. The latter is followed by a comparatively wider andalusite zone, characterised by the high development of andalusite. Practically all the andalusite present in the aureole has been formed at this stage, and is characterised by being

devoid of recognisable inclusions of the groundmass of the rock. Andalusite is formed in bands of different thickness representing clayey layers in the original sediment and brings out the rhythmic banding and graded bedding of the sediment in the entirely recrystallised high grade hornfelses.

At this stage, at least some vein-like quartz-andalusite sweats or exudations were formed by a process of metamorphic differentiation.

Thin beds of calcareous composition found in the inner aureole were changed to bands of calc-silicate with typical contact minerals such as grossular, idocrase, diopside, zoisite, clinozoisite, epidote, tremolite and plagioclase, along with calcite, quartz and potash felspar.

At this stage also, while the hornfelses of the sillimanite and andalusite zones were still in a plastic condition, a few ptygmatic quartz veins were intruded.

In the Upper Portnoo Limestone, the thick pelitic member is also represented by andalusite hornfels resembling those of the Clooney Pelitic Group. The other banded pelitic and semi-pelitic members, which are rather calcareous in nature, show a marked development of 'New Garnet' and the change of 'Old Chlorite' to biotite, the latter in pseudomorphs after the original 'Old Garnet'. 'New Chlorite' also changes to biotite. A small quantity of zoisite and clinozoisite is also formed in the calcareous schists.

The Lower Portnoo Limestone, forming the limestone barrier, together with the limestone members in the Upper Portnoo Limestone, are practically unaffected by the contact effects. The pelites and semi-pelites in the outer aureole - belonging to the Maas Semi-pelitic group - are affected to a much less extent. At Carrickfad, one mile from the granite, pseudomorphs of 'Old Chlorite' change to biotite, meanwhile 'New Chlorite' shows incipient changes to biotite. Quartz is recrystallised. At Inishkeel, more than one-and-a-half miles from the granite, 'Old Chlorite' is changed only in part to biotite, meanwhile 'New Chlorite' is unchanged. Hence there is a difference in the susceptibility towards contact effects between the 'Old' and 'New' chlorites.

At a later stage, when the northern aureole of the Ardara granite was thus formed, there was a further but minor 'diapiric swelling' of the granite pluton, accompanied by movements in the aureole and a second wave of heat.

The movements were more effective and perceptible in the Ardlougher area, in the vicinity of the major dislocation - the Ardlougher Thrust. Drag folds in the Upper Pelite of the Upper Portnoo Limestone, became very tight. Meanwhile in the Banded Semi-pelite, in addition to the apparent tightening of its folding, thin sections show the 'New Garnet' breaking mechanically. Also, two quartz-andalusite veins are clearly broken after their formation.

Both staurolite and 'New Garnet' now tend to become less stable, and both the minerals show a tendency to dwindle.

Probably when the forces were acting in a rather mild way, a second generation of andalusite was developed, both as individual crystals and as mantles around cores of older andalusite. In one place, this slightly later andalusite takes the form of chiastolite crystals all oriented horizontally parallel to the granite contact i.e. normal to the thrusting forces in the aureole. Andalusite of the second generation is sometimes characterised by inclusions of the groundmass of the hornfels still retaining the same orientation as in the 'foliation'. Another form of the presumably late andalusite is that of irregular masses with large poikilitic inclusions of quartz, biotite and rare staurolite.

Also at this stage, it seems that the sillimanite zone shows slight 'creeping' over the andalusite zone, by the appearance of pseudomorphs of fibrolite after andalusite along the boundary of the two zones.

The period immediately after the cessation of movements was characterised by the formation of large poikiloblasts of andesine plagioclase, particularly in the Upper Portnoo Limestone. Few poikiloblasts of plagioclase were also formed in some of the sillimanite hornfelses.

Late movements along the Ardlougher Thrust is recorded by the paracrystalline deformation of poikiloblastic plagio-

class in the Upper Pelite member of the Upper Portnoo Limestone.

Chapter NINE.

THE NORTHERN AUREOLE - THERMAL METAMORPHISM OF METADOLERITES AND LAMPROPHYRES.

I. Introduction.

The northern aureole of the Ardara pluton includes a large number of masses of metadolerite situated in the inner and outer parts of the aureole. These metadolerite bodies represent early basic intrusions of a doleritic nature, intruded into the metasediments prior to the regional metamorphism of the area. They appear to have been intruded in the form of thick sills and/or dykes. Together with their metasediment host, they dip steeply towards the granite contact, especially in the inner aureole. A few thin metadolerite bodies show clear evidence of having been torn apart with the distention of the country rocks resulting from the emplacement of the granite pluton.

A study of the contact effects of the granite upon these metadolerites has shown that they exhibit a notable 'Metamorphic lag' behind their pelitic and semi-pelitic hosts in the aureole. No contact effects have been noted in the metadolerites occurring in the outer aureole, and hence only those found in the inner aureole will be considered in the present section. These latter metadolerites can be further sub-divided into the metadolerites occurring in the Clooney area and those in the Maas area.

As seen in Map No.4, the larger part of the metadolerites in the Clooney area occur within the andalusite zone and only a few others occur along the boundary of the sillimanite and andalusite zones. The metadolerites in the Maas area occur within the sillimanite zone. In comparing the metadolerites of the Maas area with those of Clooney, it will be found that, in general, the metamorphism of the metadolerites bears a distinct relation to the 'grade' of the hornfels host; the metadolerites in the Maas area exhibit a more advanced stage than those of the Clooney area.

II. Metadolerites of the Clooney Area.

A. General Description.

The metadolerites of the Clooney area show in the field a wide variation in grain, texture and colour, in addition to sheared and unsheared types. Usually the fresh rock from the inner part of a metadolerite mass differs considerably from that towards the margin of the same mass. Garnet is present only in a few small bodies. In one case, garnet was noted only along the contact of a metadolerite with the enclosing hornfels, as seen in a small quarried exposure at Clooney. The peripheries and margins of a single metadolerite body are highly sheared compared to the central part, as described on p.43.

A feature characteristic of some of these metadolerites is the remarkable abundance of joints, many of which have no

equivalent in the surrounding andalusite and sillimanite hornfelses. It is a reasonable explanation that early joint systems, impressed upon the pelites and their associated metadolerites, have been obliterated only in the pelites due to the mobilisation and recrystallisation of the hornfels. A new set of joint fractures would normally be impressed on the hornfelses and their included metadolerites as soon as the temperature of the rocks in the aureole had fallen below a certain point.

Exposed contacts of metadolerites and hornfelses are few in number, and these do not exhibit, at present, any contact effects. Practically every one of the metadolerite bodies is foliated parallel to the arcuate strike.

B. Petrography and Metamorphism.

1. Introduction. The study of thin sections of the different types, and from different parts of one single body, has shown that the metadolerites have responded to the contact effects of the granite pluton to a variable extent. While some metadolerite bodies show relatively advanced stages of thermal metamorphism, the cores of the thicker masses are more or less unaffected.

It was thus necessary, on a petrographic basis, to treat the various metadolerites separately rather than to classify them into groups.

2. Parts Unaffected by Contact Metamorphism. Masses

of metadolerites which are about 40yds. thick or more, have their central parts totally unaffected by contact effects. The central parts of the large mass of metadolerite N.E. of Cleoney is a typical case.

In hand specimen, the rock is medium grained, medium to dark green with a speckled appearance. In thin section (93), the amphibole is seen to occur in large patches or aggregates of small and irregular prisms of pale actinolite, highly poikilitic. The quartzo-felspathic portion of the rock is full of slender prisms of actinolite. The plagioclase is only partly recrystallised as an andesine (An.33), with poikilitic inclusions of quartz, felspar and actinolite. The rest of the plagioclase is acid oligoclase as water-clear grains. Quartz is subordinate. Sphene is fairly abundant, forming irregular patches and rims around magnetite and small amounts of rutile. Epidote appears as minute granules in the poikilitic actinolite aggregates. Biotite is completely lacking.

3. Types showing Contact Effects. The metadolerites which have responded to contact effects can be further subdivided into coarse- and fine- grained types. The elongated mass of metadolerite at the bifercation of the road from Ardara, affords a typical example of a fine-grained metadolerite with contact effects.

Slices (55 and 57) are from the two quarries in this

mass and show the rock to consist of hornblende, plagioclase, sphene, biotite and iron ore. The amphibole is completely recrystallised now forming small crystals of hornblende with pleochroism Z' = green with a brown tinge, Y' = dark olive green, and X' = greenish yellow. Some prismatic sections still show poikilitic inclusions. The plagioclase has the composition of andesine (about An.39), both as twinned and untwinned grains, in part sericitised. The quartz shows undulose extinction, and forms a mosaic with the plagioclase. Sphene forms rims and irregular patches around the iron oxide, or can be entirely lacking (57). Biotite occurs only in (57) as golden brown flakes, interleaved with chlorite.

A typical example of the coarse-grained type is represented by the elongated metadolerite located a few yards to the north of the roadside quarry at Clogher. The rock is coarse grained, dark green with a strong foliation. Slices (69 and 80) are from the same mass, yet (69) represents a rock slightly more recrystallised than that of (80). The hornblende is in larger crystals, and of a dark green colour.

Changes studied in several thin sections can be summarised as follows :-

(a) The hornblende changes in colour from a light green through dark olive green to brownish green, the most advanced type also possessing a better crystal form.

(b) Oligoclase recrystallises as an andesine of composition An.35-40.

(c) Epidote is entirely lacking.

(d) Sphene is usually absent, though rutile appears at times.

C. Hornblende Schists.

Minor masses of metadolerite occurring along, or in the close neighbourhood of the numerous lines of minor dislocation in the Clooney hornfelses, are converted to green highly foliated and almost schistose types - hornblende schists. Biotite is usually discernible in the hand specimen.

A typical hornblende schist is found in the roadside quarry at Clogher. Slide (75) represents the rock 2ft. away from a line of movement. It consists of hornblende, quartz, plagioclase, biotite and iron oxide, all the minerals attaining a high degree of alignment parallel to the foliation.

The hornblende is green to brownish green, in small stout prisms. Biotite, as a dark reddish brown 'hornfels type', is relatively abundant. Plagioclase occurs mainly in thin streaks along the foliation, it is very highly altered and encloses minute grains of quartz. Quartz, together with some water-clear oligoclase, form a mosaic of fine grains. The relative proportion of the oligoclase-felspar is rather high compared to that of ordinary metadolerite. Iron oxide is also present as thin streaks and trails of grains along the foliation.

The hornblende schists, in general, are characterised by increased quartz and biotite which may represent an addition of silica and potash. They clearly result from dislocation combined with temperature variations, both the consequence of the emplacement of the Ardara pluton.

D. Garnet-Metadolerites.

The presence of garnet in metadolerites in the aureole of the Ardara granite is of particular interest. Garnet-metadolerites have been found to occur in three places in the inner aureole.

The first occurrence is a small metadolerite body situated on the western side of Clooney Hill and about 150yds. N.N.E. of the small quarry at Clogher. The rock is dark green fine grained, with abundant small black garnet crystals. It is non-foliated, and in thin section (63), it is seen to consist of actinolitic hornblende, garnet, oligoclase and quartz with iron oxide and accessory biotite and apatite. It is entirely devoid of sphene or epidote. The garnet is in perfect euhedral crystals about 1½ m.m. across, and contains minute inclusions. The actinolitic hornblende is a pale iron-poor variety, and the iron-oxide forms minute pellets of even distribution.

The second occurrence of garnet-metadolerite is in a small quarry immediately N.W. of Clooney. Here the garnet is seen only towards the contact of the metadolerite and the

sillimanite hornfels. Again it is an actinolite-garnet-oligoclase-quartz rock with iron oxide and biotite. The only difference between this rock and that from the west of Clooney Hill, is the presence of a faint shear structure in the former, and the slightly less euhedral form of the garnet. The actinolitic hornblende is very slightly darker in colour.

The third occurrence of garnet-metadolerite is a small mass on the left-hand side of the quarry at Ardlougher. It is more of a hornblende schist and is associated with the closely folded Calc-Phyllite in that quarry.

In slice (149), the garnet is cracked and broken, and rarely shows good crystal form. The amphibole is mainly hornblende with a slight bluish colour. Biotite is of the usual honey-brown type. Quartz is in excess of the oligoclase. Sphene, iron oxide and rutile are accessories.

From the foregoing, it can be seen that the garnet-metadolerites occurring within the inner aureole have the following characteristics :-

(1) Garnet euhedra.

(2) Pale actinolitic hornblende, sometimes bluish in colour.

(3) The plagioclase is generally oligoclase, a more basic plagioclase is rare.

(4) Abundance of quartz and iron oxide.

(5) Absence of sphene and epidote.

(6) Presence of biotite in unsheared types.

Besides these occurrences of garnet-metadolerite in the inner part of the aureole, there are other occurrences well outside the influence of the granite, these have been termed Garnet-Metadolerite 'Dykes'.

In the southern part of Orinish is found a 2ft. thick dyke of garnet-metadolerite trending E.-W. and about 40yds. long. The dyke appears quite normal, and shows no signs of deformation.

Also at Auninsh island, the graphitic phyllites on the northern part of the island are protected from the sea by a vertical 6ft. thick dyke running roughly E.-W. This dyke is composed of a garnet-bearing metadolerite, and here again the dyke shows no signs of any movement since its intrusion.

The rocks of both these dykes are almost identical to the garnet-metadolerites occurring in the inner aureole. Thin sections (153 and 1476), from the above two dykes, show these massive rocks to consist of pale actinolite, garnet, oligoclase, abundant quartz, biotite, iron oxide and accessory sphene and rutile. Epidote is entirely lacking.

The characters of each individual mineral are also similar to those of the garnet-metadolerites of Clooney.

It can be inferred then, that the Garnet has developed only in the smaller metadolerite bodies essentially prior to the emplacement of the Ardara pluton, and most probably

during the main regional metamorphism of the area.

It follows that this garnet has survived both the regional retrograde metamorphism as well as the local retrograde metamorphism. Mithal (1952, p.153-154) is inclined to ascribe such features as saussuritisation of oligoclase, alteration of biotite and the chloritisation of garnet in metadolerites to diaphthoresis. The writer has not been able to see much changes in the metadolerites under consideration.

The most interesting point regarding the garnet-metadolerites is that in spite of their small size, they show an even greater reluctance towards thermal metamorphism than the normal type of garnet-free metadolerite.

The normal type of garnet amphibolite from the Bogie area - Sutherland (Charlu, 1951) affords a striking similarity to the present garnet-metadolerites. Charlu holds that the garnet has derived its material from both mafic and felspathic sources. Further, to account for the presence of large garnets along the contact of the amphibolites, he suggests that "the garnet substance has drained towards the contact". In view of the mineral assemblage of the garnet-metadolerites at Clooney, and the presence of garnet towards the contact, the writer is inclined to adopt a similar interpretation, essentially a metamorphic redistribution of material, assuming, of course, uniform composition for all the original doleritic intrusions.

In this case, if the mineral assemblage of the garnet-metadolerites is compared with that of normal garnet-free metadolerites containing pale actinolite and oligoclase felspar, it is found that the epidote and sphene of the latter type would have to balance the garnet and excess quarts of the garnet-metadolerite. The excess quarts can always be accounted for by an influx of silica together with a small quantity of potash for the biotite.

The presence of garnet in parts of epidorite masses has been noted by many workers on these rocks.

Iyengar (1950, p.152) "probably the minerals involved in their formation are iron oxide, hornblende and plagioclase, while quartz is one of the end products of the reaction".

Suzuki (1930, p.51) "In certain places the amphibolite proper assumes a peculiar appearance through the development of phenoblasts of garnet" .... "It seems probable that the part rich in garnet is neither a late intrusion nor an extremely altered one of the amphibolite proper produced during metamorphic movement, but a special phase of the original rock".

Wiseman (1934) suggests differences in bulk composition as well as progressive conditions of metamorphism.

III. Metadolerites of the Maas Area.

A. General Description.

The sillimanite hornfelses of Maas are studded with numerous early basic intrusions - now metadolerites. These show a considerable variation as regards size and shape, appearing usually as lenticular bodies or disrupted sill-like masses. Transgressive sheets are of less frequent occurrence. As a result of the emplacement of the granite pluton, together with their metasediment host, the metadolerites have undergone thermal metamorphism accompanied by the impregnation of quartzose material. Salient features distinguishing the metadolerites of the Maas area from those in the Clooney area, are their dark colour, coarse grain and the strong shearing which affected some of these bodies, though others remain unsheared. The latter massive types have a peculiarly coarse and speckled appearance. The strong shearing which is marked by the parallelism of thin white bands of quartzo-felspathic material 0.5 to 2.0 m.m. thick is not limited to the originally chilled margins, but is seen to affect a metadolerite mass in a uniform manner. The metadolerites in this area are often cut by thin pegmatitic and quartz veins, which always show tendencies to ramify and taper.

B. Petrography and Thermal Metamorphism.

The granite pluton is in direct contact with a small mass of metadolerite situated about 300yds. due west of

B.M. 13.3 near Ballyiristen Bridge. The metadolerite possesses a weak foliation and a coarse speckled appearance. Plagioclase occurs in rounded blebs. The contact of the granite and the metadolerite is cut by a dyke of micro-granite about one foot thick.

In thin section (1463) the metadolerite from the immediate contact of the granite is found to consist of hornblende and plagioclase with minor quartz, iron oxide and accessory sphene. The hornblende is in well developed crystals with six-sided sections, now-poikilitic, and of a distinctly darker colour relative to the normal amphibole of the metadolerites. Its pleochroism is Z' = brownish green, Y' = light greenish brown, X' = golden yellow. Plagioclase has the composition of labradorite (An.48-52). A few irregular areas of plagioclase include aggregates of clinozoisite and rare fragments of a sodic blue amphibole, strongly corroded. The rock is devoid of epidote and biotite.

Thin section (529) represents a typical highly sheared biotite-rich variety, from about 50yds. from the granite contact S.W. of B.M. 99.4. The hornblende is of a brownish variety and while some crystals are well developed, others show progressive coalescence. The plagioclase is a labradorite (An.50-53). Biotite is in aggregates of fresh flakes ½ m.m. long and of a deep red-brown colour. These aggregates of biotite are evenly distributed throughout the rock.

Quartz occurs as small recrystallised grains. The rock is devoid of sphene and epidote.

Thus the metadolerites of the Maas area exhibit a distinct higher grade in thermal metamorphism compared to those of the Clooney area. The following are the main characteristics:-

1. The rock is coarser grained and dark blackish green in colour, due to the appearance of a dark greenish brown hornblende.
2. The plagioclase becomes much more basic in composition, Andesine (An.33) becomes labradorite (An.50-53).
3. Epidote is lacking entirely and sphene is generally absent.

IV. Thermal Metamorphism of Lamprophyre Dykes.

Only a few lamprophyre dykes, older than the granite pluton, occur in the inner aureole. The best representative of these dykes is found about 200yds. from the granite contact at the Narin crossroads. Here a dyke which is about two feet thick, runs parallel to the strike of the almost vertical hornfelses striking N.E.- S.W. The dyke is torn into boudins and segments up to 13ft. long.

In hand specimen, the rock is fine grained and of a dull greyish brown colour, and does not differ much from the normal lamprophyres. In thin section (47) it is seen to consist of biotite, hornblende, plagioclase and subordinate quartz.

Biotite is typical 'hornfels type', with pleochroism Z = bright reddish brown, Y = honey brown and X = pale yellow to colourless, with a small axial angle. It is present as small irregular flakes practically all of which appear in the slice as basal sections. Thus the new biotite has been oriented parallel to a phase of foliation unseen in the hand specimen. Hornblende which is subordinate to the biotite, appears as stout but irregular prisms, sometimes poikilitic. Its pleochroism is Z' = pale green and bluish green, Y' = olive green and X' = pale grey green. The felspar is mainly untwinned oligoclase. Quartz appears as recrystallised grains.

Another lamprophyre dyke is found cutting the limestone at Cashelgoland. It is discontinuous and the blocks are 'floating' in the mobilised limestone. In thin section (40) the rock possesses a metamorphic texture and appearance. It consists of pale actinolite, biotite, chlorite, oligoclase felspar with minor quartz, epidote, sphene and iron oxide. The actinolite is very pale green in irregular patches lacking the brown-tan cores typical of the original spessartites of this area. It is also highly poikilitic. Biotite is in small flakes interleaved and associated with chlorite. The chlorite, which is partly after amphibole, is seen to be altering to biotite along its cleavages.

V. Summary and Conclusions.

Prior to the emplacement of the Ardara pluton, the metadolerites in the northern part of the area represented regionally metamorphosed basic intrusions, and consisted of pale actinolitic hornblende, oligoclase felspar, epidote, quartz, sphene and iron oxide in their order of abundance.

As a result of the emplacement of the Ardara granite and the formation of the wide thermal aureole, the masses of metadolerite have responded to thermal metamorphism in a non-uniform manner, in striking contrast to the metasediments.

In general, while some of the metadolerite masses have been affected by thermal metamorphism, others appear almost unchanged. Even in these masses which have responded to contact metamorphism, the cores may be unaltered.

A large number of the metadolerite masses in the Cloney area occur within the andalusite zone, and the others occur along the boundary between the andalusite and sillimanite zones. The contact effects noted can be summarised as follows :-

(1) Pale actinolitic hornblende, usually poikilitic, changes to dark green hornblende of good crystal form.

(2) Oligoclase felspar alters to Andesine (An.35-40).

(3) Epidote disappears.

(4) Sphene decreases considerably.

(5) Biotite is sometimes present in sheared types.

(6) Notable increase in grain size.

On the other hand in the Maas area, the metadolerites occur in the sillimanite zone of the hornfelses, and do in fact represent a more advanced stage compared to those in the Clooney area. The amphibole is a brownish-green hornblende, devoid of inclusions. The plagioclase is labradorite (An.53). Epidote is completely lacking. Sheared types in the Maas area contain abundant biotite and quartz. These metadolerites were impregnated with quartzose material and potash.

Small bodies of garnet-metadolerite occur in the Clooney area, and consist of pale actinolite, garnet euhedra, oligoclase felspar and an unusually high proportion of quartz and biotite, in spite of their unsheared nature. Epidote and sphene are completely absent. These garnet-metadolerites show striking reluctance towards thermal metamorphism.

Thus in spite of the noted 'metamorphic lag' between the metadolerites, in the inner aureole in general, and the hornfelses, thermal metamorphism of the normal metadolerite - garnet-free type - seems to bear a direct relation to the 'metamorphic grade' of the enveloping hornfels.

Chapter TEN.

TECTONIC EFFECTS OF THE ARDARA PLUTON.

1. Tectonics in the Northern Aureole.

A. Introduction.

It may be recalled that the Ardara pluton was emplaced along the south-western flank of the Mulnamin anticline, the axis of which runs roughly N.W. - S.E. Those lithological groups involved in the tectonics associated with the emplacement of the granite pluton, belong to the Maas Succession. The complex structural deformation recorded in these metasediments was invaluable in elucidating the general movement and structural pictures which have supported the conclusions of the present thesis regarding the emplacement of the granite pluton.

The intrusion of the granite was fundamentally of a diapiric nature, the displacement of metasediments by magma in the northern part of the area being effected mainly by two mechanisms functioning together.

There are marked changes in the strike and dip of a succession of lithological groups including the Clooney Pelitic group, the Portnoo Limestone group and the Maas Semipelitic group ; over a distance of three miles there is an angular deflection of this belt of metasediments through about 40° or more in the anticlockwise direction. Movements were at a minimum in the west near Narin, where the regional

strike of the metasediments changes gradually to the arcuate structure of the northern aureole. They were at a maximum in the east, at Maas and Ardlougher, where the locus of the angular deflection is marked by a major dislocation. This shifting of metasediments outward from a gradually inflating granite diapir has caused much of the folding of the metasediments in the aureole, and resulted in the over all arcuate structure of the country rocks around the granite, involving both the tightening of the previously existing folds and a marked degree of dilation.

Secondly, thrusting of the metasediments was effected on every scale. It is necessary to state here that the outward pushing of the metasediments by the granite diapir, and the accompanying thrusting will be dealt with separately for the sake of simplicity in presentation ; both are operating simultaneously and are not actually separable. Thus the angular deflection of the metasediments in the inner aureole involves the removal of the Upper Portnoo Limestone against the Cashelgolan Thrust, as well as the development of minor thrusts by which thin wedges of the Clooney hornfelses override one another.

In the outer aureole, similar movements were operating. At Carrickfad - lying in front of the arcuate structure of the aureole - the rocks are overfolded and thrust outwards. Meanwhile, the rocks of Inishkeel island, in view of their

position with regard to the general movement picture, experience forces acting as a couple in a horizontal and anti-clockwise direction.

B. Alteration of the Strike and Dip.

1. General. From observations in Inishkeel as well as the neighbouring areas of Portnoo and Maas, the regional strike in the area was originally N.W. - S.E. to W.N.W.-E.S.E. prior to the emplacement of the granite pluton. When the lithological groups in Inishkeel and Portnoo are considered with respect to the Mulnamin anticline, it will be found that the Maas Semi-pelitic group, the Portnoo Limestone group and the Clooney Pelitic group originally had this same trend in the area now occupied by the northern part of the granite pluton and its northern aureole.

Thus the emplacement of the Granite pluton had a marked effect on the alteration of the strike and dip of the succession of metasediments during the formation of its northern aureole. The hornfelses now exhibit an arcuate structure parallel to the granite contact and the dip of the metasediments shows a marked increase towards the granite, changing from 25 - 30° to vertical at the contact.

Within the writer's area, the hinge of deviation located between the regional strikeand the arcuate structure of the aureole is at Narin. Hence the Lower Portnoo Limestone near the Golf Club strikes N.W.- S.E. and dips about

30° S.W. It changes its strike to east-west dipping 50° south and finally the metasediments stand vertical striking N.E.- S.W. near the Ardara road.

The belt of metasediments constituting the northern aureole from Narin to the structural break at Ardlougher seems to have been deflected through an angle of not less than 40° in an anticlockwise direction. This belt, hinged at Narin, is most moved to the north in a major structural break - the Ardlougher dislocation.

If the fact that the northern part of the granite pluton wedges towards the north is taken into consideration, it is seen that the original length of the metasediments had been inevitably reduced during the earlier phases of the emplacement of the pluton - when the angular deflection was small. With the further introduction of magma and the gradual swelling of the diapir, the enveloping belt of metasediments must have been stretched, distended or dilated before attaining the present arcuate structure. The shortening of the strike of the metasediments is obtained through folding, meanwhile their later stretching by the shouldering granite involves the tightening of previous folds in the direction of pitch, and the boudinage or tearing apart of the more competent bands, veins or dykes normal to this direction. It will be clarified in a later part how the folding and boudinaging occur side by side and that the

period of folding preceeded to some extent the formation of boudins.

Conditions are somewhat different in the Maas - Letterilly area. Here the granite pluton did not affect the general strike of the metasediments but rather was itself guided by their structure.

2. Folding and Alteration of Strike in the Lower Portnoo Limestone. Near the Golf Club at Narin, the Lower Portnoo Limestone still retains the regional strike of N.W.-S.E. to W.N.W.-E.S.E. and dips at about 30° S.W. In this area the limestone shows distinct drag folds indicating the movement of the upper layers over the lower ones towards the west and west-north-west, i.e. outwards from the aureole.

A traverse over the limestone, towards the Hotel at Narin, makes clear the change of strike to east-west and finally E.N.E.-W.S.W. with an increase of dip to 60° S. At the same time, the folding changes from open drag folds to very tight isoclinal folding towards the granite contact. Behind the Co-operative Stores, the limestone is thrown into isoclinal folds whose axes plunge at various angles along the strike. Again in the lower ground north of Clooney Hill, the Lower Portnoo Limestone shows drag folds indicating the movement of the upper beds over the lower ones in a northernly direction.

Thus the change from regional strike to the arcuate

structure in the aureole, the increase in dip from 25-30° to sub-vertical as well as the change from open drag folding to isoclinal folding as the granite is approached, are all related movements and seem to be the direct result of compression by an outward push.

3. Structures of the Clooney Hornfelses.

The Clooney Hornfelses form the most important group associated with the northern contact of the Ardara granite. The outer part of the andalusite hornfelses shows tight isoclinal folding, and at places, this is accompanied by boudinage structures of later date (Plate 17A). The dip of the hornfelses is about 55 - 60° south.

In the middle part of the Andalusite Zone, the folding tends to become less isoclinal, though still tight. In strong contrast, the inner fifty yards or so of the Andalusite Zone together with the whole of the Sillimanite Zone about 200yds. constitute a Zone of Mobilisation in which the hornfelses exhibit free and unrestrained movements developing swirling flow patterns. The mobilisation in the innermost part of the aureole is more obvious in the andalusite hornfelses than it is in the sillimanite hornfelses, due to the presence of thick bands rich in andalusite crystals (p.240, Plate 12B and 19A). The distortion of these bands emphasizes the flowage of the rocks. Meanwhile, the sillimanite hornfelses

appear to stand vertical or nearly so, and the majority of sedimentary structures are here obliterated by the impress of late shearing and their dull and massive nature.

4. Folding in the Upper Portnoo Limestone.

The Upper Pelite member of the Upper Portnoo Limestone exhibits a peculiar type of folding. The folds are essentially drag folds in agreement with the major anticlinal structure of the area, except that they are extremely tight. The underlying banded graphitic flags are thrown into intricate close folds, the axes of which dip moderately along the strike. Further, the Banded Semi-pelites with the large porphyroblasts of andesine felspar are folded very closely. When these latter rocks are viewed from the top surface of the rocky coast, the axial planes and limbs of the folds are seen to have been folded gently, indicating a second movement approximately at right angles to the first one.

In the well exposed limestone at Drumshantony, two distinct and opposite movements are clearly recorded. Very steep folds, cremulations and compression structures of the metasediments are accompanied by clear boudinage structures indicative of a later distention of the metasediments. This is illustrated by the following :-

The lowermost limestone member shows compression of the mobilised limestone - in a direction oblique to the bedding and normal to the granite contact - the thin micaceous

PLATE 16.

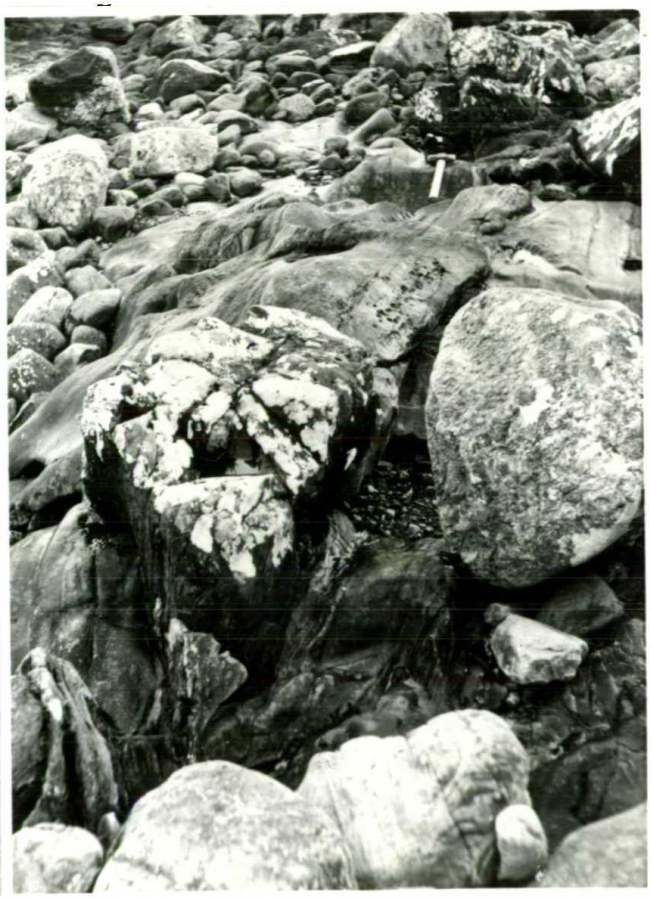
A. Part of the Lower Banded Limestone at Drumshantony beach showing the compressive effect oblique to its strike caused by the forceful emplacement of the granite pluton. The thin micaceous partings marking the original bedding of the limestone are thrown into very close zig-zag folds meanwhile the pure limestone seems to have been in a plastic condition.

B. Original sill-like bodies of metadolerite in the limestone at Drumshantony are torn apart, and here two such segments or boudins (one in the foreground and the other near the hammer) are separated by an interval of 8ft. into which the enclosing marble has flowed.

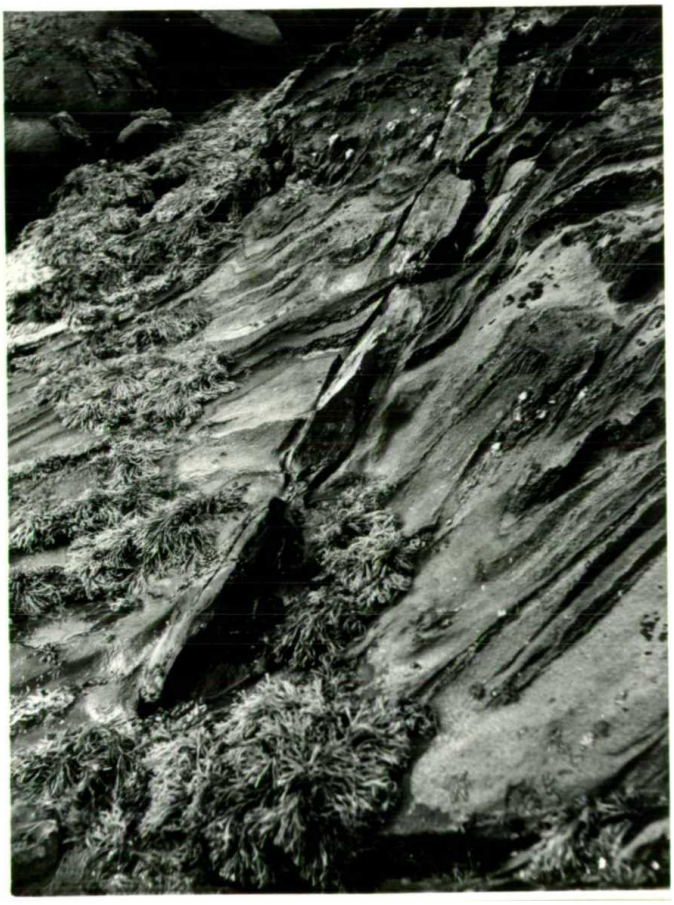
C. A thin lamprophyre dyke at Drumshantony showing excellent boudinage structure. The surrounding limestone shows steep folding and intricate crenulations apparently earlier than the formation of the boudinage structure.



A



B



C

partings are thrown into very close zig-zag folds (Plate 16A). A few feet from this last exposure, this limestone contains large boudins of metadolerite (Plate 16B).

The steep folds and crenulations of the thick micaceous and siliceous bands in the limestone (Plate 16C), indicate a movement precisely compatible with the above case of compression in the limestone, and represent typical steep structures closely associated with the tectonics of granite emplacement. As seen in Plate 16C, the same crenulated limestone contains a lamprophyre dyke showing boudinage structure.

Thexinterbanded limestone and graphitic flags of this group also exhibit complex folding and crenulations plunging very steeply towards the granite contact (Plate 3C).

No such steep structures are seen in the western part of the aureole.

C. Dilation of the Country Rocks in the Aureole.

1. Introduction.

From the foregoing consideration of change of strike of metasediments in the aureole and their attaining an arcuate form, it is only natural to expect that they have undergone a certain amount of dilation or distention during the later phases of the emplacement of the granite pluton. It has been shown how the rocks in the aureole attain tight isoclinal folding together with the change of strike and increase in dip.

It is intended now to review the factual evidence of the distention of the rocks in the aureole, recorded mainly by boudinage structures. In the inner part of the aureole, several types of boudinage structures are found. The direction of the latter usually appear to plunge at very steep angles, even near the vertical, towards the granite contact ; others show a moderate pitch in the steep bedding plane. A few boudins are horizontal, parallel to the contact of the granite.

The following are the main types and occurrences of boudinage structures.

2. Boudinage Structures at Drumshantony.

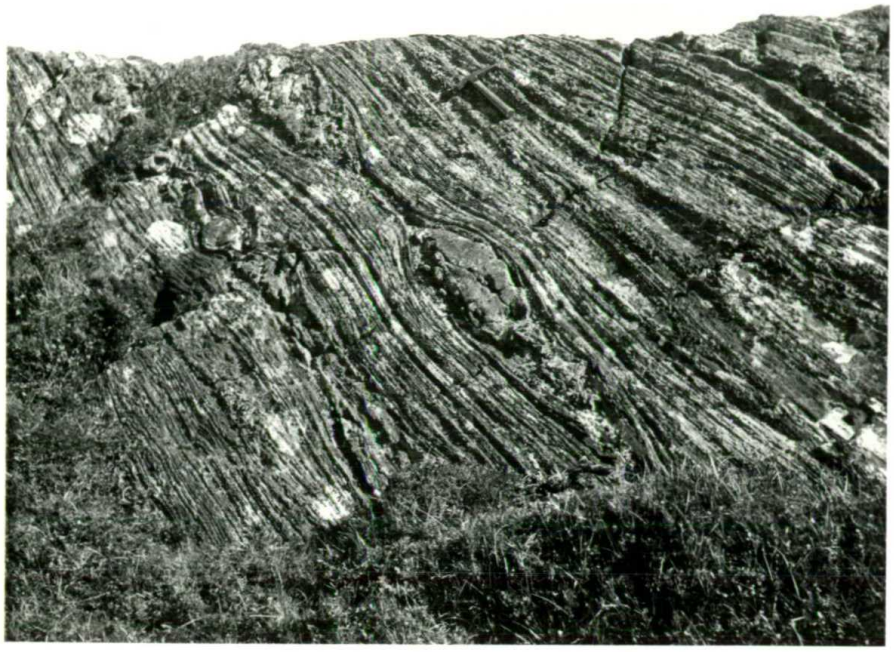
In the Upper Portnoo Limestone at Drumshantony beach, dyke-like bodies of metadolerite lie parallel to the bedding of the marbles. These dyke-like bodies, which average about 2ft. in thickness, are torn apart into lenses or boudins, the length of which varies between 3 to 7ft. with intervals of 7 - 9ft. between them into which the limestone has 'flowed'. Over the small exposed area in this rocky beach, the limestone seems to have been distended to slightly more than double its original length. The distances between the boudins into which the limestone has flowed, exceeds the length of the metadolerite boudins. Sometimes two adjacent boudins are seen to have separated along a more or less flat surface, which may represent a joint plane (Plate 16B).

A steep lamprophyre dyke running oblique to the bedding

PLATE 17.

A. Quartz boudins plunging steeply to the right (towards the granite pluton). The steeply dipping andalusite hornfels surrounding the boudins is folded very tightly, as seen below the hammer. Outer part of the andalusite zone between the summits of Clooney and Cashelgolan Hills, photo looking due east.

B. Boudins of metadolerite with rhomb-shaped cross sections standing almost vertical in the mobilised sillimanite hornfels at Maas. The original sill-like body of metadolerite appears to have been already jointed prior to the distention of the country rocks, during which the joint blocks were pulled apart and slightly rotated.



A



B

of the limestone also shows well developed boudinage structure, but does not show a high degree of distention (Plate 16C).

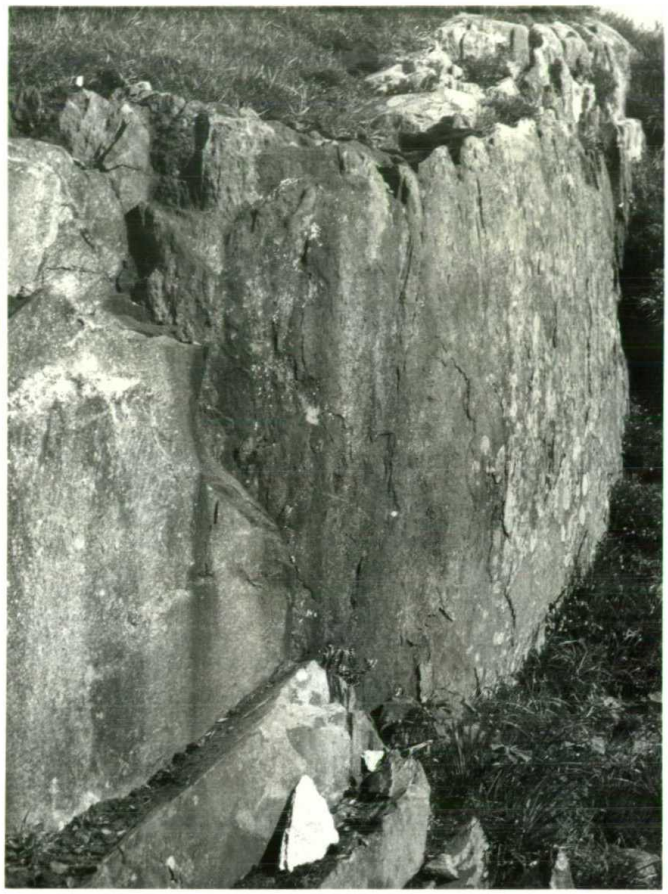
Again in the limestones towards north-eastern Cashelgolan, several boudinaged quartz veins are seen. These are in the form of straight rows of augen and sausage-shaped boudins separated by intervals roughly equivalent to the length of their section. All boudins plunge steeply towards the granite contact.

3. Boudinage of Quartz Veins at Clooney Hill.

In the outer part of the andalusite hornfelses, particularly between the summits of Clooney and Cashelgolan Hills, one finds striking evidence of the late dilation of the already folded hornfelses. Thick quartz veins parallel to the strike are torn apart into boudins, almost two feet long in section, which presumably dip steeply towards the granite contact. In Plate 17A, the hornfelses surrounding the boudins are seen to have been tightly folded beforehand. The interval between the boudins is also about two feet, and assuming a certain elongation of the quartz itself, the hornfelses would appear to have undergone a distention of more than double their original length. By 'original length' it is meant their length after the hornfelses had been folded, the quartz veins having been intruded later than the folding and earlier than the distention.

PLATE 18.

A vertical boudin of metadolerite well exposed after the surrounding sillimanite hornfels has been quarried.
It measures about 7ft. by 1½ ft. in section. Road-side quarry - Clogher.



In the inner part of the andalusite zone, there occurs a peculiar type of boudinage structure in quartz. This is in the form of mullion-like logs of quartz (Plate 19A) plunging steeply towards the granite, and with a strong lineation and rodding parallel to their length. While some of these are undoubted boudinaged quartz veins, the exact nature of others remains rather doubtful.

4. Boudinage of Metadolerites at Clooney and Maas.

In the sillimanite hornfelses at Clooney, metadolerite bodies of an original sill- or dyke-like nature, appear to have been torn apart into sub-vertical boudins plunging steeply towards the granite contact. Several rows of boudins are found in the area west of Clooney, where exposures occur in the small quarries in that area (Plate 18). They are usually between 1 and 2½ft. thick, and about 5 to 7ft. long in section.

In the case of the larger masses of metadolerite aligned parallel to the granite contact, there is a possibility of their having been intruded in the form of one thick sheet and subsequently torn apart with the distended hornfelses. As seen from the map of the area, all these elongated masses lie in one line and their thickness does not vary much. Moreover, if the method of outcrop mapping is also taken into consideration, it will be found that the unexposed parts adjacent to a metadolerite body is naturally represented on

the final map as the enveloping metasediment - in this case pelitic hornfels. Hence there is a tendency to reduce the actual size and probably the continuity of these metadolerite masses.

A very peculiar type of boudins, consisting of metadolerite or hornblende schist, occurs in the highly mobilised sillimanite hornfels at Maas. A few thin sill-like bodies appear conformable with the bedding of the hornfels. Subsequent to their regional metamorphism, a set of joints have been impressed upon them. Due to the dilation and mobilisation of the hornfelses they have been separated along the joint planes, and form steep boudins with cross sections varying from rhombs to rough parallelograms (Plate 17B).

5. Boudinage of Lamprophyre Dykes.

Good representatives of lamprophyre dykes of earlier age than the granite pluton occur at the crossroads at Narin. The largest of these dykes is about 1½ft. thick, and is conformable with the steep hornfelses. It is torn apart into segments up to 13ft. long and the interval between these boudins varies between 4 and 8ft. Again some of the boudins have separated along sharp surfaces, apparently earlier joint planes, and the hornfels has flowed around them in a striking manner (Plate 4A).

6. Boudinage of Competent Sedimentary Bands.

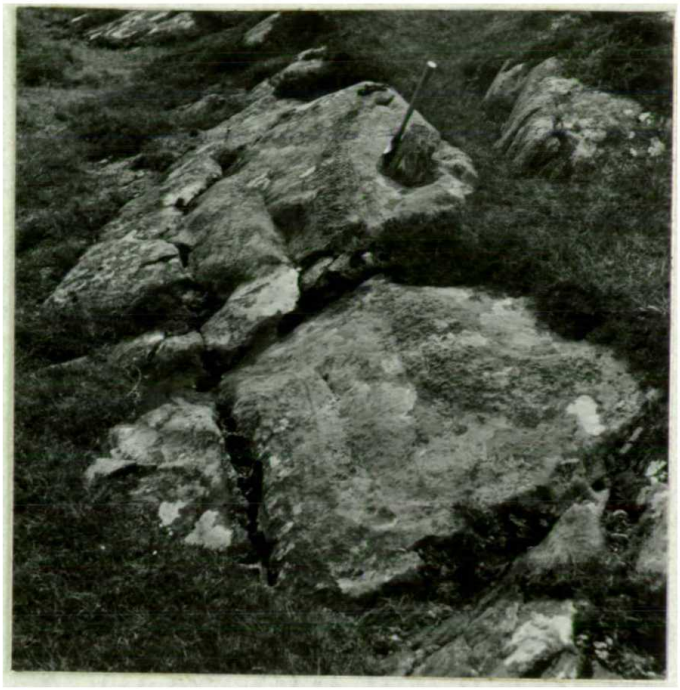
So far, the formation of boudins of metadolerites, lamprophyres and quartz veins have been considered. Boudinage

PLATE 19.

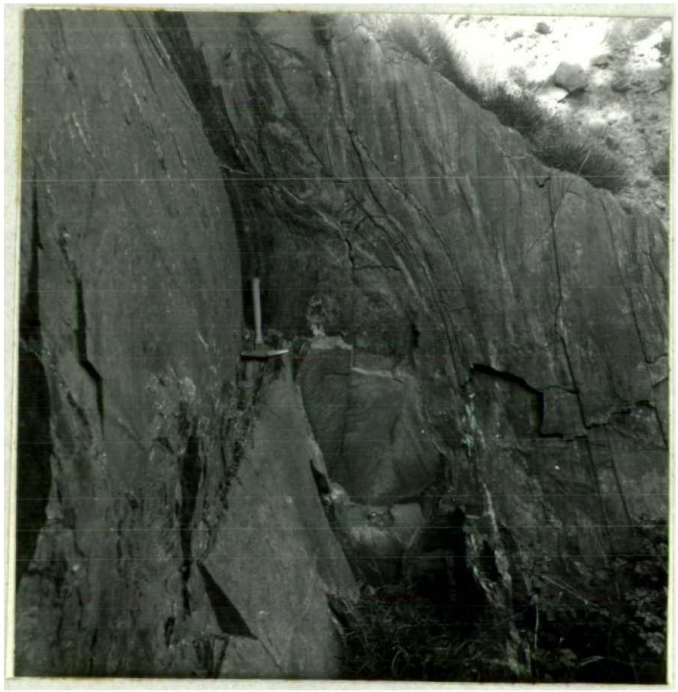
A. Mullion-like quartz boudin in the inner-part of the andalusite zone, plunging steeply towards the granite contact. It is strongly lineated and rodded parallel to its length. The folding of the hornfels is made clear by the presence of the andalusite-rich bands.

B. Cross sections of the horizontal boudins of a calc-silicate band in the sillimanite hornfels at a quarry east of Clooney. Note the vertical hornfels 'flowing in' between the boudins.

A



B



structures are exhibited also by the more competent sedimentary bands, particularly siliceous and calc-silicate bands. The best example of boudins in siliceous bands is seen in the road-side quarry at Clogher. As viewed on the flat joint surfaces, the more competent bands in the sillimanite hornfels are torn into subvertical bouding. Examples of subhorizontal boudins of siliceous bands occur in the cordierite hornfels near the granite contact, where the road from Clooney ascends to meet the Ardara road.

Thin calc-silicate bands in the hornfels of Clooney and Maas show notable boudinage structures. The thick calc-silicate band in the road-side quarry east of Clooney, described on page 253 affords the best example of horizontal bouding. The band is about 1½ft. thick, and is torn apart, the length of the boudins lie horizontally parallel to the granite contact, and with roughly elliptical cross section (Plate 19B).

7. Discussion - Vertical and Horizontal Boudins.

The foregoing has given a detailed description of vertical and horizontal boudins plunging steeply towards the granite contact, as well as a smaller number of horizontal or sub-horizontal boudins roughly parallel to the arcuate structure of the aureole. A small number of boudins occupy an intermediate position, and have different angles of pitch along the bedding plane of the hornfelses. All the boudins

lie in planes parallel to that of the contact of the granite and the enveloping hornfels, and afford the evidence of dilation in these planes in the country rocks, in a similar way as the flattened dark xenoliths in the granite showed the planar distention in the plane of foliation. It has also been shown (p.105) that the relative dimensions of flattened xenoliths as seen on the plane of foliation could be taken to represent the relative proportion of the different components in the planar distention of the outer foliated zone of the pluton. The flattened xenoliths in the plane of foliation had their longest axes lying horizontal and the intermediate axes vertical, indicating a horizontal component greater than the vertical one in the planar distention.

In the country rocks, on the other hand, the majority of the boudins show a tendency to lie steeply in that plane, which would, at first sight, suggest that the dilation of the hornfelses possesses a greater horizontal component. However, the following three points should be considered in th respect :-

(a) Exposures at the present surface of erosion tend to over-emphasize the importance of subvertical boudins over sub-horizontal ones.

(b) Boudinage structures are quite commonly seen on flat rock surfaces, in many cases of which the exact pitch of the bouding along the bedding plane is difficult to determine.

(c) The length of a boudin need not necessarily be precisely normal to the direction of tension, for it has been shown in several instances in the present area (pp.304 and 307) that the more competent bands tend to separate along pre-existing planes of discontinuity, particularly joints, if such are available.

The ratio of the lengths of the boudinaged segments to the length of the intervals between the boudins, into which the less competent rock has flowed, is constant and entirely independent of the orientation of the exposed surface on which the observations are made. The metasediments in the aureole are seen to have been distended to at least double their original length.

D. Thrusting in the Inner Aureole.

1. Introduction.

The change of strike and dip of metasediments, as a result of their displacement by the inflation of the granite pluton, was accompanied by both major and minor thrusting in the aureole. The thrusts are all at a high angle, and can be classified as of two main types :- first, large scale structural breaks in which the hiatus tends to decrease towards one of its ends, including the Cashelgolan Thrust and the Letterilly-Maas-Ardlougher dislocation, secondly, thrusts by which parts of the members of the succession in the inner aureole override one another. They all conform to the

arcuate structure of the enveloping metasediments.

2. The Cashelgolan Thrust.

The Clooney hornfelses forming the high-ground of Clooney and Cashelgolan Hills, are underlain unconformably on their northern side by the Lower Portnoo Limestone forming the low ground to the north. The line of junction marks a considerable high angle thrust plane responsible for the cutting out of the Upper Portnoo Limestone and the evident overriding of the Clooney hornfelses over the limestone. The actual plane of thrust is usually covered, but the topography at the foot of the hornfelses confirms the structural break. Towards the west, it traverses Clooney Lough and is then marked by a deep depression leading to the junction of the two groups on the north-eastern slopes of Narin Hill.

The Cashelgolan Thrust tends to fade out towards the west and at Narin Hill, the graphitic flags of the Upper Portnoo Limestone appear on its northern slopes. The presence of schist intercalations in the limestone at Portnoo and the northern part of Dunmore is evidence of continuity of the Portnoo Limestone Group in this area.

A small number of exposures show the disrupted black flags along the thrust plane north-east of Cashelgolan Hill. From the map, it can be seen that the Clooney hornfelses show maximum overstepping of the limestone near the point where the Cashelgolan and Ardloughor dislocations meet.

Thus the hiatus decreases towards the west, confirming that the alteration of dip and strike of the metasediments and the thrusting were operating hand in hand.

3. Minor Thrusts in the Aureole.

The inner part of the aureole is traversed by several lines of minor dislocation trending parallel to the arcuate structure of the aureole, and marked in the field by narrow straight depressions. These dislocations seem to be high angle thrusts, and are more notable in the andalusite hornfelses at Clooney and Cashelgolan Hills. In the western part of the aureole, three such thrusts run straight towards Marin Hill (Map No.2).

The Lower Portnoo Limestone at Boleymore and Castlegoland House shows clear evidence of minor thrusting.

This small scale thrusting and overriding of the rocks characterises the inner aureole. These appear to be of the same nature as the major thrusting and the thrust planes dip at angles of about 60 - 70° south.

4. The Ardlougher Dislocation.

The Ardlougher dislocation is distinctly marked by a straight depression trending in the N.W.- S.E. direction. This structural break brings the Clooney Pelitic group (as the Clooney hornfelses) structurally against the Upper Portnoo Limestone. Although the break involves no great hiatus stratigraphically, yet there is a strong contrast in dip

and strike as well as in lithology on either side of it, The Clooney hornfels strike approximately east-west and dip at about 65° south, meanwhile the Upper Pelite member of the Upper Portnoo Limestone stands vertical trending N.W.-S.E.

The Ardlougher dislocation is, in all probability, a continuation of a major break, the Maas-Letterilly dislocation as will be shown later. It is of earlier age than the Cashelgolan Thrust which involves the thrusting of the Clooney hornfels towards the outer part of the aureole. The north-western end of the Ardlougher thrust is capped by a low angle thrust slice of andalusite hornfels, which is continuous with the andalusite hornfels of Clooney.

5. The Letterilly-Maas Dislocation.

The band of sillimanite hornfels at Maas, belonging to the Clooney Pelitic group, is bounded on its north-eastern side by a major dislocation trending in a north-western direction and located just west of the road between Letterilly House and the hotel at Maas. This dislocation has been mapped by Iyengar, Pitcher and Read (1953). It proceeds further to the north-west to form the Ardlougher thrust.

From south-east to north-west, this dislocation brings the Clooney Pelitic group in turn against the Mulnamin Calc-silicate flags, the Maas Semi-pelites and the Lower Portnoo Limestone ; the extension in the Ardlougher thrust brings the Clooney Pelitic group against the Upper Portnoo Lime-

stone. Thus along the major structural break, running from Letterilly House through Maas to Ardlougher and north-east Cashelgolan, the hiatus decreases towards the north-west. In an earlier part of this chapter (p.297) it has been shown that this arcuate structural break was essentially the locus along which the end of the Clooney belt of metasediments has moved. It has also been shown from a study of hornfelses in thin section, that there has been movement along the Ardlougher dislocation during the latest stages of the emplacement of the pluton. This is perfectly compatible with the explanation already put forward, for any late feeding of the diapir would result mainly in the angular deflection of the Clooney belt, in other words, a further sliding along the Letterilly-Ardlougher dislocation.

E. Tectonics in the Outer Aureole.

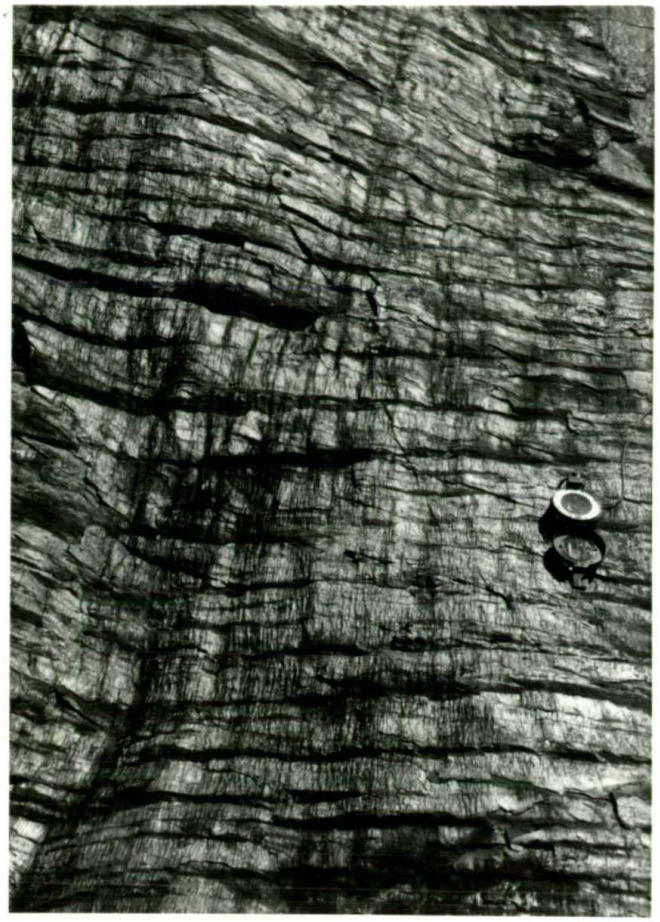
1. Introduction.

The granite tectonics in the outer part of the aureole are recorded mainly at Carrickfad and in Inishkeel island. At Carrickfad, the banded semi-pelitic rocks of the Maas Semi-pelitic group are strongly folded, overturned and thrust over the phyllites forming the lower members of the same group. The whole island of Inishkeel appears to have experienced forces in the form of a horizontal couple acting in the anti-clockwise direction. These forces acting on the island resulted in the partial mobilisation of limestone bands

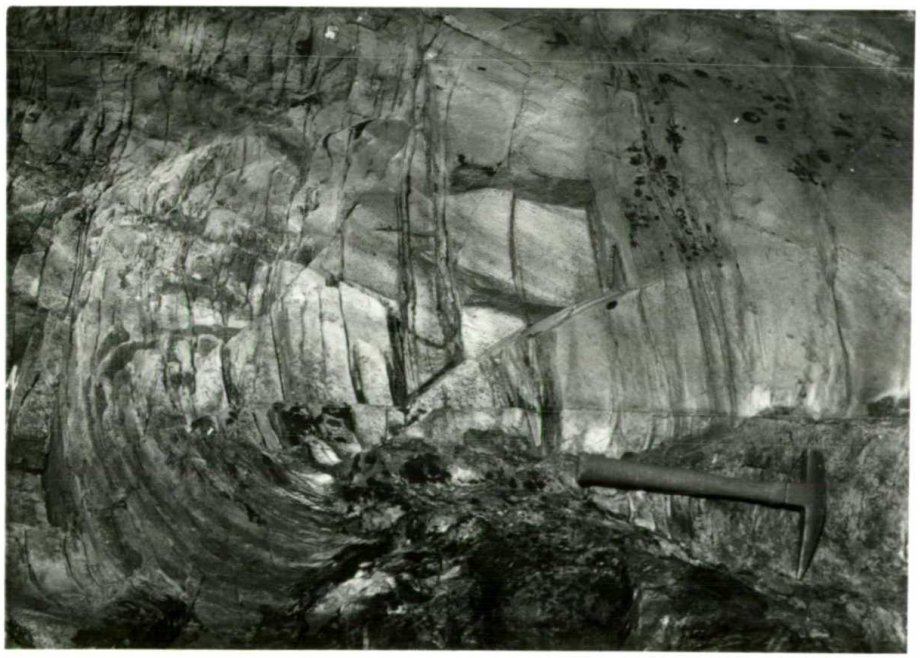
PLATE 20.

A. Closely spaced cross joints (AC joint) associated with the regional folding of the pelitic rocks in Inishkeel Island. These were subsequently distorted by the tectonics of the emplacement of the Ardara Pluton, and appear as gaping gashes. As seen in the centre of the photograph, the joints cease to be straight planes as a result of the schists undergoing a <u>non-affine movement</u> along the bedding planes which is also the plane of schistosity. The strong lineation marks the crests of the minute pucker folds of the 'early' or regional fracture cleavage.

B. Closely spaced cross joints in the silvery phyllite are only slightly distorted (upper part of photograph). These are seen to be curved in the anticlockwise direction as they enter the limestone which is rendered plastic and mobile.



A



B

and the distortion of older cross joints. A new system of conjugate shear joints was formed, with movement taking place along the set of joints, trending N.E.- S.W. This couple of forces also resulted in the faulting present in the western part of the island. All movements conform to one single movement pattern compatible with the position of the island with respect to the diapiric emplacement of the granite pluton.

2. Mobilisation of Limestone and Distortion of Primary Cross Joints.

The closely spaced cross joints (AC joints) which are closely related to the regional folding of the metasediments in Inishkeel (p.42) have been notably distorted as a result of the emplacement of the Ardara granite. As seen in Plate 20A, these cross joints are rendered somewhat irregular and the pelitic schists have undergone a 'non-affine' movement along the bedding. The joint surfaces tend to become curved similar to the sliding of a pack of cards. In some places, the cross joints have been distorted and moved in the anti-clockwise direction (Plate 20B). This is particularly clear where the pelitic schist is in the neighbourhood of a limestone band. The latter appears to have undergone a certain degree of mobilisation.

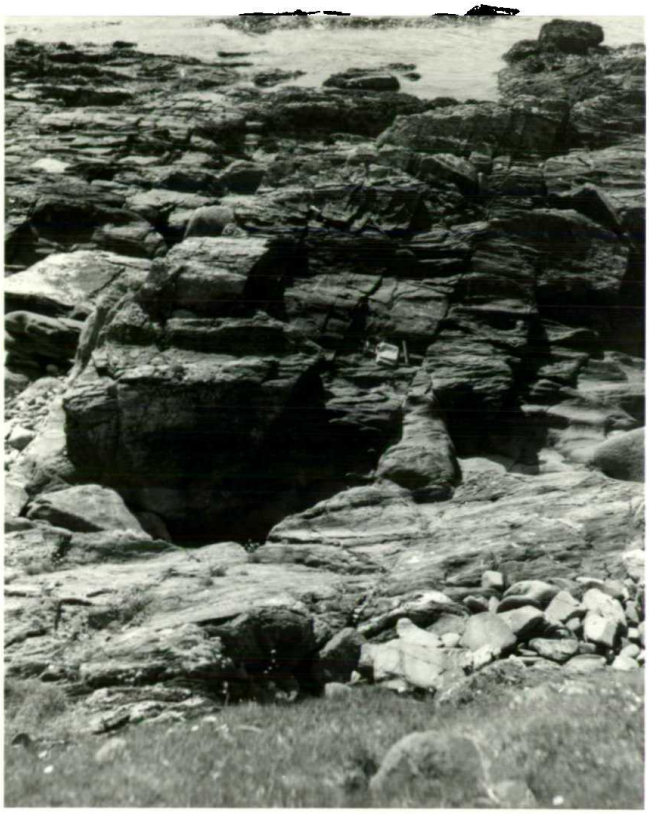
3. Formation of Shear Joints - Inishkeel.

The same forces responsible for the distortion and deformation of primary cross joints have also given rise to

PLATE 21.

A. The well developed N.E. - S.W. trending set of the conjugate system of vertical diagonal joints in Inishkeel as seen on the southern shores of the island. The joints are straight and spaced from 1 - 3ft. apart quite distinct from the distorted 'early' cross joints (plate 20).

B. The N.E.- S.W. set of shear joints cut the lamprophyre dykes into rhomboidal blocks each of which undergoes a small displacement with respect to the next block. The net result is that the trend of the dyke (originally W.N.W.- E.S.E.) locally suffers an angular deflection of 10 - 15° in the antiolockwise direction. The nature of the surrounding interbanded schists (lineated) and limestone (massive) is clear, South Inishkeel.



A



B

FIGURE 5.

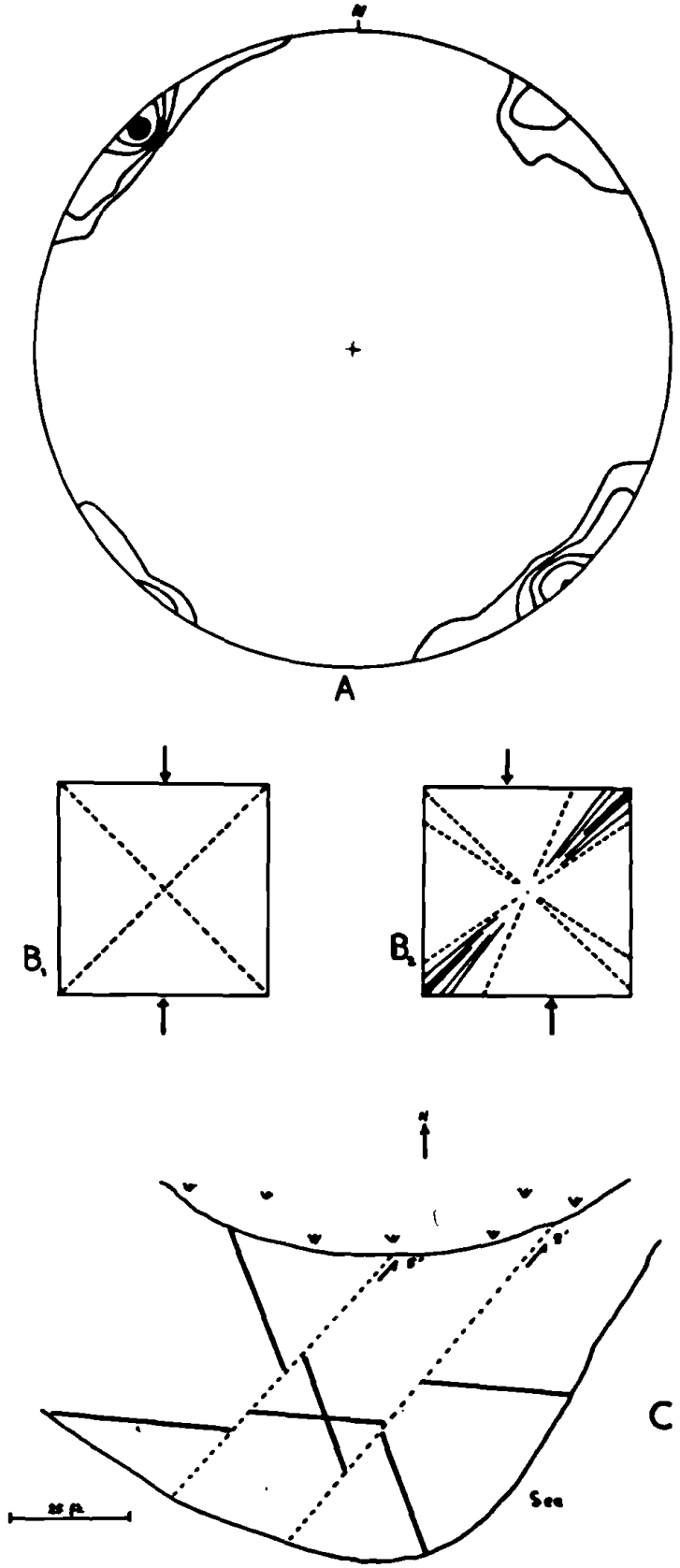
A. Stereographic projection of poles of the conjugate system of 'late' shear joints, Inishkeel Island. 150 joints, contours 2, 5, 10, 15 and 20- % (max).

B1. Theoretical shear fractures in block subjected to compressive forces.

B2. The conjugate system of shear joints from Fig.5A. reconstructed on the face of a block subjected to a couple of forces acting in the anticlockwise direction.

C. Movement of blocks of semi-pelitic schist along the N.E. - S.W. trending set of shear joints with the displacement of lamprophyre-felsite dykes. Southern shores of Inishkeel Island.

FIG . 5



the formation of a system of joints clearly distinct from the earlier ones. The late joint system has perfectly straight fractures which are spaced from one to three feet apart, (Plate 21A).

Fig.5A represents the stereographic projection of the later joint system. It clearly appears to be a conjugate system of diagonal joints, with a set of vertical joints running N.E.-S.W. better developed than the complementary set of joints trending N.W.-S.E. These two sets of joints are of the same nature as stress shear fractures, and appear more obviously so when the maxima and sub-maxima of the stereographic projection are represented on a block diagram, the horizontal section of which is shown by Fig.5B. These forces are a couple or tongue acting in the anticlockwise direction and not acting normally (Billings, 1942, p.304).

Consideration of the potition of the island of Inishkeel in relation to the position of the granite pluton, shows that such forces are in total agreement with the movement picture in the whole aureole.

4. Movement along N.E.- S.W. Shear Joints.

All along the southern coast of Inishkeel, and particularly between Pollowen and Island Mouth, small yet distinct movements have taken place along the well-developed set of vertical shear joints trending N.E.-S.W. These movements are all in the anticlockwise direction, and are marked by the

dislocation of fold axes as well as the lamprophyre dykes.

Fig. 5C shows how the movement of the blocks of schist along the vertical joints is brought out by the displacement of the lamprophyre dykes. Movements on these joints in the pelitic and semi-pelitic schists do not involve any cataclasis or brecciation.

Where the lamprophyre dykes run through calcareous schists or schists interbanded with thin bands of limestone, they are cut by the same set of joint planes into small rhomboidal blocks. While thin bands of schist show the joint fractures fairly distinct, the limestone layers are devoid of any trace of the joint plane, suggestive of a somewhat mobile condition. Each one of the rhomboidal blocks of the lamprophyre dykes trending W.N.W. - E.S.E. undergoes a small displacement with respect to the next block (Plate 21B). The successive kinks or displacement amount to about 10" in every 5ft. along the dyke. The net result would be that the trend of the lamprophyre dyke locally suffers an angular deflection of about 10 - 15° in the anticlockwise direction.

Among the numerous sets of joints in the metadolerite mass at Inishkeel, a vertical set of joints trending N.E.-S.W. is rather outstanding. These joints are seen to run through the whole mass in a remarkably straight manner. A certain amount of movement has taken place along this set of joints, and where the latter are closely spaced, at

PLATE 22.

A. Fault breccia along one of the N.E.-S.W. trending faults in the western part of Inishkeel Island. The fragments in the breccia have a sigmoidal arrangement indicating the direction of movement.

B. Strongly overturned folds towards the north in the banded pelites of the eastern block, Carrickfad. Parts of folded quartz vein are torn apart into boudins lying horizontally E.-W. and have an almost circular cross section. Photo looking due east.

A



B



intervals of about 6" to 9", the rock in between usually shows shattering and brecciation.

5. Faulting in Inishkeel.

The western extremity of Inishkeel is traversed by several faults all trending N.N.E.- S.S.W. The movement along the faults is very clearly seen in that part of the island, and the displacement of the flat lying sheets of felsitic lamprophyre and basic lamprophyre indicate a horizontal movement in the anticlockwise direction with an insignificant vertical component. The faults are marked by well developed fault breccias (Plate 22A), in which the fragments in the breccia have a sigmoidal arrangement indicating the direction of movement.

6. Overfolding and Thrusting at Carrickfad.

The group of isolated rocks at Carrickfad consist of an eastern unit of alternately banded semi-pelites and pelites thrust against quartz-mica-phyllites, belonging to the upper and lowermost members of the Maas Semi-pelitic group.

The banded pelites of the eastern block show strongly overturned folds, with the axial planes dipping gently to the south (Plate 22B). Meanwhile the hard phyllites in the west lie flat and do not show any signs of folding.

The folding of the thrust block of banded pelites is rather peculiar as regards its recumbent nature and high degree of overturning, as well as the fold axes. First, the regional

FIGURE 6.

Stereographic projection of the fracture cleavage (poles) in Inishkeel, Carrickfad and Grabbindoe. The fracture cleavage in Inishkeel trending W.N.W.- E.S.E. (dots on right hand side of diagram) is the early fracture cleavage associated with the regional folding. The other set of fracture cleavage (dots on left hand side) together with that at Carrickfad and Grabbindoe form an arcuate parallel to the outer margin of the pluton; this is the late fracture cleavage associated with the tectonics of the emplacement of the pluton. (Lower hemisphere or equal area net).

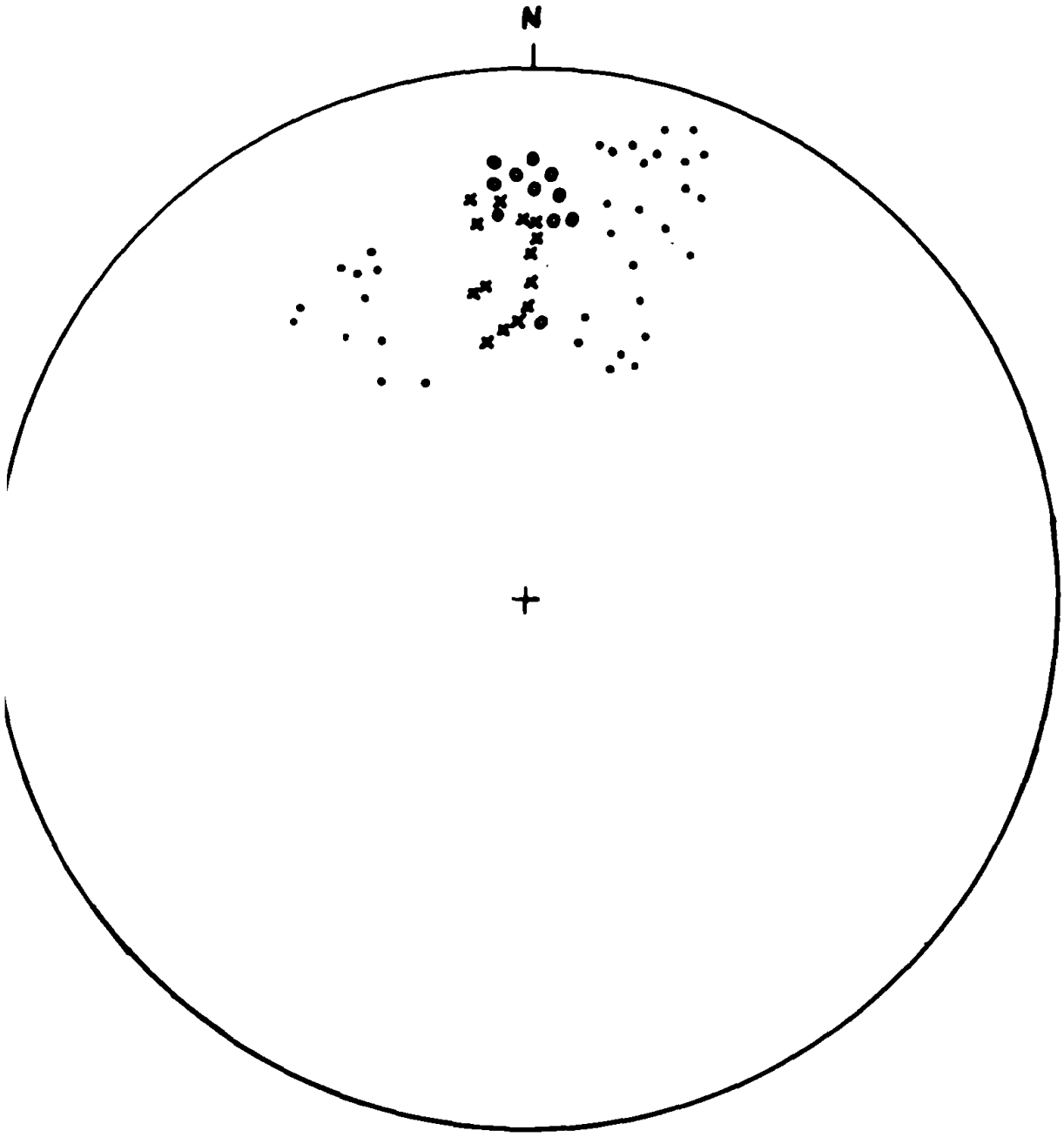


Fig. 6 Poles to Fracture Cleavage

• Inishkeel Island

× Carrickfad

o Grabbindoo

folding both in the present area and in the neighbouring areas is very seldom overturned and never does it reach such a high degree of overturning, though the folding is usually asymmetrical. Secondly, the axes of folds, do not agree with the regional folding or even with the post orogenic movements from the south-east. The axes of folding are, however, tangential to the arcuate structure in the aureole.

Hence it seems that the thrusting and strong recumbent folding at Carrickfad is associated entirely with the tectonics of the Ardara pluton.

7. Development of late Fracture Cleavage.

The fracture cleavage associated with the regional folding of the rocks at Inishkeel has already been described (p.41) As a result of the emplacement of the granite pluton, a late set of fracture cleavage has been impressed upon the rocks in Carrickfad, Grabbindoo-Auninish and part of Inishkeel.

Fig.6 represents the stereographic projection of the normals or poles to the fracture cleavage in these localities. It is clear that there are two sets of fracture cleavage in Inishkeel, that trending W.N.W.-E.S.E. (dots on the right hand side) already shown to be associated with the main orogeny, and a later set trending N.E.-S.W. (dots on the extreme left). When this latter set is considered together with those in Carrickfad and Grabbindoo-Auninish (crosses and circles respectively) they are found to form a planar struct-

ure compatible with the arcuate structure of the aureole and dipping towards the pluton.

This planar element of fracture assumes the form of a joint system in the more competent phyllites, (Hills, E.S. 1940, p.101 and Leith, K.C. 1923, p.154) both state that fracture cleavage can take the form of a joint system in more competent beds.

It is also of the same nature as Mead's (1940) Shear Cleavage, which Wilson (1946) refers to as "occurring in beds which, after they have once been folded and possibly cleaved, have been further subjected to stress".

II. Granite Tectonics in the South.

A. Introduction.

The Ardara pluton is bounded on its southern side by the Glenties Pelites, the lowermost member of the Glenties Series.

The tectonics of the Ardara granite at this contact are of a simple nature and afford a striking contrast to the corresponding tectonics in the northern aureole. No thrusting of metasediments away from the immediate contact of the granite has been noted, and the field evidence suggests that there has been very little dilation of the country rocks. The granite was apparently able only to compress its southern envelope outwards to a limited extent, but essentially in an even manner normal to the original strike of the

metasediments. This involves practically no change in the strike and only a small change in dip of the metasediments at the contact. Vertical structures are restricted to the more competent bands and metadolerite inclusions.

Many structures in the close vicinity of the granite are entirely independent of it and are the result of post granite movements to be considered later. However, it is to be expected that these late movements have contributed towards the obliteration of small structures associated with the emplacement of the pluton.

B. Dip and Strike of the Contact Metasediments.

The rocks of the Glenties Series strike N.E. - S.W. parallel to the Carbane Thrust at the base of the Quartzite group, and dip south at angles of 55 - 70°. The strike gradually deviates from N.E. - S.W. to E. -W. and E.S.E. - W.N.W. from near Gortnacart School through Woodhill to Ardara. This deviation is also parallel to the Carbane Thrust, and the Glenties Series tends to retain the same thickness between the granite and the Quartzite group. Thus there is no evidence on which to ascribe this deviation in trend to the emplacement of the granite pluton.

Again, it is found that in distinction to the northern aureole, there is no appreciable increase in dip as the granite is approached. This together with all the field observations suggest that there has been no pushing and

shouldering of any great magnitude by the granite. However, the general structure of the area and particularly the relation of the Glenties Series to the Mulnamin anticline and the presumed mode of emplacement of the pluton along the Glenties thrust between these two blocks, suggest the possibility of the Glenties Series as a whole having been pushed or compressed to the south-east over a distance equivalent to about half the width of the neck of the pluton.

C. Boudinage Structures near Glenties.

In the well exposed pelites around the new housing site south of Glenties, are frequent sill-like bodies of metadolerite and hornblende schist forming boudins. These are about 5" to 20" thick and the length of the segments varies widely between 6" and 2½ft. They have the strong foliation characteristic of the metadolerites in the great imbricate zone of the Glenties Series, and this foliation is usually oblique to the longer axis of elliptical cross section of the vertical boudins. At the broken ends of the boudins, the foliation showed marked deflection and drawing out.

These boudins show definite evidence of movement later than their tearing apart, and thus the extent of dilation cannot be estimated.

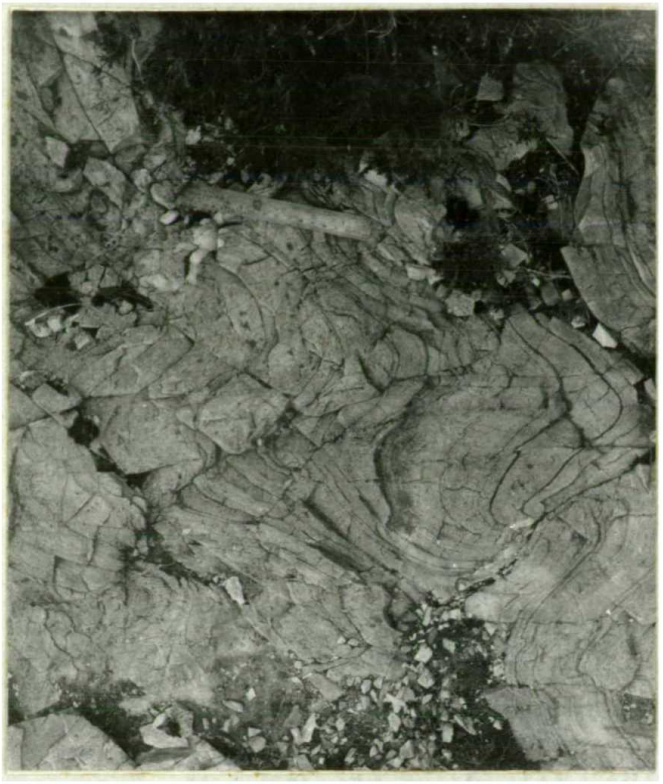
D. Vertical Structures.

In a large quarry along the Glenties-Ardara road about ¼ mile south-west of Corn Mill, the Glenties Quartzite is

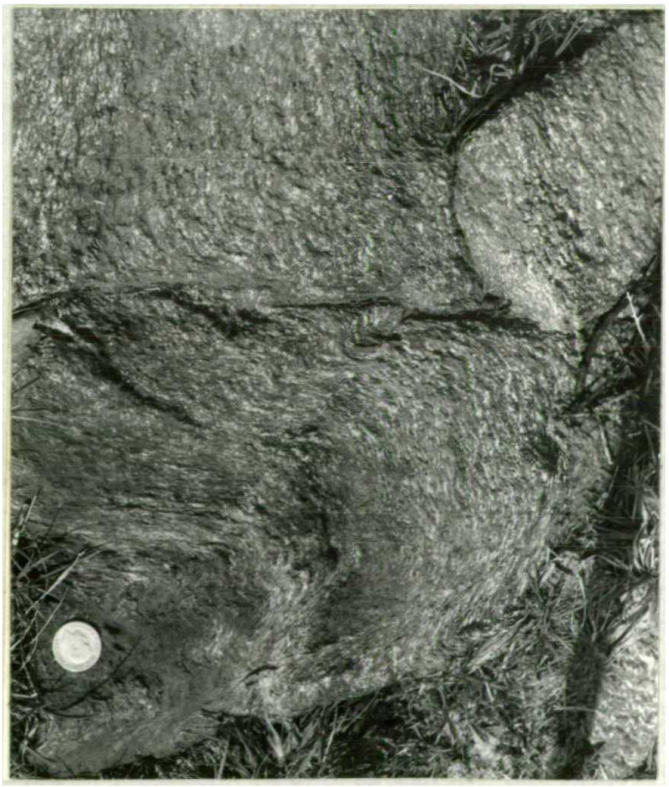
PLATE 23.

A. Highly schistose hornblende scnist showing folding and frilling upon vertical axes, near the southern contact of the pluton.

B. The Glenties Quartzite, near the southern margin of the pluton, is intricately folded along vertical axes and is moved and disrupted along vertical planes of movement, large quarry by the side of the Glenties-Ardara road, about ¼mile south-west of Corn Mill.



A



B

vertical and trends N.E. - S.W. The quartzite is intricately folded along vertical axes as well as having been moved and disrupted along vertical planes of movement (Plate 23B). The latter are usually filled with quartz.

The quarried parts of the quartzite are seen to contain small inclusions of hornblende schist with a strong foliation. The movement of the enclosing quartzites has brought about similar vertical folding and frilling in the hornblende schist (Spc.643 and Plate 23A).

All these are vertical structures related to the tectonics of emplacement of the granite pluton.

III. Summary.

The space now occupied by the larger part of the pluton was originally occupied by part of the Maas Succession consisting of the Maas Semi-pelitic Group, the Portnoo Limestone Group, the Clooney Pelitic group as well as the Rosbeg Semi-pelitic group. These metasediments trending N.W. - S.E. formed the south-western flank of the Mulnamin anticline. Along the southern flank of the anticline, these lithological groups were sheared out by the Glenties Thrust during the post-orogenic movements. It has been considered in detail how the pluton was first emplaced by movement of magma along the Glenties Thrust and the formation of the nucleus of the diapir at the point of divergence between the major thrust and the axis of the Mulnamin Anticline.

The Rosbeg Semipelitic group which originally existed in the area now occupied by the southern half of the pluton, was mainly sheared out by the inflating diapir and a small part of it may have been deflected to the west. Meanwhile, the Clooney Pelitic group and the Portnoo Limestone group originally occurring as a belt in the area of the northern part of the pluton and its northern aureole, have experienced an angular deflection towards the north, with the formation of a dislocation of the nature of a tear fault from Letterilly to Ardlougher. This belt of metasediments was hinged at Narin in the west and its eastern end slid along the locus of movement - the Ardlougher dislocation. As the latter trends S.E.-N.W., the belt of metasediments was continually being reduced in length by small scale folding on steep axes.

In the latter phases of the emplacement of the pluton, the northernly deflected belt of hornfelses was made to assume an arcuate structure bounding the inflating diapir on the northern side ; this has caused a distention of the metasediments up to at least double their length after the folding. This dilation was also accompanied by the development of major and minor thrusts p rallel to the arcuate structure of the aureole.

In view of its position relative to the pluton, Inishkeel island was subject to forces in the form of a tongue acting horizontally in the anticlockwise direction.

There is no evidence of the pluton to have caused any considerable shouldering of the metasediments of the Glenties Series.

Hence the Ardara Granitic Pluton is seen to have been emplaced along a major structural break and further to have accommodated itself by the forceful displacement of metasediments.

Chapter ELEVEN.

POST GRANITE TECTONICS AND THE AREA SOUTH OF THE ARDARA PLUTON.

I. Introduction.

Subsequent to the emplacement of the Ardara pluton, the area to the south of the pluton has experienced two distinct movements.

The first of these was a further thrust of the Quartzite group over the Glenties Series, resulting in the phyllonitisation of the southern aureole of the Ardara pluton and the 'cold' mylonitisation of the early band of tonalite converting it into the Mylonitic Gneiss of Carbane. This movement is also marked by a lineation, mullion structure and small overturned folds trending horizontal N.E. - S.W. or plunging gently to the north-east. The overturned folds indicate a movement to the north-west.

Secondly, it has been shown in the study of the 'neck' of the Ardara pluton, that late movements have impressed secondary linear structures upon the quartz-diorite and the pegmatitic fringe of the Doocharry granite while the rocks were in a somewhat warm state. Identical secondary structures have been impressed upon the rocks of the Glenties Series adjacent to the pluton.

The pelitic rocks of the Glenties Series situated to the north and north-east of Glenties, as well as those in the

easternmost part of the area, contain staurolite ; this is attributed to the emplacement of the Doocharry Granite.

II. The Second Thrusting of the Quartzite Group.

A. General Statement.

It has been stated already that the Glenties Series lying between the southern and south-eastern margins of the Ardara pluton - the original Glenties Thrust - and the Carbane Thrust at the foot of the Quartzite thrust blocks, is divided into two groups; the Glenties Pelites and Semi-pelites, and the Glenties Calc-group. It has been shown that the rocks of the Glenties Series lie in a great imbricate zone and that the marker horizons, such as bands of limestone and quartzite, are usually sheared out and disappear abruptly. The whole belt trending N.E. - S.W. seems to contain an infinite number of minor thrusts and dislocations parallel to the strike and to the main thrusts. The Glenties Series also contains a band of tonalite apparently intruded in the form of a sheet-like body along a subsidiary dislocation during the post-orogenic movements.

The further thrusting of the Quartzite group over the Glenties Series subsequent to the emplacement of the Ardara pluton, has caused the destruction of the southern aureole of the Ardara pluton and the conversion of the tonalite band into a mylonitic gneiss. This Mylonitic Gneiss of Carbane together with its contact metasediments will be

considered separately in the next chapter. The pelites and semi-pelites of the Glenties Series show progressive cataclasis and destruction of the contact minerals - marking the thermal effect of the pluton - from near the margin of the granite pluton towards the Quartzites. Hence a rather detailed petrographic description of these rocks is inevitable. Bands of limestone are also disrupted.

B. Petrographic Description of the Glenties Pelites and Semi-Pelites.

1. Hornfelses near the Southern Contact of the Pluton.

The pelitic and semi-pelitic rocks near the southern margin of the granite pluton retain their identity as hornfelses and show progressive retrogression away from the contact. A typical hornfels from a large quarry at Doochill North is seen in slice 663 to be a sillimanite-biotite-hornfels. It consists of biotite, muscovite, sillimanite, and quartz, with subordinate felspar and accessory iron oxide and zircon. Sericite and chlorite are secondary. The sillimanite, mainly as fibrolite, is almost entirely altered to sericite. The fibrolite was apparently growing at the expense of the biotite. Biotite is locally altered to chlorite.

In the lower part of the Glenties Pelites, the rocks are occasionally interbedded with thin calcareous bands. Representative pelitic and calcareous bands along the granite

contact 300yds. west of Garvegort School are seen in slices 656A and 656B. The pelitic band consists of red-brown biotite, quartz, oligoclase felspar with subordinate clinozoisite, sphene and iron oxide. The rock is suspected to contain cordierite altered to pinite. The calcareous band consists of calcite, clinozoisite, actinolite, quartz and iron oxide.

Slice 864 represents a garnet-staurolite-hornfels from the lowermost exposures of the Glenties Pelites in the Owentocker river, exactly $^1/_3$ mile from the granite contact. The rock consists of pelitic layers alternating with more siliceous bands. The pelitic layers consist mainly of muscovite with some biotite, minute grains of garnet and less abundant staurolite; the semi-pelitic bands consist mainly of quartz with some red-brown biotite, muscovite and minute crystals of garnet. The rock also contains rounded aggregates of fine sericite and chlorite, probably after staurolite. Tourmaline is a notable accessory.

At Tuck Mill, the pelitic rocks seem to have locally escaped the high shear. They appear to be highly mobilised, and the bedding is partly obliterated. Slice 850 contains patches $^1/_3$ m.m. to 1 m.m. across of schimmer-chlorite aggregates apparently after staurolite, which are sometimes surrounded by rims of iron oxide. Other such pseudomorphs 1 m.m. across, which appear to have originally pushed the

foliation aside, contain chlorite, biotite and fragments of garnet. Porphyroblasts of acid plagioclase also grow along the planes of schistosity.

2. Typical Glenties Pelites.

The typical Glenties Pelites are coarse muscovite-biotite-chlorite-phyllonites dark brown to greyish brown in colour and with a distinct knotty structure on the bedding plane. These pelites are very distinct in the field and the rock type is readily recognised in buildings and walls around Glenties and Ardara. The rocks are highly sheared and do not show any indication of their previous hornfelsed condition. Slice 737 is representative and comes from the large road-side exposure near the Parsonage near Glenties. It consists of biotite, muscovite and quartz with subordinate oligoclase-andesine. Iron oxide and apatite are accessory. The biotite is honey-brown and shows strong bending.

Typical Glenties Pelites are also well exposed at Snug-borough. In slice 737, the rock appears as a muscovite-biotite-chlorite-phyllonite with accessory apatite, tourmaline and iron oxide. Sericite forms thin partings associated with the muscovite which is strongly bent. The biotite is largely altered to chlorite. The rock is highly disrupted, and contains undulating veins and eyelets of late quartz.

3. Maximum Cataclasis in the Glenties Pelites.

The Glenties Pelites show a progressive increase in

shearing and cataclasis towards the Quartzites, the rock being ultimately granulated. The maximum cataclasis in these pelites is distinct at a locality due east of Mill Ponds. There the bedding and all other structural elements are completely obliterated and the rock is almost rodded horizontally in a direction N.65° E. It will be shown in the next chapter how this strong linear element marks the thrust movements of the Quartzites responsible for the production of the mylonitic gneiss.

In slice 750, the almost rodded pelitic rock consists of disrupted and crinkled bands and isolated masses of muscovite set in a very finely granulated groundmass of quartz, chlorite, muscovite and iron oxide. The muscovite bands contain older trails of opaque dust shewing the same crinkling. Veinlets of late quartz are seen to contain elongated inclusions of the finely granulated groundmass.

A similar rock comes from the new housing site at Glenties. Slice 732 shows the rocks to consist of muscovite in the form of disrupted lenticular masses or frilled bands set in a finely granulated matrix of quartz, red-brown biotite is largely chloritised.

C. Quartzite and Limestone bands in the Glenties Series.

1. The Glenties Quartzite.

A band of quartzite about 80yds. thick occurs immediately east of Glenties. It is either vertical or dips very steeply to the south-east. It is distinctly banded and

includes bands of dark grey siliceous granulites. At its north-eastern extremity, it tapers alongside a fault. It reappears once more in the quarry near Mullantiboyle. A small lenticle of quartzite about 40yds. long occurs by the roadside near the Salmon Hatchery.

The white quartzite from the quarry at Mullantiboyle (slice 642) possesses a light banding marked by the alignment of minute flakes of muscovite. Zones of cataclasis and granulation lie parallel to the banding. The rock consists of quartz with porphyroblasts of microperthite in part reverting to microcline. The banded grey quartzite which is well exposed in the Fair Ground at Glenties appears in slice 709 to be a quartz-biotite-granulite with bands rich in biotite. The latter occurs as minute flakes aligned parallel to the bedding, with pleochroism Z = Y = dull brown X = pale yellow. Muscovite is subordinate to the biotite and seems to be restricted to certain bands. Apatite, epidote and iron oxide are accessory.

2. The Glenties Limestone.

The Glenties Limestone forms a band about 25ft. wide, and is very well exposed below Stracashel bridge north of Glenties. The limestone contains thin bands of calc silicates which are highly disrupted and appear as broken fragments in a groundmass of mobilised limestone. Slice 706, represents one of the folded and disrupted calc-silicate bands, in-

cluding a dark green band up to 5 m.m. thick and other layers of a medium green colour. The pure limestone base is white. The dark grey band consists of fragments of garnet surrounded by pools of yellowish green chlorite. The green bands consist of calcite, clinozoisite minute fragments of unaltered garnet and opaque dust.

At Kilreen, a similar limestone band contains similar disrupted calc-silicate bands (slice 772).

D. The Glenties Calc-group.

The Glenties Calc-group, comprising a wide variety of rocks of calc-silicate origin, is closely associated with the Mylonitic Gneiss of Carbane, and the whole group of calc-silicate lie within the contact zone of the original sheet-like intrusion of tonalite. In general, these rocks do not exhibit distinct cataclastic textures in spite of their close neighbourhood to the Carbane Thrust. However, at Kilreen Upper, the calc-silicate rocks are either disrupted or folded along horizontal axes trending N.E.- S.W. ; a representative rock showing late cataclasis is provided by slice 760. It consists of bands rich in epidote and chlorite alternating with bands consisting mainly of a finely granulated matrix of quartz and minor felspar porphyroclasts. The epidote-rich bands do not exhibit any cataclasis.

E. Metadolerites in the Glenties Series.

1. General Description. The metadolerites in the

Glenties Series are very distinct from the metadolerites found in other parts of the area owing to their highly sheared nature. The rocks possess a remarkably strong foliation and are appropriately termed hornblende schists. At a large quarry facing the bridge above Salmon Weir, Glenties, the hornblende schist is quarried as thin slabs resembling slates. In another quarried exposure along the Glenties-Ardara road, situated at a point 1000yds. east of the fault at Garvegort School, the highly schistose hornblende schist contains a distinct strain slip cleavage almost normal to the schistosity (Spc.652). Sometimes thin veins of quartz follow the schistosity of the rock.

At Stracashel bridge, North of Glenties, the highly foliated metadolerite is clearly folded along an almost horizontal axis.

The rather advanced shearing of these metadolerites in the Glenties Series becomes more interesting when the following observations are considered.

The metadolerites lying within the contact altered zone round the Mylonitic Gneiss of Carbane (p.356), exhibit a highly mobilised foliation, the latter being of the usual type of foliation characterising the metadolerites of the Glenties Series. This seems to indicate that at least part of this high shearing in these metadolerites had been effected during the main phase of the thrust movements from

the S.E. even before the sheet-like tonalite had been intruded along a subsidiary plane of dislocation.

Also the strongly schistose hornblende had been affected by the tectonics of the Ardara Granite (p.323).

2. Petrography of the Hornblende Schists.

In slice 707, the hornblende schists of Stracashel Bridge is seen to consist of pale green hornblende, andesine of composition about An.40-42 and oligoclase with minor quartz, sphene, epidote and iron oxide. Apatite is accessory. The amphibole occurs as small particles with poikilitic inclusions and pleochroism Z' = medium green, Y' = Yellowish green and X' = almost colourless. The hornblende schist with the strain slip cleavage from Stranacross, seems to bear the contact effect of the granite pluton which is about 60yds. away. In slice 652, the amphibole is seen to occur as minute crystals, greenish brown in colour and aligned parallel to the foliation of the rock. In some parts of the thin section, brown hornblende is developing along the cleavages of the green hornblende. Andesine of composition about An.45 occurs as minute grains, usually sericitised. Sphene forms minute crystals or elongated masses associated with iron oxide.

III. Late Movements Contemporaneous with the Doocharry Granite.

A. Structural features and time relations.

It has already been shown (pp.213-215) that the xenolithic quartz-diorite in the 'neck' of the pluton has experienced late movements impressing upon it secondary linear structures plunging gently to the south-west. It has also been stated (p.215) that the pegmatitic fringe of the Doocharry Granite in the north-eastern part of the 'neck', first contains large inclusions of the strongly lineated and rodded quartz-diorite, and secondly that it possesses an identical linear structure - though much weaker in intensity. It was thus concluded that the pegmatitic fringe of the Doocharry Granite had reached its present level while the late movements were still in operation but essentially after these had attained their climax.

Structures identical in direction and plunge are present in the Glenties Pelites bounding the granite pluton on the south-east and south. The pelites are thrown into small scale folds plunging about 20° to the south-west. These structures occur in a belt, $^{1}/_{3}$ to $^{2}/_{3}$ miles wide which is fairly distinct from the belt of drastic phyllonitisation and 'cold' cataclasis parallel to the Quartzite group.

The evidence that the movements contemporaneous with the Doocharry Granite are later than the second thrusting of the Quartzites causing the 'cold' mylonitisation, lies in the

fact that the Doocharry Granite has a definite thermal aureole characterised by the development of staurolite. These staurolite-bearing pelites occur around Glenties and to the north-east of the town and extend to near the mylonitic gneiss at Glenmaccive ; in this locality they are not sheared. These hornfelses exhibit very clearly the small scale folds plunging to the south-west, and their staurolite porphyroblasts are distinctly rolled.

The lineation and small scale folding in the pelites adjacent to the southern contact of the pluton, changes its direction from south-west to west-south-west and finally tends to plunge almost in a westerly direction near Doochill North, but the plunge remains constant at about 20°. Metadolerites and hornblende schists lying in the zone of metasediments showing the linear structure plunging to the south-west, also possess a parallelism of hornblende crystals plunging in the same direction. This structure can be very strong locally.

B. <u>The Staurolite-Hornfelses near Glenties</u>.

1. <u>General Description</u>.

The part of the Glenties Pelites to the north of Glenties and lying between the Glenties Quartzite band and the margin of the pluton, are characterised by the presence of large porphyroblasts of staurolite. In places, the rocks show clear evidence of strong mobilisation and disruption of early quartz veins, but in general possess small folds

plunging to the south-west. The strong mobilisation of these pelites and subordinatr semi-pelites is seen to extend to the east along the boundary of the present area and to approach the mylonitic gneiss near Lough Glenmacaccive ; in this locality the mobilisation is distinctly later than the mylonitisation of the mylonitic gneiss.

2. Petrography.

Slice 704 is a representative staurolite-bearing pelite from a locality 60yds. from the contact of the pluton. The rock is a staurolite-garnet-biotite-muscovite-hornfels. Large porphyroblasts of staurolite up to 5 m.m. across occur in the form of augen along the schistosity. These porphyroblasts possess trails of inclusions mainly of elongated grains and particles of untwinned felspar, quartz, muscovite, biotite and opaque dust. These trails of inclusions are undulating and their direction is usually oblique or normal to the schistosity of the rock, clearly indicating the rolling of the porphyroblasts during a late phase. Garnet occurs as small crystals 0.1 m.m. across, either as inclusions in the staurolite crystals and plagioclase porphyroblasts or in the groundmass. Porphyroblasts of oligoclase-andesine 1½ x 1 m.m. contain trails of inclusions from the groundmass. These porphyroblasts are usually rounded and appear to have been rolled. In one case, the trails of inclusions in a porphyroblast show a perfect fold, meanwhile the porphyroblast itself lies along

the straight schistosity. Muscovite occurs in two distinct forms; first minute bent flakes forming undulating bands, and the agreement between the banding of individual flakes and the trails of opaque dust in flakes further confirms that this muscovite is older than the movement. Apatite inclusions are frequent in this muscovite. Secondly, a muscovite is apparently younger than the movement, and grows at an angle to the schistosity of the rock. It also grows in the shaded areas of the augen containing the rolled staurolite porphyroblasts. The groundmass of the rock consists of quartz and red-brown biotite. In one part of the thin section, a large clot of fibrolite is largely altered to sericite.

3. Special Features of the Contact Metasediments.

The pegmatitic fringe of the Doocharry Granite is seen at the present level to have wedged its way between the Glenties Pelites and the original margin of the pluton. The following observations seem to suggest the possibility that the Doocharry Granite has sent off irregular apophyses in the area around Glenties :-

First, the shape and distribution of the small areas exhibiting the above described mobilisation is very irregular and variable. Secondly, the very peculiar mobilisation in the Glenties Quartzite band as is not usual with quartzites. The quartzite is thrown into very irregular folds and innumerable minute crinkles and unrestrained swirlings.

The other parts of the quartzite band stand vertical and appear perfectly normal. A few yards east of this mobilised quartzite, an isolated patch of pelites and semi-pelites, about 150 x 75yds. also exhibit unusually high mobilisation.

IV. Summary.

Subsequent to the emplacement of the Ardara pluton, and the superimposition of a thermal metamorphism upon low grade phyllonites, the area to the south of the Ardara pluton experienced two distinct periods of movement.

First, the Quartzite group was further thrust over the Glenties Series in a north-westerly direction. This has caused the conversion of the early tonalite band into a mylonitic gneiss, and the shearing and phyllonitisation of the larger part of the southern aureole of the pluton. These movements also caused the development of a distinct linear structure lying horizontally N.E.- S.W. or plunging gently to the north-east.

Secondly, later movements affecting the granites in the 'neck' of the pluton as well as its contact metasediments impressing upon these rocks a secondary linear structure and small scale folding all plunging at about 20° S.W. After these movements had reached their climax, the pegmatitic fringe of another member of the Donegal Granite Series was intruded across the 'neck' of the pluton and wedged its way

along the contact of the 'neck' with the Glenties Series. This intrusion has caused the development of staurolite in the pelitic rocks to the north and north-east of Glenties.

Chapter TWELVE.

THE MYLONITIC GNEISS OF CARBANE AND ITS CONTACT METASEDIMENTS.

I. Introduction.

The mylonitic gneiss of Carbane is a mylonitised granitic rock, tonalitic in composition, with a distinct gneissic structure, and forms a band running parallel to the great thrust at the base of the Quartzite group (Map No.3). The gneiss possesses a strong mylonitic structure parallel to the length of the mass and to the main thrust and dipping about 50° S.E. It enters the eastern boundary of the writer's area at Glenmacannive and extends for 5 miles in a south-westernly direction to Owenea Lough, at the southern boundary of the area, where it disappears below drift and peat. Its present width varies between 220yds. and 500yds. In places it is overridden by the Quartzite group. It takes its name after Carbane, a hill over 400ft. in height situated east of Glenties. Carbane Hill is the hill about which G.A.J.Cole in 1906 wrote the rather entertaining paper "On a hillside in Donegal: A glimpse into the great earth-cauldrons". There, the mylonitic gneiss is very well exposed, and together with the quartzite of Drumnasilla Hill, forms high ground separated by a straight depression making the great thrust. The south-eastern side of Carbane facing the Quartzite contains thick veins of pegmatite, also possessing mylonitic

gneiss of Carbane usually exhibits good contacts with the pelites and semi-pelites of the Glenties Series and also possesses intricate contacts with the Glenties Calc-group. Together with its contact calc-silicate rocks, the mylonitic gneisses show a lineation and mullion structure plunging very gently to the N.E. parallel to the major thrust.

The mylonitic gneiss represents an early intrusion of coarse-grained biotite-tonalite, in the form of a sheet conformable with the Glenties Calc-group. Its emplacement parallel to the imbricate structure of the area and over a distance greater than 5 miles seems to support its having been emplaced along a structural break in the relatively more competent Calc-group, subsequent to the main orogeny of the area and prior to the main stages of later thrusting from the south-east.

This early granitic intrusion has caused contact effects, particularly in the pelites and semi-pelites of the Glenties Series, in a zone parallel to the strike and about 200yds. wide. The rocks in this zone are characterised by a high degree of mobilisation and free swirling and the development of staurolite in some places. In general, these rocks are hornfelsed and indurated and seem to have resisted later shear and cataclasis better than the rest of the Glenties Series.

II. General Morphology of the Mylonitic Gneiss.

The main mass of mylonitic gneiss is a medium- to coarse-grained granitic rock with a distinct gneissic foliation or banding parallel to the regional structure and dipping at about 55° S.E. On the flat surfaces of the rock, the felspar crystals are seen to occur in augen along the trace of the foliation, and vary in size and colour. The colour of these felspar porphyroclasts varies in different shades of pink, pale grey and white. The fresh rock breaks easily along the plane of gneissic foliation and is seen to possess a rough lineation in that place. On the plane normal to the foliation, the rock is usually lighter in colour. In general, the rock shows some variation in the relative proportion of the ferro-magnesian minerals, the size of the felspar as well as the intensity of the mylonitic structure.

The mylonitic gneiss possesses a pegmatitic fringe which differs considerably from the main body of the gneiss. It is much poorer in ferromagnesian minerals and exhibits the mylonitic texture very well. In the area between Kilrean Upper and Stackiniller, the northern boundary of the mylonitic gneiss has a pegmatite fringe about 70yds. wide and almost one mile long. Also, to the east of Glenties, the main gneiss at Carbane has several apophyses composed of this pegmatitic material. Here, as well as at N.E.Carbane, the pegmatitic fringe usually contains thin bands of the

confining pelitic and semi-pelitic rock (Specs.882 and 883). In the same way, these contact rocks contain abundant thin veins and stringers of quartzo-felspathic material in a lit-par-lit manner.

A feature characteristic of the mylonitic gneiss is its tendency to interdigitate with the country rocks. This is of a particularly complex nature at Carbane Well, Glenties, and to the south-east of it where the gneiss forms numerous tongue-like protrusions in the pelites and semi-pelites. All along the south-eastern side of Carbane, the boundaries between the gneiss and the rocks of the Glenties Calc-group are extremely intricate; and in many cases it is uncertain whether larger masses of the sediments are isolated enclaves in the gneiss or merely interdigitating with it. The mylonitic gneiss also interdigitates with the Glenties-calcs, to the west of Derries Village. Here again as at Carbane, the gneiss contains several xenoliths of the calc-rock and semi-pelites.

III. Petrography and Description of Rock Types.

A. General.

The mylonitic gneiss includes practically all stages between highly sheared granitic rocks with distinct cataclasis, to types appropriately classified as fault breccias. Besides this variation in the degree of cataclasis and mylonitisation, the main body of the mylonitic gneiss includes rock types varying considerably in the relative proportion

of the ferro-magnesian constituents as well as in the size of the original felspars. The average fresh rock from quarries consists of rounded or ellipsoidal felspar porphyroclasts set in a fine-grained matrix of minute biotite flakes, finely granulated quarts and epidote. The intense shear characterising these rocks is not as evident in the fresh quarried rock as it appears on the weathered surfaces. In general, the original granite seems to have been a medium-grained granodiorite or tonalite, rather poor in potash-felspar, and decidedly inconsistent in the relative proportion of the light and dark components. A rather detailed description of several representatives of the mylonitic gneiss seems to be justified.

B. The Main Mylonitic Gneiss.

Specimen 874 G. is from a quarried exposure south-west of the road from Corn Hill, and represents a variety of the gneiss unusually rich in biotite and also finer grained than the average type. The rock is dark grey in colour, consisting of rounded felspar porphyroclasts in a fine grained micaceous groundmass. The rock has a very weak planar structure. In slice 874 G, the felspar forms roughly rounded porphyroclasts of andesine ½ to 1/3 m.m. across, with cores of composition up to An.35 surrounded by rims of oligoclase. Most of the porphyroclasts show rolling in one direction in the thin section and a small proportion have bent twin lamellae.

Potash felspar is very subordinate. The groundmass consists of granulated quartz, felspar, biotite, epidote and sphene. The quartz granules sometimes contain minute inclusions of biotite. Minute granules of felspar are highly altered. Biotite, dark green in colour, occurs as minute flakes, usually bent and broken. It is partly altered to chlorite. Epidote is fairly abundant as minute grains, less often as large grains ½ m.m. across. Sphene occurs as subangular grains and sometimes as wedge-shaped crystals standing up to the cataclasis.

The least mylonitised granite of average composition comes from a quarried exposure situated between the Convent School and Carbane Well, Glenties. One rock is medium grained and possesses a rough foliation containing a linear element. In the plane normal to the latter, (plane of the thin section), the rock is lighter in colour due to abundance of felspar. In slice 731, the plagioclase porphyroclasts, 1 - 3 m.m. across, show evidence of rolling by their relation to the undulating zones of granulation. The latter, forming the groundmass of the rock, consist of finely granulated quartz and biotite of a honey-brown colour. In strong contrast to the crushed nature of the rock, veins of quartz 2 m.m. thick are seen to follow the planes of cataclasis and are coarse-grained and devoid of biotite or any other mineral. These veins contain strained individual grains ½ to 1 m.m. and appear to be later than

the main cataclasis of the rock.

A slightly more advanced stage of cataclasis, in a variety of average composition but coarser grained than the average, comes from the large quarry along the road to Meenachallow. In thin section 735, cut normal to the rough lineation, porphyroclasts of plagioclase up to 6 m.m. across show distinct rolling. Microcline is rather sparse and also occurs as rounded porphyroclasts. The biotite is dark green, and occurs either as small bent and ragged flakes closely following the outlines of the plagioclase porphyroclasts, or as minute particles in the finely granulated groundmass. The epidote is not of even distribution in the groundmass and appears in part to be of late origin.

With further cataclasis, the auten structure becomes very distinct in the hand specimen. Slice 723 represents the gneiss on the south-eastern side of Carbane facing the quartzite of Drumnasilla Hill. The plagiodlase porphyroclasts, which are up to 10 m.m., lie along the foliation of the rock and the finely granulated groundmass forms an augen structure around them. The groundmass consists of very minute grains of quartz, fragments of chloritised biotite and relatively large grains of epidote about ½ m.m. across. The veinlets of late quartz are highly strained, include slightly sutured grains and seem to suggest further cataclasis.

The stage of cataclasis and mylonitisation immediately preceeding that of the actual crush breccias is represented

by the rock a few yards from the foot of the quartzite block of Drumnasilla Hill. In hand specimen, the rock is medium to dark green and contains dark pink felspar. In thin section 725, the plagioclase is usually bent and sometimes broken, while the mylonitised groundmass is extremely fine. The biotite is largely altered to chlorite, Epidote and sphene are rather abundant.

The ultimate phase in cataclasis, in which the rock appears as a kneaded breccia consisting of fragments of dark pink and red felspar in a dark green chloritic matrix, is represented by specimen 739 from the actual thrust plane to the north-east of the fault running below the quartzite of Meenechallow Hill. This rock is in contact with quartzite breccia.

C. The Pegmatitic Fringe.

The pegmatitic fringe of the mylonitic gneiss east of Glenties, as well as at the Owentocker river, consists of coarse-grained rocks greyish white in colour, again in different stages of cataclasis. The typical mylonites which are of less common occurrence will be described later in association with the mylonitic structure (p.352). The average rock type of the pegmatitic fringe contains large porphyroclasts of plagioclase and potash felspar, with thin mylonitic banding of a pale grey brown colour (Spc.712). In slice 712, the porphyroclasts include broken crystals of oligoclase 2 m.m. across, as well as perthitic orthoclase. The latter occurs

as large crystals 9 m.m. across, show pronounced hazy extinction and conversion to microcline. The thin mylonitic bands marking the augen structure consist of finely granulated quartz with minor chloritized biotite, epidote, sphene and abundant streaks of yellow staining. Late quartz veinlets and lenticular masses 2½ m.m. thick, include fragments of the crushed groundmass of the rock. The pegmatitic fringe, in general, is decidedly rich in potash felspar as compared with the main mass of the gneiss.

D. Early Pegmatite Veins.

On the south-eastern side of Carbane occur several thick veins of pegmatite, 5ft. to 8ft. thick, trending parallel to the structure (Map.No.3). The fresh rock is pink in colour and possesses a weak foliation along which is a pronounced lineation (Spc.720. In thin section (720), cut normal to the lineation, porphyroclasts of plagioclase and potash felspar show clear rolling movements in a groundmass of finely granulated quartz and felspar with minor biotite, muscovite and epidote.

IV. Structure of the Mylonitic Gneiss.

The long band of mylonitic gneiss lies along the great thrust at the foot of the Slieve Tooey Quartzite, and at several places, the latter is carried across the gneiss in a manner resembling an unconformity. Apart from this,

it seems that in general, the actual width of the band of gneiss has most probably been reduced by the shearing out of a part of it along its southern margin, particularly so, where the gneiss is bounded by the Strawoaghter Thrust.

The gneiss had been faulted at Meenachallow prior to the main and final thrusting, and seem to have also been faulted together with the Quartzite at Kilrean Upper, either during or subsequent to the thrust movements.

The mylonitic gneiss possesses a very strong planar shear parallel to both its length and the main thrust, and dipping 50° to 70° S.E., more usually 55° to 60° S.E. This planar structure represents the phase of cataclasis and mylonitisation caused by the thrust movements of the Quartzite group against the Glenties Series, the direction of translation being towards the north-west.

The following observations seem to be in support of a direction of translation towards the north-west.

(a) In the Carbane area as well as other parts, the mylonitic gneiss, together with its contact calc-silicate rocks, possess a distinct mullion structure plunging very gently to the N.E. The amphibolitic rocks among the calc-silicates exhibit a strict parallelism of the amphiboles in that direction.

(b) The typical mylonites in the pegmatitic fringe

of the gneiss as well as the mylonitised early pegmatite veins possess a remarkable distinct lineation running about horizontal N.E. - S.W. or plunging very gently to the N.E. The whole mass of gneiss possesses a lineation which is much less prominent.

(c) The rocks of the Glenties Calc-group, especially near Derries Village, are folded along axes N.E. - S.W. Some of these folds together with folds in the calc-silicate bands along the north-western margins of Carbane are overturned in a complex manner but clearly indicate a direction of translation towards the N.W.

A preliminary study of the mylonitic banded structure with augen of porphyroclastic felspar in the typical mylonites of the pegmatitic fringe of the gneiss east of Glenties, as well as in the mylonitised pegmatite veins on the S.E. side of Carbane lead to the following points:-

1. The plane of cataclasis or mylonitisation, in which lies the finely granulated matrix of the rock, contains a distinct lineation parallel to which the blades of biotite are aligned. This is particularly evident in the early pegmatitic veins on the S.E. side of Carbane where the lineation plunges at 14° in a direction N.35° E.

2. The plane normal to the lineation contains a very weak foliation and the rock is of a lighter colour. In

this plane, the rolling of the felspar porphyroclasts is very clear, as in slice 720 described in the main mylonitic gneisses (p.350).

3. The plane normal to that of mylonitisation and parallel to the lineation is that on which appears the mylonitic banded structure containing the felspar porphyroclasts in augen form, (Spec.881). Slice 881, parallel to this plane, shows all the biotite flakes to lie parallel to the foliation and that a large proportion of the porphyroclasts are elongated parallel to the lineation.

The exposed part of the band of mylonite gneiss within the writer's area is slightly over 5 miles in length, and in view of its remarkably straight nature and parallelism with the main thrust of the Slieve Tooey Quartzites, it seems highly fortuitous if the original tonalite magma had not been emplaced as a southernly dipping sheet along an earlier structural break. The field evidence indicate that the thrust movements from the south and south-east had been in operation over a rather prolonged period, and such a subsidiary structural break in the more competent Glenties Calc-group (as that presumed to have been in existence) is only natural in the tremendous inbricate zone.

V. The Contact Metasediments.

A. General Statement.

The mylonitic gneiss of Carbane had been originally intruded conformably with the Glenties Calc-group, and possesses many contacts with the rocks of this group. It is also in contact with the Glenties pelites and semi-pelites mainly along the north-eastern margin of Carbane. This early sheet-like intrusion appears to have had a definite contact effect upon its metasediment envelope. Though the Glenties Calcs do not show clearly this effect owing to their nature and position with regard to the gneiss, the pelites and semi-pelites exhibit contact effects and strong mobilisation, in a zone 150-250yds. wide and parallel to the mylonitic gneiss. In several places in this zone, a contact-metamorphic mineral is clearly seen in the field in the form of protruding silvery nodule of sericite aggregates. The pelites and semi-pelites in this zone have a certain amount of contrast to the remainder of the rocks in the Glenties Series.

B. Rocks of the Calc-group.

Only a short description of the calc-rocks immediately in contact with the mylonitic gneiss will be considered here. The general description of the Glenties calc-group is given on pages 32 and 333.

All along the south-easternly slopes of Carbane, the calc-rocks show distinct lit-par-lit injection with

granitic material. The rocks consist of green bands alternating with irregular bands of a pink colour (Specs.718 and 879). In thin section (718), the green bands are composed of actinolitic hornblende, tremolite and epidote with minor sphene, rutile and iron oxide. The actinolite which has small poikilitic inclusions is usually very pale green, but may possess patches either colourless or of a medium green colour. Tremolite occurs in fibrous form parallel to the banding of the rock. Epidote forms aggregates or minute equant grains of even distribution. Sphene is a rather notable accessory and occurs as wedge-shaped crystals with rounded points.

In the large quarry along the road to Meenachallow, the mylonitic gneiss is in contact with folded calc-silicate rock. Slice 736 shows the rock to consist solely of actinolite and epidote with accessory sphene. The actinolite is pale green to almost colourless and occurs as irregular masses in fibrous form. The epidote is non-pleochroic and forms grains $^1/_3$ m.m. across.

At Derries village, the mylonite gneiss is in contact with highly deformed green rocks. Slice 764 shows the rock to consist of actinolite, epidote, chlorite, microcline, plagioclase, calcite and quartz in their order of abundance with accessory sphene. The rock is entirely structureless.

The mylonitic gneiss contains occasional xenoliths

of calc-silicates. Spc.370 from north-eastern Carbane consists of epidote rich bands with bands mainly of dark green amphibole.

C. Zone of Mobilised Pelites and Semi-Pelites.

The pelites and semi-pelites of the Glenties group, adjacent to the mylonitic gneiss of Carbane, are highly mobilised in a zone about 150yds. to 250yds. wide. In spite of the considerable shearing in the Glenties Series as a whole, the rocks in this zone exhibit much of the original contact effects and particularly the free swirling of the bedding plane. They appear to have resisted substantially the later shearing forces as compared with the other rocks in the group. Early quartz veins in this zone are either disrupted or intricately folded, incipient boudinage structures are sometimes noted in the more competent bands. Bodies of metadolerite show a certain degree of swirling of their original foliation as at Glenmacannive. At times, small elongated bodies of amphibolite are displayed at random in the massive and indurated semi-pelite. At Kilrean Upper, the highly mobilised semi-pelites contain isolated fragments of disrupted calc-silicate bands. The bands of thinly bedded granulite show intricate small scale folding (Spec.759). Even when the rocks in this zone do not locally show the mobilisation, they are somewhat indurated and of a dull appearance.

D. Petrography of Mobilised Semi-pelites and Pelites.

In hand specimen, these semi-pelites and pelites are fine-grained, grey to brownish grey in colour and vary in their degree of shearing. In thin section, the rocks show some variation but are characterised by the presence of pseudomorphs of sericite and chlorite after staurolite, minute crystals of garnet and biotite of the red-brown hornfels type in a fine grained and partly fragmented matrix of muscovite, biotite, chlorite, plagioclase, potash felspar, quartz and abundant opaque dust. Patches of schimmer aggregates and colourless chlorite sometimes contain opaque dust. Garnet as small grains 0.1 to 0.3 m.m. usually turbid and broken, occurs both in the groundmass of the rock and in the patches of sericite-chlorite. Red-brown biotite occurs sometimes as minute flakes but is usually chloritised. Muscovite occurs in flakes of different sizes and is usually strained and deformed together with its trails of dark inclusions. Porphyroblasts of plagioclase of composition about An.15, and containing trails of inclusions, form lenticles along the foliation of the rock as in slice 751. Other plagioclase and potash felspar are associated with the crushed quartz and abundant opaque dust.

The best representative of the original hornfelses (Slice 708) comes from near the swampy Lough at Glenmacannive. The rock is very rich in the pseudomorphs of sericite and

chlorite, some of which contain garnet and staurolite. The staurolite is deep golden yellow and occurs either as isolated masses in optical continuity in the pseudomorphs of sericite-chlorite or as larger crystals with inclusions of euhedral garnet. The staurolite is usually crammed with trails of opaque dust which persist in the pseudomorphs. The groundmass of the rock consists of bands of muscovite, chlorite, garnet and red-brown biotite alternating with bands rich in quartz, felspar, garnet and minor biotite.

VI. History of the Mylonitic Gneiss and Contact Altered Metasediments.

The Mylonitic Gneiss of Carbane represents an early intrusion of biotite-tonalite, rather inconsistent in its relative proportion of dark minerals and its grain size, and possessing a pegmatitic fringe which is decidedly richer in potash felspar. This tonalite was intruded as a south-easternly dipping sheet, exceeding five miles in length, along a structural break parallel with and close to the main N.E.- S.W. thrusts, at a time essentially before the main phase of these movements from the S.E..

This sheet like intrusion has impressed a marked thermal effect upon its confining metasediments, now seen only on its northern side. This contact effect is marked only in the pelitic and semi-pelitic rocks by their free mobilisation and swirling and the development of staurolite,

garnet, red-brown biotite and porphyroblasts of oligoclase.

After the tonadite sheet had cooled below a certain limit, the main phase of the thrust movements from the S.E., taking place along the same lines, resulted in the following:-

(a) The shearing off of part of the igneous band along the Strawoaghter thrust.

(b) The partial overriding of parts of the tonalite sheet by the Slieve Teoey Quartzites.

(c) The shearing of the tonalite into a mylonitic gneiss with a planar structure of cataclasis and mylonitisation parallel to the thrust and dipping 55 - 60° S.E. The mylonite gneiss consists essentially of rolled porphyroclasts of felspar in a fine grained matrix of granulated quartz, felspar, biotiteand epidote.

(d) The formation of a lineation and mullion structure in both the mylonitic gneiss and the metasediments immediately in contact with it, trending horizontally N.E.- S.W. or plunging very gently N.E.

(e) The partial obliteration of the localised thermal aureole of the tonalite sheet, mainly in the alteration of staurolite to aggregates of sericite and chlorite and the cracking of the garnet and its partial alteration to chlorite.

Chapter THIRTEEN.

LATE EVENTS IN THE PLUTONIC HISTORY.

I. Local Retrograde Metamorphism in the Northern Aureole.

A. Introduction.

After the Ardara pluton had completely solidified, it appears to have undergone some movement in the vertical direction, either upwards or downwards. This has caused the development of a shear in the hornfelses on the north-western, northern and north-eastern sides of the pluton, and the development of occasional steep planes of dislocation trending parallel to its arcuate margin. This was closely associated with the hydrothermal intruduction of potash into the hornfelses causing partial alteration of andalusite and sillimanite to sericite and the development of porphyroblastic muscovite.

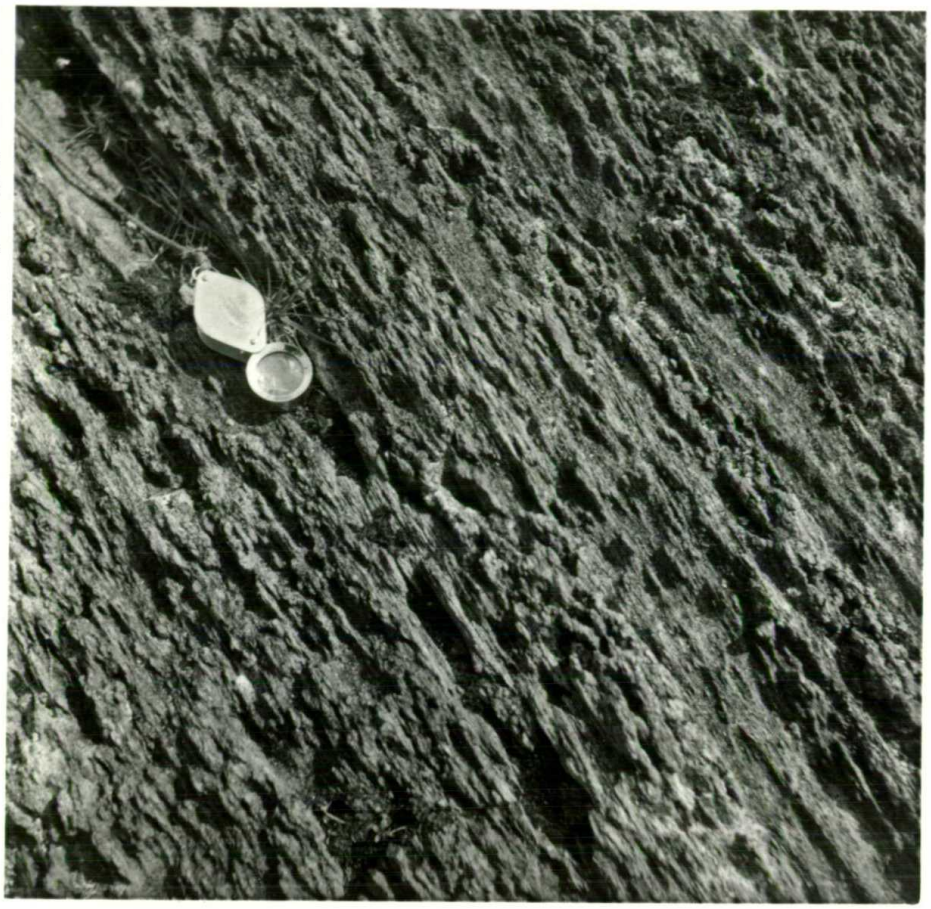
B. Late Shearing in the Clooney Hornfelses.

The Clooney and Maas hornfelses are affected by a late shearing which is particularly strong in the Clooney hornfels; it trends parallel to the margin of thepluton, either dipping very steeply towards the granite or stands vertical. This shearing occurs in zones which are not easily mappable, and the intensity of the shear varies from one place to another, and may be entirely lacking over small areas. The shearing is very distinct in the more siliceous horizons and in the bands rich in andalusite. On the northern slopes of Clooney

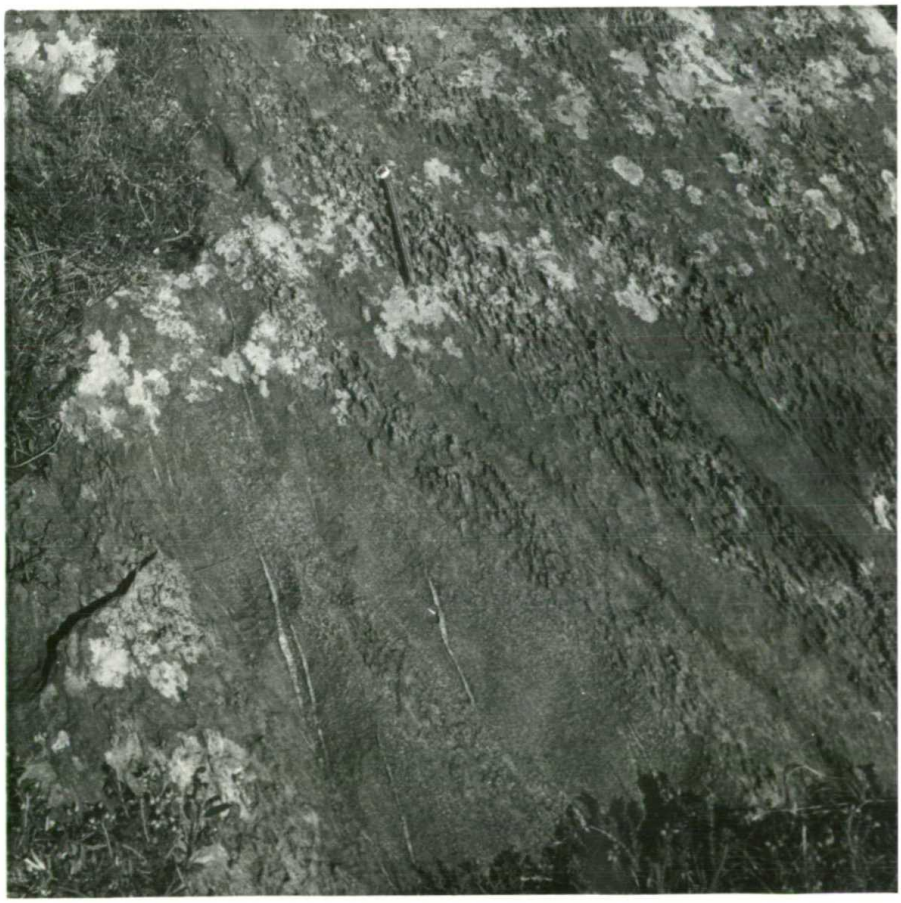
PLATE 24.

A. A close up of one of the andalusite-rich bands in the outer part of the andalusite zone, clearly showing the late shearing passing through the crystals of andalusite. A single andalusite crystal may be cut by as many as 5 or 6 shear planes.

B. The andalusite-rich bands in the high grade hornfelses marking the more clayey bands in the original sediment. The thickness of these or the more sandy bands is not uniform as well as the boundary between the bands, sometimes they are sharp and sometimes show certain gradation (centre of photograph). The late shearing (parallel to pencil) is less distinct in the more sandy layers except where the smears are filled with quartz.



A



B

and Cashelgolan Hills, the shearing is seen to pass through the andalusite crystals (Plate 24A), as already described in thin section (p.245).

At the Marin crossroads, where the more siliceous hornfelses stand vertical, the shearing is seen to form two linear elements in these rocks. First, a sub-vertical lineation formed by the intersection of the steep shear planes and the almost vertical bedding, and secondly, the trace of the shear plane as seen on the flat surfaces of the exposures - essentially a sub-horizontal lineation parallel to the arcuate margin of the pluton.

In the pelitic hornfelses, the shearing impresses a planar structure which tends to obliterate the original bedding of the rock.

C. Minor Planes of Dislocation.

Several minor steep planes of dislocation occur in the Clooney hornfelses and trend parallel to the arcuate structure of the aureole. These dislocations are marked by narrow zones in which the hornfelses are shattered and almost brecciated. One of these dislocations is seen in a small quarry at the south-western foot of Marin Hill. The nature of the brecciation along such planes clearly indicates their total independence of the formation of the sub-horizontal boudins ; the latter having been shown to mark the diapiric emplacement of the pluton (p.308).

D. Introduction of Potash.

It has already been described in detail (p.245) how the andalusite, in particular, is altered to schimmer aggregates. This is especially clear in the cases when the individual crystals of andalusite have been sliced by the shearing. The hornfelses also contain porphyroblastic plates of muscovite with trails of inclusions passing through them undisturbed. This muscovite usually grows along the shear planes. Both the conversion of the aluminium silicate mineral into schimmer aggregates and the growth of porphyroblastic muscovite involve an introduction of potash and water, and mark a localised retrograde metamorphism associated with the shear movements.

The source of potash and water seems to be the granitic pluton, which naturally would not be lacking in late phase hydrothermal solution, there is ample evidence from the petrographic study of the granite types in the pluton that potash rich solutions were available in the later phases of solidification. Billings (1937) has reported similar introduction of potash into completely recrystallised sillimanite schists from Loon Mountain in the Franconia Quadrangle, New Hampshire.

E. Relation with Retrograde Metamorphism in the Southern Aureole. The exact relation of this retrograde metamorphism in the northern aureole to that on the southern side of the pluton, is not supported directly by field evidence.

However, both are found to be contemporaneous with regard to other events in the history of the area. Also the retrograde metamorphisms in both areas have involved the introduction of potash and water and finally, the retrograde metamorphism may have taken place all around the pluton but is not very distinct in the south due to the drastic nature of the post-granite tectonics in that area.

II. Tourmalinisation.

The sharp contacts of the northern and north-eastern margins of the Ardara pluton with the Clooney and Maas hornfelses is usually marked by a band of pure tourmaline or quartz-tourmaline rock, varying in thickness between 1" and 10".

At Narin crossroads, the sharp contact is usually marked by the presence of tourmaline and Spec.235 shows the tourmaline to have followed the actual contact and to have attacked both the gneissic tonalite and the banded hornfels. The gneissic structure of the original tonalite is clearly preserved in the quartz tourmaline rock. A few yards to the east, a vein of quartz-tourmaline about 1ft. thick marks the contact.

At Clooney, the contact of the tonalite and the country rocks is also marked by almost pure tourmaline rock about 2" thick. The contact of the tonalite with the sillimanite hornfels at Maas is also marked by tourmaline, especially

in the south-eastern part.

Tourmaline does not appear as an accessory in the tonalite or in any other granite type in the Ardara pluton, and not a single grain of tourmaline was encountered in 30 thin sections of the tonalite from near the occurrences of tourmaline along the margins of the pluton. The only occurrence of tourmaline in the whole pluton was in the form of a few crystals lying in the middle of a thin aplite vein situated 200yds. east-north-east of B.M. 127-5, Clogher West. Similarly, the hornfelses very occasionally contain tourmaline as a rare accessory.

It is thought, therefore, that late emanations rich in boron have made their way along the northern margin of the pluton. The strict confinement of this tourmaline to the actual contact and its entire ansence anywhere else, seems to suggest the presence of an earlier structural break or fracture along the margin of the pluton similar to those ascribed to the vertical movement of the pluton in the solid state.

The tourmaline rock at the granite contact at Clooney is seen in slice 236 to consist of about 65% of tourmaline and about 35% quartz. The tourmaline exhibits a remarkable variation in colour and pleochroism in different parts of a single crystal. Some parts may be pleochroic orange red and pale gold while other parts of the same crystal are pleochroic blackish-brown and pale greenish brown. This appears to be

due to the changes in the tourmalinising emanations. The quartz occurs as large grains with high undulose extinction. A large quartz grain is seen to contain a few needles of fibrolite which have apparently managed to escape the effects of the boron-rich emanations.

III. Porphyry Dykes.

A. Introduction.

Twelve porphyry dykes have been mapped by the writer in the area covered by this thesis. These dykes show a marked uniformity of character, and form a distinct group of known age. They are comparatively late, and probably terminate the igneous activity in the area, except for basalt dykes thought to be of Tertiary age. The porphyry dykes cut through the Ardara pluton as well as the hornfelsed country rocks. The dykes are of unfailing porphyritic nature, and vary very little in composition between oligoclase-biotite-porphyry and oligoclase-quartz-porphyry. In hand specimen, they show either porphyritic felspar or porphyritic quartz, or both set in a fine grained matrix.

B. Occurrence and Distribution.

The porphyry dykes do not appear to be confined to any particular member among the constituents of the Ardara pluton. The majority of the dykes, as well as the best developed ones, appear to cut the outermost tonalite. Examples of this relationship occur in a small area north-east of Binwee and

and north-west of Lough Killayenna. From there, the dykes proceed due north to reappear once more in a small quarry by the roadside east of Clooney.

Two dykes are found to cut the xenolithic quartz-diorite, a small one at St. Connal Church and the largest of all the porphyry dykes in the south-west Letterilly.

Only one porphyry dyke was found to occur in the central granodiorite, in the main quarry at Lough Derryduff.

A. Age Relations.

There is ample evidence in support of the view that the porphyry dykes were intruded into the Ardara granite after the latter had completely solidified. In the roadside quarry at Clooney, the porphyry dykes are seen to end abruptly against the sharply defined joint planes of the sillimanite hornfels. They also contain angular inclusions of the hornfels (Spec. 547). The sheets and dykes of micro-granodiorite as well as aplites and pegmatites are all earlier than the porphyry dykes. Nevertheless they may be considered as 'late granite phenomena'.

Similar dykes in the Maas-Derrylogan area have been shown by Iyengar, Pitcher and Read (1953) to be the latest phase in the plutonic history of this part of Donegal.

D. General Field Characters.

The porphyry dykes very seldom deviate from their characteristic features in the field, of which the following are the most important :-

(a) Unfailing porphyritic texture.

(b) Remarkably straight with little or no deviation or banding, particularly so within the granite.

(c) Their thickness is usually constant. Eleven dykes vary in thickness between one and two feet. One dyke is, however, fourteen feet thick.

(d) North-south trend.

(e) All dykes contain small dark clots resembling fragments of inclusions.

(f) Show a tendency to include enclaves of the wall rock whether in the granite or the hornfels.

E. Petrography.

In hand specimen, the rocks are always porphyritic in texture, with either felspar or quartz as phenocrysts set in a finer grained rather massive matrix. Sometimes both quartz and felspar appear as phenocrysts in the same rock. The rocks vary in colour from light pink to greyish pink to pale ash grey.

Seven specimens outof the eleven dykes have been sliced. In thin section, the rocks vary between a quartz-oligoclase-porphyry as in slice (268) and an oligoclase-biotite-porphyry (slice 295). They consist of plagioclase, quartz, biotite, potash-felspar, epidote and sphene. Rutile and apatite are accessory.

Plagioclase felspar is the dominant constituent as well as the main porphyritic mineral. Euhedral crystals vary in size between 3 x 2 m.m. and 0.3 x 0.2 m.m., Zoning is particularly well developed in all dykes. Oscillatory zoning is present in only one dyke where it is highly developed (slice 286). The large phenocrysts of plagioclase in slice 295 have cores of uniform composition about An.26. The peripheries vary between An.20 and An.12. The composition of the fine grained plagioclase in the matrix, in the same slide, was determined as An.16, and the corresponding one in slice 286 An.14. The oligoclase phenocrysts are sometimes surrounded by a peripheral outgrowth of irregular particles of quartz and potash felspar. The plagioclase commonly shows embayments of myrmekite. The boundaries between the advancing plagioclase and the residual mineral, whether quartz or microcline, is always indented and sutured. It seems to suggest an early and active replacement of microcline and quartz by the plagioclase, suddenly restrained or checked when the dyke congealed. It seems probable that the Survey Memoir (1890 p.143) mistakes such pseudo-cataclastic textures in the porphyry dykes of N.W.Donegal for cataclasis through mechanical forces.

Microcline is subordinate to the plagioclase felspar, and has abundant poikilitic inclusions of quartz grains.

Quartz has been actively resorbed and appears as rounded and elliptical blebs about 2 m.m. across.

The matrix of the rocks consist of oligoclase, quartz, microcline and minute shreds of green biotite with accessory apatite and rutile.

The biotite in these rocks is of some interest. In addition to the small flakes and shreds of biotite in the matrix of the rocks, biotite also forms small circular clots or untidy nests in association with epidote, sphene and rutile. The biotite is always dark green in colour as long as the dyke is in the granite. The granite also has dark green biotite. On the other hand the dykes in the hornfelses have their biotite similar to that of their host - red-brown hornfels type.

Slices 237 and particularly 236, of porphyry dykes in the granite, contain large flakes of brown biotite in addition to the usual clots and fine shreds of green biotite. This is the only case so far where btown biotite occurs within the boundary of the Ardara pluton.

Epidote, non-pleochroic and of an irregular form is of persistant occurrence in association with the green biotite. Sphene turbid and brown in colour, is more abundant than the other accessories, rutile and chlorite. Apatite is most abundant in slice 583.

The clots and untidy nests of biotite associated with epidote and sometimes sphene, show a remarkable persistence throughout the dykes. Their average diameter is about 2-3 m.m.

but this frequently reaches 7 m.m. and more. They resemble the small micaceous clots in the minor granite bodies occurring on the southern shores of Gweebarra Bay. They also resemble the flattened disc-like micaceous aggregates in the blind dyke-like intrusion in the tonalite at Clogher. They appear to be of the nature of minute xenoliths of the country rocks and which have been altered by the dyke magma.

The thirteen foot thick dyke at Letterilly has inclusions of the xenolithic quarts-diorite host measuring anout one foot square. In the roadside quarry at Cloney, the porphyry dykes are seen to contain sharply angular enclaves of the sillimanite hornfels host. The porphyry dykes have no contact effect on the latter as seen in slice (563).

F. Sheared Porphyry Dyke at Letterilly.

It has already been stated that at S.W. Letterilly occurs the largest porphyry dyke in the area. This is particularly well seen in a large exposure, part of which is quarried, situated along a winding track leading to the main peat cutting area in Letterilly. The porphyry dyke which is about 13ft. thick, trending in a north-south direction, is highly sheared, the direction of the shearing being about N.15° E. Slice 583 is cut normal to the plane of shear. The small biotite flakes in the matrix of the rock are aligned parallel to the shear, and are more abundant in bands which

'flow' around the phenocrysts of oligoclase. A few elongated phenocrysts of the latter are also aligned parallel to the shear. It is probable that this is a 'flow shear' produced while the dyke was still in a highly viscous state.

No features strictly cataclastic are seen in thin section. The quartz, however, shows strong undulose extinction.

G. Porphyry Dykes in Other Parts of Donegal.

The Survey Memoir (1890 pp.141 - 143) refers to a group of felstones and felstone-porphyries and notes that these names cover a large and varied series of rocks. Quartz porphyries are stated to be uncommon. From the description given, the writer would clasify the rest of the said dykes as biotite-oligoclase-porphyries.

The dykes from the Strawoughter area, as described in the same memoir (p.87), do not seem to belong to the group of porphyry dykes.

McCall (1951 p.178) described acid dykes with porphyritic quartz and felspar in a fine grained matrix from near Portnablagh, but has made no distinctions as to their age relations.

Pitcher (1953) has reported similar porphyry dykes trending north-south in the Rosses Ring Complex. In this latter case as well as in the Ardara pluton, the host rocks had been completely solidified and jointed when the dykes were intruded. This gives rise to a point of interest that the material of the dykes although intruded in older rocks

possessing many different sets of joints, yet tends to occupy only one set of fractures - in this case fractures trending north-south. This relevant to the observations regarding the persistence of trend among the dykes of the lamprophyre-felsite suite.

As already noted, Iyengar, Pitcher and Read (1953) recorded late porphyrite dykes trending north-south in the Letterilly area.

Chapter FOURTEEN.

THE AMPHIBOLITIC COMPLEX OF MILL PONDS.

1. Introduction.

The Amphibolitic Complex of Mill Ponds is situated in the townlands of Kilrean Lower, Kilrean Upper and Drumnacross, in the area between the towns of Ardara and Glenties. It is traversed by the road to Donegal Town, and lies to the east and north-east of the Owentocker river. The locality of Mill Ponds, after which the complex is named, is located near its centre on the south-eastern side of the main road, as shown on the main map of the area.

The main complex covers an area of over $^{2}/_{3}$ sq. mile and measures about 2500yds. E.-W. by 1400yds. N.-S. It is surrounded by the pelites and semi-pelites of the Glenties Series, lying between the southern boundary of the Ardara pluton and the Mylonitic Gneiss of Carbane.

The complex possesses a central core mainly of olivine-bearing amphibolites, surrounded by a mantle or peripheral zone of almost pure amphibole rock. On the western side of the complex, this amphibole rock passes into progressively more altered and dioritised amphibolites including appinitic types.

Besides the main complex of Mill Ponds, a number of relatively small and apparently isolated masses of almost pure amphibole rock and its altered derivatives occur in

the area as far west as Ardara.

It is important to emphasize here, that all the amphibolitic rocks together with their altered derivatives dealt with in the present section are quite distinct from the common metadolerites and hornblende schists associated with the metasediments of Donegal and representing early doleritic intrusions emplaced during the geosynclinal phase.

Since the time relations of this complex are not definite, it is considered best to place this account in its present position.

II. Sub-division of the Complex.

The main complex of Mill Ponds can be divided into two principal and rather contrasted parts :-

First, the eastern part of the complex consists of a central core characterised by olivine-bearing amphibolites and an outer mantle of almost pure amphibole rock. These two members represent the partially altered and completely recrystallised portions respectively of an original plug-like intrusion of peridotite, emplaced in the rocks of the Glenties Series prior to the intrusion of the Ardara granitic pluton. This eastern part of the complex lies mainly to the east of the road to Donegal Town. The outer mantle surrounding the central core consists of an ultrabasic amphibolite with an average of 93% amphibole. This is a

very distinct rock type, and as it will be shown to play an important role in the complex, it is necessary to refer to it as amphibolite of Kilrean type or simply 'Kilrean amphibolite' after its type locality.

Second, the western part of the complex consists mainly of altered and 'dioritised' derivatives of the ultrabasic Kilrean amphibolite. These rather variable rocks, which include several appinitic types, are essentially hybrid rocks resulting from the interaction between the ultrabasic amphibolite and oligoclase-andesine material at a lower level, and which have subsequently moved upwards. In this part of the complex, a few rafts and screens of the country rocks are found to retain faithfully the regional strike, and are only locally mobilised and migmatised.

The main points of difference between the eastern and western parts of the complex can be summarised as follows :-

I. The central core, characterised by olivine-bearing amphibolites, with its outer periphery of Kilrean amphibolite, afford a perfect zonal structure of progressive metamorphism. On the other hand, the rocks of the western part of the complex lack any zoned structure and occur as typical mixed rocks with intrusive relations.

2. Although each of the two broad rock types in either of the core and outer mantle include varieties exhibiting stages of pregressive metamorphism from the centre outwards,

none of the various rock types indicate any appreciable addition or removal of material. Meanwhile, the rocks of the western part of the complex are typical hybrid rocks clearly exhibiting the addition of the components of alkaline plagioclase in a non-uniform manner.

3. The eastern part of the complex, roughly circular in shape, is entirely devoid of any enclaves of the surrounding country rocks, and appears in all probability to have been originally a plug-like intrusion. The surrounding country rocks are not well exposed, and only at two places do they show a strong deflection of strike.

On the other hand, the western part of the complex contains both small and large rafts and screens of the country rocks. Also when the dioritic rocks are banded, the banding is seen to run parallel to the regional strike. The intrusion here seems to be more or less in sheets rising from below with the rafts forming parts of roof pendants.

III. The Eastern Part of the Complex.

A. The Central Core- Morphological Description.

The central core of the eastern part of the complex around Mill Ponds is characterised mainly by the presence of olivine-bearing amphibolites. It measures about ½ a mile across, and is the best exposed part of the whole complex. The rocks are dark blackish green to medium green with a

distinct greasy lustre on the fresh surfaces. At times, they show a tendency to weather to a talcose rock of a pale greenish to ash-grey colour, but in general, the rocks of this central core are exceedingly hard and fresh. It must be explained that the rocks constituting this central core - variable as they are in hand specimen and thin section - form a distinctly mappable unit in the field. Its boundary with the outer mantle of Kilrean amphibolite is drawn between exposures of the two rock types which may only be a few yards apart, though actual contacts are not exposed.

B. Petrographical Sub-division of the Central Core.

As already stated, the central core represents the partially altered central portion of an original plug-like intrusion of peridotite. In hand specimen, the rocks of this central core vary from a dark green or blackish green coarse-grained rock, which is the almost unaltered and original peridotite, to a medium green amphibolitic rock representing the maximum alteration (within the core) of the original peridotite. Rocks representing intermediate stages between these two end-members are coarse-grained and peculiar looking amphibolitic varieties usually of a mottled dark green colour.

Petrographically, these rocks represent all stages of metamorphism ranging from the unaltered peridotite to an amphibolite which retains only part of the original pyroxene.

The following are the main types :-

(i) Unaltered Peridotite.

(ii) Olivine - Serpentine - Pyroxene - Amphibolite.

(iii) Serpentine - Pyroxene - Amphibolite.

(iv) Pyroxene - Amphibolite.

Some of these groups, particularly the pyroxene - amphibolites exhibit additional minor stages in their progressive alteration.

The above four main types, showing progressive stages of metamorphism, are distributed in concentric order with the unaltered peridotite in the inner part of the core and the pyroxene-amphibolites near the periphery.

C. Petrography of Rock Types in the Central Core.

1. Unaltered Peridotite.

The rocks well exposed in the field adjoining the disused burial ground near Mill Ponds consist of almost unaltered peridotite. The rock is medium- to coarse-grained, dark greenish black in colour and of sp.gr. 3.03. In thin section (1025), it is seen to consist of olivine, pyroxene, serpentine and very subordinate amphibole and accessory iron oxide. The olivine originally in the form of large grains up to 6 m.m. across, now occurs as small colourless isolated masses with channels of serpentine and iron oxide. Colourless diopside or sometimes diallage occurs in plates up to 3½ m.m. across. The diopside is usually cut by very thin and ramifying channels of serpentine about 0.03 m.m. wide,

(serpophite) greenish buff in colour and almost isotropic. The diopside surrounding the areas of serpentine and olivine, is also replaced by serpentine, bearing minute particles as remnants in the latter. The diopside encloses minute areas of a pale coloured actinolitic amphibole along its cleavages, all such shreds of amphibole within one crystal of diopside being in optical continuity. The serpentine minerals in this rock include a variety of types. The sub-rounded and polygonal areas of fresh olivine are separated from each other and surrounded by a network of clear and colourless chrysolite; (very pale greenish yellow under high power). It occurs as fibres across the veinlets, some of the latter also containing trails of iron oxide. These areas of olivine with the chrysotile channels are surrounded by wider zones of pale yellow-green serpophite, lacking any structure and showing a very weak birefringence. Antigorite is associated with the serpophite and is decidedly of a darker greenish colour than the latter. The antigorite sometimes contains a fine dust of iron oxide. Phlogopite occurs as a minor accessory in flakes up to 1 m.m. across and is pleochroic colourless to pale brownish pink. In addition to the thick trails of iron-oxide within the serpentine and olivine, iron oxide also occurs as minute particles in the pyroxene.

This diopside-peridotite resembles a rock named Koswite (Johannsen Vol.IV. p.440) and seems to resemble

morphologically the scyelite from Caithness (Judd 1885).

2. Olivine-Serpentine-Pyroxene-Amphibolite.

The olivine-serpentine-pyroxene-amphibolite forms a large part of the central core and is the most characteristic rock type in it. It represents the first principal stage in the metamorphism of the peridotite. The rock is coarse-grained, blackish green in colour with small patches of light green and olive green. The rock from a point 240yds. along the lane due east of Mill Ponds is representative of this type and has a Sp.gr. of 3.251. In slice (744) the rock is seen to consist of almost equal quantities of diopside and amphibole together with some olivine and serpentine. Iron oxide and phlogopite are accessory. The amphibole occurs as large plates up to 7 m.m. across with abundant grains of pyroxene as inclusions. The amphibole is mainly a brownish-hornblende of pleochroism Z' = buff to pale tan, Y' = pale yellowish tan and X' = tan brown. This brownish variety, which forms some small masses and all the cores of the larger plates of amphibole, gradually merges into greenish coloured peripheries of an actinolite nature. The latter has the following pleochroism, Z' = lavender green, Y' = very pale yellowish green and X' = yellowish green. Diopside occurs as rounded and equant grains, from 0.2 m.m. to 2 m.m. across, embedded in the amphibole. It shows a greater degree of internal alteration of pale actinolite along its cleavages

and is more turbid especially in the centres of the grains. Olivine occurs as elongated grains up to 3½ m.m. long or as aggregates of small grains about 013 to 1 m.m. across. It is traversed by a net of veins of iron oxide and chrysotile. The serpentine is mainly antigorite in rounded masses up to 2 m.m. across. Isolated masses of serpophite, almost isotropic, are enclosed in the amphibole. Phlogopite, pleochroic tan to a burnt sienna colour, is accessory together with iron-oxide.

3. Serpentine - Pyroxene - Amphibolite.

The second stage in the metamorphism is marked by the entire disappearance of olivine and the appearance of tremolite associated with the serpentine. The typical rock comes from the quarry on the southern side of the track due east of Mill Ponds. It is slightly lighter in colour than the previous example and has a sp.gr. of 3.160. In slice (1027), the hornblende which is mainly pale brown in colour is well in excess of the diopside. The serpentine is a medium yellowish green antigorite usually stained bright red around iron oxide. The serpentine is associated with a brownish yellow mineral which is lamellar with a straight extinction and a fine but prominent cleavage, probably bowlingite? The serpentine and probable bowlingite are present in large areas of a colourless fibrous tremolite and appear to be isolated remnants in the latter. The tremolite also seems

to develop at the expense of the outer rims of the surrounding diopside with the shedding of iron oxide.

4. Pyroxene-Amphibolites.

In general, the pyroxene-amphibolites represent the final alteration, within the central core, of the original peridotite, and this stage is marked by the complete disappearance of serpentine and its associated bowlingite. However, this stage can be divided into three sub-stages. The first sub-stage is marked by the complete disappearance of the serpentine and associated bowlingite and by the persistence of the colourless tremolite and iron oxide in their place. In the second sub-stage, the tremolite dwindles and the pale brown hornblende forms large crystals. In the third step, the amphibole appears as large crystals of a green colour and the diopside decreases considerably. It should be stated that all the pyroxene-amphibolites come from the outer periphery of the core.

Spec. 1029 represents the rock along the stream in the north-western corner of the central core at a distance of about 120yds. from its outer boundary. In thin section (1029), the rock consists mainly of brownish hornblende with its inclusions of diopside and small areas of colourless tremolite and iron oxide dust. Slice 1028 shows the entire disappearance of the tremolite and the growth of large crystals of brownish green hornblende with inclusions of diopside. The rock along

the outer boundary at the north-eastern corner of the core (Spec.776) is corase-grained and consists of large crystals of dark green hornblende set in a finer-grained matrix of pale green diopside. In thin section (776), the large greenish hornblende crystals about 7 - 8 m.m. across have smal inclusions of turbid diopside. The latter is, in part, altering to colourless and pale green tremolite usually fibrous in form.

D. Steps in the Alteration of the Central Core.

From the foregoing description of the main rock types in the central core, it is clear that the metamorphism of the original diopside-peridotite takes place in the following steps :-

Olivine-Serpentine-Diopside-Peridotite.

Step 1.	Olivine-Serpentine-Diopside-brownish Hornblende -	Amphibolite.
" 2.	Serpentine-Diopside-brownish-Hornblende -	Amphibolite.
" 3.	Tremolite-Diopside-brownish-Hornblende-	Amphibolite.
" 4.	Diopside-brownish-Hornblende -	Amphibolite.
" 5.	Diopside-greenish-Hornblende -	Amphibolite.

As already stated, the diopside in the original unaltere peridotite contains along its cleavages minute shreds of pale actinolite in optical continuity. This feature was found to increase from step 1 to 5 and it is difficult therefore to ascribe its presence in the unaltered peridotite to magmatic

crystallisation. In steps 1, 2 and 3, the diopside becomes more turbid with very fine iron oxide along its borders. In steps 4 and 5, where the brownish and greenish hornblende forms large crystals and close up upon the diopside, the latter is rendered very turbid.

Friedman (1953) described an olivine amphibolite from Ontario consisting of cummingtonite, olivine and serpentine with accessory spinel, magnetite and carbonate. This is believed to be after a picrite, the abundant magnesium and iron of the original rock being reflected in the cummingtonite and spinel. Hadley (1949) ascribes the presence of corundum in amphibolite after troctolite to the original plagioclase in the rock. In view of the entire absence of plagioclase in the peridotite around Mill Ponds, and also the nature of the pyroxene, the rocks described above are expected to be rather deficient in alumina. This can be witnessed from the actinolitic borders of the hornblende, and the fact that the rocks are usually deficient in alumina will be encountered in several places in the present work.

The cause of the metamorphism of the whole eastern part of the complex is considered on p.388.

E. The Amphibolite Mantle.

1. General Description.

The central core of the eastern part of the complex is surrounded by an outer mantle of amphibolite representing

the completely metamorphosed outer periphery of the presumed plug-like intrusion of peridotite. This outer mantle of amphibolite varies in width between 30yds. and 300yds. with an average width of about 120yds. It is narrowest on the south-eastern side and is much wider on the north-eastern and western sides. At the north-western corner of the complex, this outer mantle is almost discontinuous, where the diopside amphibolite are in contact with the mixed rocks of the western part of the complex.

The amphibolitic rocks of this outer mantle show very slight and almost imperceptible differences in the hand specimen. They form a distinct mappable unit in the field. The rocks are dark blackish green, medium- to coarse-grained and have the following composition (average of 3 slices) :- 92.57% amphibole, 4.16 plagioclase, 1.71 biotite with minor epidote, sphene, iron oxide and average sp.gr. 3.108. In many places, this amphibolite shows a notable degree of preferred orientation of the prismatic crystals of hornblende in a direction N 80° - 107° E.

As already stated, this ultrabasic amphibolite is referred to as the Kilrean amphibolite and is thought to represent the completely recrystallised representative of the diopside-peridotite with little or no addition of extraneous material. In the tongue-like protrusion at the eastern extremity of the complex, the amphibolite contains

a small but noticeable amount of leucocratic material in excess of the average content.

The Kilrean amphibolite will be shown to be one of the parents of the dioritised amphibolites, dioritic rocks and appinitic types in the western part of the complex.

2. Petrography of the Kilrean Amphibolite.

Petrographically, the Kilrean amphibolites show only very little differences, there being mainly small differences in composition as well as a slight degree in the crystallisation of the hornblende. Slice 1026 represents the rock from the interior of the north-eastern part of the mantle, and which has a Sp.gr. of 3'100. The hornblende occurs as elongated prisms up to 6 m.m. long, with cross sections up to 3 m.m. across. It is generally coloured very pale brown and pale green in one and the same crystal.

Some of the hornblende is decidedly brownish in colour with the following pleochroism Z' = greenish tan, Y' = pale brown and X' = pale yellow. It is crammed with fine dust of iron oxide and sometimes contains slender needles of rutile aligned oblique to the cleavage. The plagioclase occurs interstitially as small polygonal areas and is completely sericitised. The biotite is largely chloritised. Sphene, epidote and iron oxide are accessory.

Slice 743 represents the rock at the outer periphery in the northern part of the mantle. The hornblende is of a

darker colour, pleochroic Z' = medium brown tan, Y' = medium brown and X' = pale golden yellow. Sometimes it has thin outer rims of a deep green colour. The plagioclase is usually sericitised but occasional particles show a composition about oligoclase-andesine. The biotite is red-brown and occurs in small flakes usually embedded in the hornblende. At times, several flakes within one plate of hornblende are in optical continuity. It usually has rutile needles along its cleavages, and is at times altered to chlorite (negative penninite). Magnetite, sphene, epidote and apatite are accessory. In the hand specimen this rock is much more lustrous compared to the rocks from the inner part of the amphibolite mantle.

The rock from the tongue-like protrusion in the eastern part of the complex appears in slice 749 to have the following characteristics:- The amphibole is usually broken and bent and in one case it is very strongly bent in a monoclinal manner. Also part of the amphibole is notably chloritised. The plagioclase is strongly strained, sericitised, and is slightly more abundant than in the other Kilrean amphibolites. The rock is entirely free of biotite. The shearing and cataclastic textures in the rock are undoubtedly due to its forming a protrusion capable of being affected by the post-granite tectonics.

F. Metamorphism of the Eastern Part of the Complex.

The agencies responsible for the metamorphism of the

original peridotite mass, in the eastern part of the complex, do not appear to be simple. The original ultrabasic intrusion is certainly not older than the main orogeny and regional metamorphism because of the fact that if compared with some of the thick sill-like bodies of metadolerite, the metamorphism of the outer parts of the central core is found to be very mild. It appears that the peridotite intrusion is younger than the regional metamorphism and has thus escaped complete alteration together with the early doleritic intrusions - now metadolerites. The alteration of the peridotite is thought to have been due merely to its presence in an environment of prolonged plutonic and orogenic activity, - already dealt with in detail and briefly summarised in the next chapter of this work. Besides the general set up and the detailed history of the area, the fact that the central core includes unaltered peridotite in its centre surrounded by progressively more altered rocks towards the outer parts, rules out its being a case of auto-metamorphism (as defined by Turner 1948) of an ultrabasic rock.

The Kilrean amphibolite seems to correspond to the pure hornblende rock from Garabal Hill, the davainite of Wyllie and Scott (1913). Nockolds (1941) shares the views of Wyllie and Scott that this davainite has been produced from pyroxenite by the complete replacement of pyroxene by hornblende. Wyllie and Scott suggest that this is due to the

action of the later diorite, meanwhile Nockolds favours the idea that emanations from the magma of the adjacent fine-grained hornblende-bearing gabbro have effected the alteration of the pyroxenite to davainite.

The formation of the sharply defined mantle of Kilrean amphibolite appears to have been brought about by the contact effect of the Ardara pluton. This opinion is further confirmed by the following points:- (i) As already stated, the width of the outer mantle increases up to 300yds. on the sides facing the Ardara pluton and decreases considerably to as low as 30yds. on the opposite side. (ii) The direction of preferred orientation of the hornblende (N.80 - 107° E.) does not correspond to any of the lineations known in the area, but seems to correspond to the direction in which the Ardara pluton would be pushing in the southernly direction during its emplacement; the amphibole seems to have been formed while the forces were in operation, in other words, during the emplacement of the pluton.

Isolated masses of ultrabasic amphibolite, resembling the Kilrean type but sometimes containing a small amount of plagioclase, occur at the northern slopes of Mogumna Hill, Gortnacart School, as well as west of Kilrean along the main road. These masses also seem to be small offshoots from a larger mass of ultrabasic rock burried in the Glenties Series. This is further supported by the fact that at Smugborough

an ultrabasic diopside-amphibolite - resembling the pyroxene amphibolites of the central core - is associated with very basic amphibolite (p.413).

IV. The Western Part of the Complex.

A. General Statement.

The western part of the complex lies to the north-west of the road to Donegal Town, it is bounded by the Owentocker river on its south-western side and extends towards the north to the southern boundary of the Ardara pluton. It consists mainly of hybridised and migmatitic amphibolites, variable diorites, appinitic types and even light coloured rocks approaching an oligoclase granite in composition. These variable migmatitic rocks are thought to be the products of incomplete mixing and mutual reaction between extravaneous oligoclase-andesine material and amphibolites of Kilrean type at a lower level. At the present level, these rocks were intruded into the country rocks of the Glenties Series in the form of small sheet-like masses with small rafts of the country rocks still retaining the regional strike. The main points of difference between the eastern and western parts of the complex have already been summarised briefly (p.375). It is also suggested here that the rocks of the western part of the complex may have reached the present level later than the emplacement of the presumed plug-like intrusion of peridotite on the eastern side ;

subsequent to the emplacement of the Ardara pluton.

The rocks in the western part of the complex fall into three broad groups, first the altered amphibolitic and dioritic rocks including the appinitic types, secondly the rafts of country rocks and thirdly the small group of light coloured felspathic veins in the complex. In view of their special interest particularly in relation to the geology of Donegal, the appinitic types shall be considered separately.

B. The Altered Amphibolites and Diorites.

1. General Characters. The altered amphibolites include a very wide variety of rocks ranging from almost 'pure Kilrean amphibolite' to rocks of dioritic composition. It becomes evident in the field that the latter types represent the different stages in the 'dioritisation' of Kilrean amphibolite, especially where the latter rocks are found associated with innumerable varieties showing the progressive increase in light coloured oligoclase material, and in the later stages of which the original rocks entirely loose their identity. It must be emphasized that these altered amphibolites and dioritic types are exceedingly variable in their composition and character and that rocks of uniform composition, texture and grain size, do not exist even over short distances; they are typical products of incomplete admixture and reaction.

It is thus necessary to give a descriptive account of the more important types among the amphibolitic-dioritic rocks.

2. Banded Dioritised Amphibolites.

In a large and partly quarried exposure behind the farm house along the 'old road' to Donegal Town, amphibolitic rocks show clearly the admixture of Kilrean amphibolite with felspathic material resulting in distinctly banded hybrid rocks. Spec.1031, representing the usual amphibolite of Kilrean type in the western part of the complex, is seen to merge laterally into dioritised amphibolites (slice 1030). This rock possesses distinct light-coloured bands of variable thickness (Spec.780), running vertical and parallel to the regional strike. These rocks are cut by thin veins consisting of plagioclase and subordinate amphibole, about 1-3 inches wide and possessing well defined margins against the banded rocks. There are also occasional thin screens of the country rocks also running vertical parallel to the strike. The hornblende in the banded rocks shows a preferred orientation roughly horizontal and parallel to the strike.

3. Petrography of the Banded Dioritic Rocks.

The slightly altered amphibolite in this locality, which merges gradually into the banded dioritic types, is seen in slice (1031) to differ from typical Kilrean amphibolite merely in a decrease in the amount of hornblende and an increase in plagioclase. The amphibole is actinolitic in part, and usually contains minute particles of biotite. The plagioclase is strained and at times its twin lamellae are curved.

The average diorite in which the lighter coloured bands occur is, locally, a rather homogeneous rock of medium grain and possessing a distinct foliation. Slice 1030 shows the rock to consist of hornblende and plagioclase with minor amounts of iron oxide, epidote and biotite. The hornblende is identical with that of the Kilrean amphibolite with abundant iron oxide dust. A small proportion of the amphibole has a bluish green colour. The plagioclase is almost entirely altered, the alteration products including sericite, slightly pleochroic epidote and colourless clinozoisite. Its composition is about An.34-36. The biotite is red-brown and is partly chloritised. Apatite is an important accessory.

Slice 780 is representative of the lighter-coloured bands in the dioritic rocks. Apart from the outstanding differences in the relative proportion of hornblende and felspar, the rock is almost lacking in biotite and contains a considerable amount of apatite.

It is necessary to emphasize that all these rocks are strictly devoid of quartz and potash felspar.

4. Modal Composition of the Banded Dioritic Rocks.

The modal composition of these progressively more 'dioritised' amphibolites is given here in view of the fact that the gradual increase in the felspathic component can be observed over a distance of a few yards in the field. In

other areas, the rocks are usually of a patchy nature.

It must be noted that in these modal analyses, the biotite partly chloritised, was all recorded as biotite, and that the rocks in general contain a considerable amount of rutile and other iron oxides finely disseminated in the amphibole.

	Average of typical Kilrean Amphibolite.	Least altered rock merging into the diorites.	Diorites with lighter coloured bands.	Lighter coloured bands.
Hornblende	92.6	77.8	52.0	28.3
Plagioclase	4.2	12.4	39.6	68.1
Biotite	1.7	7.0	1.8	tr.
Epidote	0.4	tr.	3.0	1.8
Sphene	tr.	2.7	tr.	tr.
Iron oxide	0.9	tr.	3.0	1.8
Apatite	tr.	tr.	0.7	tr.
Total	99.8	99.9	100.1	100.0

5. <u>The Dioritic Rocks of Kilrean Lower</u>.

A wide variety of dioritic rocks and 'dioritised' amphibolites are found in quarried exposures situated on the northern side of the Glenties-Ardara road, between Kilrean and Gortlosk. These rocks are usually medium-grained dark greenish grey in colour. (Specs.649 and 649A).

The variable dioritic rocks in the quarry on the western side are veined with white oligoclase-rich material; in the quarry to the east, the dioritic rocks show a marked variation in the relative proportion of hornblende. These rocks also contain occasional thin bands of fine grained amphibolite in contrast to the prevalent dioritic types. Some of these thin bands possess a distinct banding and their structure and composition suggest a calc-silicate origin, as will be considered later.

Slice 649 is of a representative diorite in that locality and consists of 48.2% plagioclase, 45.0% hornblende, 5.1% biotite, 1.1% iron oxide with accessory sphene, epidote and apatite. This composition falls between that of the diorite with lighter coloured bands and the lighter coloured bands already stated above. The <u>hornblende</u> is patchy in colour with the pleochroism, Z' = brownish olive green to bluish green, Y' = pale golden yellow and X' = olive green. Rutile needles sometimes form a mesh at 70° in the hornblende and in other cases, minute blebs of iron oxide show an even distribution in the central part of the crystals. The <u>biotite</u> is of a medium honey-brown colour and is partly altered to chlorite. The <u>plagioclase</u> is usually highly sericitised but occasional small unaltered areas show a composition up to An.46. The rock is entirely free from potash felspar and quartz.

6. Special Occurrences of Migmatitic Diorites.

A few yards from the dioritic and amphibolitic rocks in the quarry just described, and on the western side of the road leading to Gortlosk, the Glenties Quartzite is well exposed and is seen to be intruded with thick dyke-like veins of a coarse dioritic rock (Spec.650). The continuation of this quartzite outcrops to the west along the same line of strike in several exposures around the farm at B.M. 169.6. Here again the quartzite is associated with the same coarse dioritic rock. These two main occurrences are at distances of 120yds. and 100yds. from the southern boundary of the Ardara pluton which is well defined in that locality.

In slice 650 the dioritic rock appears to consist of large crystals of andesine (identical to that of the outer tonalite of the pluton), hornblende and red-brown biotite (largely chloritised) with only traces of quartz.

These dioritic rocks, which differ from the outer tonalite only in the lack of potash felspar and quartz, appear once more in intimate admixture with dioritised amphibolites and amphibolites resembling the typical Kilrean amphibolite, at a locality over $^{1}/_{3}$ mile south of the main road. Spec.737 represents a mixed rock showing sharp contacts between these coarse dioritic rocks with the large crystals of andesine about 8 m.m. across and slightly altered Kilrean amphibolite. Slice 737 shows the latter to contain a remarkable

abundance of apatite in long prismatic crystals up to 1 m.m. long. This rock is devoid of potash felspar and quartz.

The migmatitic and inhomogeneous nature of the rocks in that locality is very striking. This can also be seen in the hand specimen, (Spec.733 for instance) where the variation in the relative proportion of felspar and the uneven distribution of biotite shows notable variation from one part to the other.

7. Altered Amphibolites with Large Plates of Biotite.

As well as the conversion of amphibolites into dioritic rocks by the addition of oligoclase-andesine material - such as has been described in detail - amphibolitic and dioritic rocks over quite small areas and in localised patches develop relatively large plates of biotite, apparently as a result of very localised influx of potash.

Spec.1034, from a point 150yds. N.W. of the farm house along the 'old road', is an amphibolite of Kilrean type containing large plates of biotite up to 10 m.m. across. The biotite in slice 1034 is medium brown and the flakes are severely bent. It is partly altered to chlorite and contains short prisms of rutile parallel to the hexagonal symmetry of the mica. Biotite also tends to develop in small plates and shreds in the interstitial spaces as well as along the cleavages of the amphibole. In general, the rock is only slightly richer in plagioclase than the typical Kilrean amphibolite.

On the other hand, Spec.788 from north-east Drumnacross is a typical migmatitic rock consisting of dark amphibolitic patches unevenly embued with felspathic material, and contains thick books of biotite up to 8 m.m. across.

C. Special Characters of the Dioritised Rocks.

From the foregoing detailed description of the mixed dioritic and amphibolitic rocks in the western part of the complex, it can be concluded that the 'dioritised' rocks all have the following characteristics in common :-

(i) All rocks are entirely free from quartz.

(ii) The rocks show a variable content of oligoclase and no basic plagioclase is formed in even the basic varieties of the rocks. This can only be due to a deficiency of alumina in the rocks, for they appear to contain ample lime.

(iii) The rocks are entirely free of potash felspar and the introduced material seems to be potash free. Any localised influx of potash in small quantities is marked by the formation of biotite, either as small books or as minute shreds replacing the hornblende.

D. Leucocratic Veins and Bands.

The western part of the complex also includes occasional light coloured veins characterised by the abundance of plagioclase and the invariable absence of potash felspar.

Quartz is sometimes present in small quantities. The most striking occurrence of this leucocratic trondhjemitic material is seen in the quarried exposures by the side of the Glenties-Ardara road in front of the Bord Na Mona premises. The dioritic rocks alternate with thin bands of metasediments including limestone and other granitic-looking bands of a pink colour. A representative band (Spec. & slice 1037) consists mainly of acid plagioclase with minor quartz and chloritised biotite. Iron oxide is accessory. The oligoclase, of composition about An.25, forms equant grains 1 - 3 m.m. across and is invariably altered with the production of fine red-brown material imparting to the rock its pink colour. The quartz is subordinate to the plagioclase and occurs as sutured and highly strained granules. A strongly pleochroic chlorite replaces the biotite and forms irregular wisps.

Near the western end of the large rafts of pelitic schist in the centre of the complex are found several veins cutting the schists and amphibolites. These are identical in composition to the Kersantites of the lamprophyre-felsite suite of dykes. The rock is fine-grained, of a grey-brown colour and is seen in slice (1036) to consist of oligoclase felspar, quartz, biotite with minor muscovite, magnetite, apatite and zircon. The rock bears a striking resemblance to the Kersantites in thin section. These veins are seen

to cut the highly mobilised and partly migmatised pelitic sediments to be described (p.401). These lamprophyric veins gradually merge into rocks poorer in biotite and finally into rocks consisting entirely of oligoclase and quartz (Spec. 1036A). The latter appears in the field exposure to be the material intimately associated with the migmatised pelites.

As already stated, the banded dioritic rocks are cut by thin vertical veins consisting largely of acid plagioclase with occasional hornblende crystals. These light coloured veins (Spec.871.A) are also entirely devoid of potash felspar.

Also in several localised spots, particularly at a short distance behind the farm house, thin small veins of fine grained and lighter coloured diorite are found to ramify into the more basic dioritic rock and amphibolites.

The composition of these leucocratic rocks, their occurrences and field relations on the one hand, and the composition and nature of the dioritised and mixed rocks on the other hand indicate that the former rocks, so sparingly represented in the complex, represent relatively minute fractions of the oligoclase material contributing to the formation of the intrusive rocks in the western part of the complex. These leucocratic veins sometimes contain quartz, whereas the diorites and mixed rocks are entirely free from quartz. Thus it seems that these leucocratic veins and bands are not necessarily <u>representative</u> of the great bulk of oligoclase-

andesine material which was active at depth, but merely residual fractions of such, which have managed to reach the present level in the form of veins and bands.

V. Rafts of Country Rocks in the Western part of the Complex.

A. General Characters.

One of the most distinct features of the western part of the complex is the presence of rafts of country rocks. These represent nearly all types normally present in the lower part of the Glenties Series, including pelitic and semi-pelitic schists, calc-granulites, bands of calc-silicate rocks, limestones, quartzites and hornblende schists. The important points about these rafts of country rocks is first, that the rafts of limestone and quartzite confirm in position to the known Glenties Limestone and Glenties Quartzite bands in the Glenties Series, and secondly, that all rafts of country rocks faithfully retain the regional strike and dip.

B. Main Occurrences and Petrography of Rock Types.

1. Rafts of Pelites and Semi-pelites.

The largest rafts of pelitic and semi-pelitic schists, about 100yds. long, are found around the right-angled bend in the 'old road' junction to the road to Donegal Town. These rocks which strike N.E.- S.W., are highly mobilised and in part show free swirling structures. The north-eastern extremity of these rafts are cross-cut by veins and dyke-like

bodies of lamprophyre already described (p.399). The latter are found to merge gradually into rocks consisting entirely of quartz and oligoclase. These veins cease to have well defined boundaries against the schists. The latter also begin to loose their sedimentary structures, and ultimately the metasediment and the quartzo-felspathic vein material form a typical migmatitic rock.

The average pelitic schist of these rafts appear in slice (779) to be a sillimanite-staurolite-biotite-schist. The sillimanite forms nests of fibrolite needles usually inside the large plates of muscovite, less often in the quartz grains. The staurolite occurs as irregular and corroded fragments usually surrounded by areas of very fine muscovite and chlorite. The biotite forms untidy shreds of variable size, and in general, the rock appears to have been sheared.

Rafts of pelitic rocks also occur near the south-western boundary of the complex, and are strictly parallel to the regional strike. The rocks are highly mobilised and in some cases they appear to be on the verge of loosing their sedimentary structures. Locally, they are distinctly impregnated with quartzo-felspathic material. The rafts of pelitic schists, situated to the south-east of the body of metadolerite in that locality, contains elongated and roughly oval bodies of amphibolite resembling boudins. These presumably represent the cross sections of invading tongues of amphibolite through the roof of the complex.

About 100yds. to the north-east of the banded diorites already described, are found some siliceous granulites in which the vertical bedding is hardly preserved. The rock is surrounded on all sides by amphibolites and dioritised amphibolites. In thin section (777), the siliceous granulite is seen to be distinctly banded, and consists of quartz, acid plagioclase and hornblende in their order of abundance, together with subordinate epidote and biotite.

2. Rafts of Calc-granulites.

Several small rafts of calc-granulites are found in the area characterised by the presence of appinitic types and situated to the west of the 'old road'. These usually occur as thin bands parallel to the regional strike. A representative calc-granulite from this locality (Spec.786) is fine grained, light green in colour and possesses a slight banding. In thin section, it consists of equal quantities of actinolitic hornblende and quartz with a lesser quantity of epidote and minor plagioclase, iron oxide and clinozoisite. The actinolitic hornblende occurs as small irregular fragments with the following pleochroism, Z' = pale green with a bluish tinge, Y' = pale yellow and X' = lavender green. The plagioclase is totally sericitised.

Other calc-granulite bands found within the dioritised amphibolites and appinitic types are dense and fine-grained and of a dark greenish grey colour. As seen in slice 785,

they consist of hornblende, andesine plagioclase, sphene, epidote and biotite with subordinate quartz and iron oxide.

3. Calc-silicate Rocks Simulating Amphibolites.

Rather peculiar calc-silicate rocks and amphibolites are found at a locality halfway between that of the calc-granulites just described and the main Ardara-Glenties road. The calc-silicate rocks have the regional strike and dip, retain their bedding and on the weathered surfaces the bands appear different in composition. The fresh rock bears a great resemblance to the amphibolites, and where the rock lacks good banding structures it becomes difficult to distinguish between amphibolitic rocks of calc-silicate origin and the usual amphibolites in the complex. This is rendered even more difficult by the fact that the rocks are cut by distinctly intrusive amphibolites in the form of both concordant and cross-cutting dyke-like veins.

Spec.734 A, represents one of these calc-silicate bands resembling the amphibolites in composition but which clearly retain their original banding. Even in thin section, the constituent minerals vary in their relative proportion in the different bands. The rock consists mainly of hornblende, plagioclase and quartz with accessory sphene and iron oxide. The hornblende occurs as grains of variable size from very minute particles up to plates 2½ m.m. across. The latter have localised aggregates of minute poikilitic inclusions

forming a zone around a central core. The poikilitic inclusions seem to be related to the coalesence of the amphibole into coarser grains. The hornblende has the following pleochroism, Z' = medium grass green, Y' = pale golden yellow and X' = olive green. The hornblende in one of the bands in the thin section is notably darker than that in the rest of the bands. The plagioclase has a composition of about An.32 and forms equant grains about 1 m.m. across. The quartz is usually slightly granulated and the rock appears to have experienced a certain degree of cataclasis.

A dyke-like vein of amphibolite about 18" wide cuts these calc-amphibolitic rocks, and as seen in slice 734, the rock does not vary from the typical Kilrean amphibolite except that it contains a small amount of quartz. This is almost the only case where a Kilrean amphibolite or one of its moderately altered derivatives is found to contain quartz. The quartz may possibly be attributed to the quartz-bearing calc-silicate host rock.

These calc-amphibolites appear to have attained their present state more or less in place and to have been originally one of the casual calc-silicate bands in the Glenties Series, simply by the same agencies responsible for the conversion of the original low grade pelites of the country rocks into the sillimanite staurolite schists forming the rafts. This might be due to the contact effects of the uprising intrusive amphibolites and diorites in that part

of the complex. However, there is no evidence in support of considerable transfer of basic material into an original limestone band. Moreover, in the roadside quarry near the Bord Na Mona premises, the granitic rock is interbanded with diorites (p.399) and contain thin bands of pure limestone.

Moreover, in the sillimanite zone of the northern aureole of the Ardara pluton, a calc-silicate band is converted into a rock bearing a striking similarity to the metadolerites in that area (p.258).

The only other occurrence of what seems to be a calc-silicate rock is a small 'xenolith' of pale green tremolite roc found in the migmatitic amphibolites and diorites in the north-western part.

4. Rafts of Quartzite.

The Glenties Quartzite outcrops in the northern part of the complex in the form of rafts usually surrounded by the coarse dioritic rocks already described (p.396). The quartzite is apparently unaffected.

5. Rafts of Metadolerite.

Among the rafts and screens of country rocks in the western part of the Complex are two bodies of metadolerite which also retain the regional strike and dip in their foliation. The first of these masses forms the base of the triangulation point west of the 'old road' and is strongly

foliated parallel to the strike. The second mass at a distance of nearly 200yds. is about 150yds. long by 25 to 40yds. wide. An important feature of this rock is that it is strongly foliated N.55° E. dipping 70° S.E., identical with the rest of the highly schistose hornblende schists occurring to the south of the Ardara pluton. This relation seems to indicate that the mixed dioritic rocks had reached the present level after the post-orogenic thrust movements from the south-east. The hornblende schist also possesses a frilling in certain places, the schistosity showing distinct kinks running oblique to it. The rocks do not appear to be altered in any way by virtue of their being within the complex, probably due to the usual 'metamorphic lag' shown by such rocks as compared to pelites, semi-pelites and calc-silicate rocks.

VI. The Appinitic Rocks.

A. Introduction.

Bailey (1916) defined the appinites in the S.W.Highlands as "dark rocks of medium to coarse texture and mainly composed of green or brown hornblende (either stumpy or acicular) in a groundmass which contains plagioclase, orthoclase and quartz in variable proportions; granophyric growths of quartz and orthoclase are common ; where plagioclase is the dominant felspar quartz may be almost or quite absent; apatite is a conspicuous accessory" .....

He states that "the nature of the felspars is not taken as a basis for classification" but distinguishes <u>syenitic-appinites</u> and <u>dioritic appinites</u>. Bailey also remarks that "With failure of quartz and felspar, appinites pass over into hornblendites.."

This definition of an appinite, which appears to cover a whole suite of rocks in the Highlands and a widely diverse set of rocks now known to be common in Donegal, merely implies a certain texture in rocks consisting mainly of coarse hornblende and felspar with or without quartz.

In the present work, the term 'appinite' is avoided and only the term 'appinitic' is used to imply a characteristic coarse texture and the presence of large idiomorphic crystals of hornblende in a rock consisting of hornblende with minor acid plagioclase. These rocks which are thus appinitic dioritic types, merge into almost appinitic hornblendites with the local decrease in plagioclase.

Thus 'appinitic diorite' signifies a rock dioritic in composition and containing large idiomorphic crystals of hornblende; 'appinitic amphibolite' designates a dark amphibolic rock of metamorphic nature but which contains most or all its amphibole in relatively large idiomorphic crystals.

In the western part of the complex, the altered amphibolitic rocks and migmatitic diorites are found to be associated with coarse appinitic types consisting of large hornblende crystals and subordinate plagioclase felspar.

Their occurrences do not follow any particular trend, but in the field they constitute one group distinct from the numerous types of relatively finer grained mixed hornblende-plagioclase rocks. They can occur in contact with any of these types merely as localised patches of variable size, and are certainly intrusive in nature.

B. Morphological Description of Main Occurrences.

An important occurrence of appinitic amphibolite is situated behind some derelict cottages at a distance of about 120yds. east of the old road; the rocks are exposed over an area some 50yds. across. This is associated with amphibolites of Kilrean type 'dioritised' to different degrees, though the appinitic body extends on its eastern side to near the rocks of the central core. This appinitic type consists mainly of large prisms of dark green hornblende up to 3 c.m. long with a minor proportion of smaller crystals of hornblende down to 1 m.m. across, all closely packed in a scanty matrix of white plagioclase. The rock is decidedly inequigranular and the felspar is patchily distributed. The patches and rough veins rich in plagioclase contain abundant small crystals of hornblende, and the darker coloured parts of the rock consist predominantly of large prisms of hornblende and simulate a hornblendite. Spec.775 is typical of these appinitic rocks.

A second main occurrence which does not exceed 30ft.

across is situated due west of the farm house in that locality. On one side it is associated with slightly dioritised amphibolites occurring near the banded dioritic rock already described. The rock consists of huge prisms of hornblende up to 7 and 8 c.m. long, with white plagioclase filling the polygonal interstices. As a rock type, it bears a striking resemblance to the coarse amphibolitic rock from Cor described by Gindy (1951 B).

A third main occurrence lies to the north of the large rafts of pelitic schists, and here the rock is of a more uniform nature and constitutes a distinct member among the main appinitic types. The rock consists of euhedral and subhedral stumpy crystals of dark green hornblende, roughly of equal size, set in a pale green matrix of plagioclase and fine amphibole. On the weathered surfaces in the field exposures, this type of appinitic rock can easily be mistaken for the olivine- and pyroxene-bearing amphibolites of the central core. This appinitic body is associated with amphibolites and dioritic types and contains one or two small rafts of pale green calc-granulites already described (p.403).

The fourth main occurrence situated in the south-eastern corner of the complex, consists of a most variable amphibolitic and hornblenditic body, over small patches in which, the hornblende attains a large size and usually good crystal form thus imparting an appinitic appearance to the rocks.

C. Petrography of Appinitic Types.

Slice 775 shows the appinitic rock which is almost in contact with the central core to consist mainly of hornblende with subordinate oligoclase felspar and accessory apatite, sphene, iron oxide, and biotite, epidote, rutile and quartz in very minute quantities. The hornblende is pale brown to tan with the following pleochroism, X' = pale greenish yellow, Y' = light brown to olive green and Z'= medium brown. This brownish hornblende has outer borders and indentations of green actinolitic hornblende with the following pleochroism, X' = pale golden yellow, Y' = olive green and Z' = pale grass green with a faint bluish tinge. There is sometimes a slight difference in birefringence between the outer and inner parts of the amphibole and very rarely a perceptible difference in the extinction angle. Also the brown hornblende is usually full of iron oxide dust and minute needles of rutile with a rough alignment as in the other amphiboles in the complex. The green variety is devoid of the iron oxide inclusions, but contains aggregates of sphene and iron oxide sometimes with traces of epidote. Where a mass of sphene is embedded in brownish hornblende it is usually surrounded by a rim of greenish amphibole. The plagioclase is usually oligoclase (about An.15-20) and is largely sericitised. Apatite forms grains up to ½ m.m. across.

Slice 1033 represents the very coarse appinitic rock

described in the previous section. The rock consists of greenish hornblende and plagioclase with accessory biotite, sphene, iron oxide, apatite, rutile and epidote. the hornblende is mainly greenish with only small patches of a brownish tinge. A minor proportion of the hornblende contains iron oxide in the form of peculiar trails cross cutting each other, and confined to the centre of large amphibole crystals. Biotite in the form of irregular shreds and flakes of a honey-brown colour is developing partly at the expense of the amphibole, and is usually bent rather severely. The felspar is oligoclase and is partly sericitised. Sphene forms corroded aggregates up to 2 m.m. across, and is usually associated with iron oxide and minute quantities of rutile and epidote. Apatite forms large grains up to 1.2 m.m. across. The rock is entirely devoid of potash felspar and quartz.

Slice 1032 shows the third main appinitic type to consist of actinolitic hornblende and plagioclase with accessoty apatite sphene and iron oxide. The amphibole occurs in large crystals with cross sections 4 to 12 m.m. across; for the most part it is medium to pale green, usually containing iron oxide dust. The green hornblende has outgrowths (forming outer borders or rims around cracks) composed of very pale green actinolite. The plagioclase which has a compositick about An.25, is usually highly sericitised and contains very pale green actinolite in fibrous form. In general, this rock appears to be relatively poorer in alumina.

D. Other Occurrences of Appinitic Types South of the Ardara Pluton.

1. General. Before discussing the mode of formation of the appinitic types just described from the western part of the Mill Ponds Complex, it is necessary to review the other occurrences of appinitic types in the remaining part of the area south of the Ardara pluton and extending to as far west as Ardara. The isolated masses are thought to be connected with the main complex at depth. Though individually they are difficult to interpret, they provide useful field and petrographic relations.

a. Appinitic Types at Snugborough.

The elongated mass at Snugborough marked as an appinitic type on the main map, consists in fact, of a minor portion of diopside-hornblende-actinolite-tremolite-amphibolite (slice 847) - simulating the outer rocks of the central core around Mill Ponds -, and a larger portion of dark amphibolite with an appinitic texture in part, Spec.844 shows the rock to have originally been a fine-grained amphibolite and in small areas about 1 c.m. across, the hornblende is recrystallised into idiomorphic crystals 2 – 5 m.m. in section. These are surrounded by white quartzo-felspathic material. Spec.844A represents a slightly more advanced stage where small patches of the original fine grained amphibolite still persist in a medium grained appinitic matrix. In slice 844A, the

original patches of the rock consist of irregular interpenetrating masses of green and bluish hornblende with oligoclase and accessory quartz in the minute interstices. Meanwhile, the appinitic parts consist of large sub-idiomorphic coarsely sieved crystals of hornblende 2-4 m.m. across, sericitised oligoclase and quartz. The completely recrystallised hornblende has the following pleochroism, X' = Golden yellow, Y' = olive green and Z' = brownish tan to dark olive green. Sometimes the strongly sieved hornblende, in the process of coalescence, has outer rims up to 0.3 m.m. wide of blue sodic-amphibole. Iron oxide, sphene, epidote, apatite and biotite are accessory. The appinitic portion of the thin section show a notable increase in quartz and oligoclase.

It is clear that this rock is in the process of becoming 'appinitic' and it seems that the introduced quartz and oligoclase are at least closely associated with the causes of this 'appinitisation'.

3. Appinitic Types North of Mogumna Hill.

The elongated body situated north of Mogumna Hill, south of Ardara, consists of amphibolites and their altered and 'dioritised' derivatives together with some medium grained appinitic types. The introduction of leucocratic material and its interaction with the amphibolites to produce variable dioritic rocks are very clearly seen in the field,

and in some places, the leucocratic material shows an abnormal increase, with the dioritic rock forming 'xenoliths' in it (Specs.831). Along the badly exposed northern slopes of Mogumna Hill, the mixed dioritic rocks are cut by veins of coarse appinitic rock resembling pegmatites and of a rather variable nature. Spec.802 represents one of the thin veins about 2" wide, on one side it is in contact with almost pure amphibole rock and on the other side it possesses a less sharp contact against mixed dioritic rocks. The vein itself consists of long idiomorphic prisms of hornblende, extending from one side of the vein to the other, up to 2 c.m. in section and set in a pink felspathic matrix. In slice 802, the rock appears to consist mainly of hornblende and acid plagioclase with minor calcite, apatite, sphene, and accessory epidote and quartz. Spec.803, from one of the larger appinitic veins, consists mainly of stout stumpy crystals of hornblende (largely idiomorphic and about 10 m.m. in section) closely packed in a scanty matrix of pink oligoclase felspar.

4. Appinitic Types at Odogherty.

At Odogherty, on the south-western side of the mountain road to Donegal Town, peculiar looking amphibolites rich in epidote are seen to be associated with an extremely coarse appinitic rock, sometimes with prisms of amphibol several inches long. In one of the exposures, an epidote rich rock (apparently of sedimentary origin) is cut by a medium

grained dark appinitic vein several feet wide. Both the epidote rich amphibolite and the appinitic vein are cut by a later vein of very coarse appinitic rock.

E. Origin of Appinitic Types in the Mill Ponds Complex.

The field relations, petrographic characters and composition of the coarse appinitic types, show the latter to differ in no way from the enclosing dioritised amphibolites and variable dioritic rocks except in their exceptional coarse grain of the amphibole in particular. It would be unnecessary repetition to state all the points of identical similarity between them. Moreover, there is no evidence whatsoever to suppose the appinitic types are anything but coarser varieties of the hybrid dioritic rocks and hornblende rocks.

The following points would rule out the possibility of these appinitic types being of a calc-silicate or limestone parentage :-

(i) The few small rafts of calc-granulites which happen to be in the neighbourhood of dioritic and appinitic types do not show any interaction whatsoever, the mixing and metasomatism of the hornblendic rock having taken place at a lower level.

(ii) The rocks of the rafts of calc-silicates and especially calc-granulites contain a considerable amount of quartz, meanwhile the appinitic types are entirely devoid of quartz.

(iii) There is no known calcareous group of rocks at a lower level in this N.E.-S.W. trending belt of metasediments.

(iv) In thin section, these rocks do not show any trace of minerals which could possibly be at ributed to a calc-silicate parent, such as diopside cores in amphiboles, etc.,

Thus it appears that the formation of the appinitic types from the mixed dioritic rocks and dioritised amphibolites is merely a degree of crystallisation, which could probably be promoted by the presence of 'volatiles'. Again it seems unlikely that these appinitic types managed to obtain CO_2 from calc-silicate rocks and limestone screens at the present level, especially as the usual diorites with interbanded leucocratic rocks are in contact with residual bands of limestone as described (p.309).

The appinitic types, which are themselves heterogeneous, most probably represent parts of the migmatitic diorites which are locally enriched in volatiles derived from the sodic emanations or oligoclase material involved in the fundamental process of formation of all the rocks in the western part of the complex.

The appinitic types in the other occurrences near Ardara appear to be of a 'pegmatitic" or residual nature.

Read (1931) described a coarse hybrid rock from

Allt Coire na Fearna, Central Sutherland, identical with the appinites of the S.W. Highlands. Unlike the other Achuian Hybrids, this rock is lacking in biotite and was thought to have been formed by the invasion of a basic hornblendic rock by oligoclase-rich magma of a trondhjemitic facies.

Cheng (1942) distinguished two different types of coarse appinitic rocks from near Betty Hill, North Sutherland. One of these types, together with the other rocks of the Hornblendic Complex, resulted from basic and ultrabasic rocks (in the Moine Series) already hybridised before the period of general migmatisation. During this migmatisation, these rocks were profoundly modified. The other appinitic rock is formed during the period of migmatisation.

F. Appinitic Types in Donegal - General Consideration.

Gindy (1951A) described a lamprophyre sill part of which is loaded with quartzite xenoliths and amphibolic xenoliths, the latter thought to be related to a limestone parent and subsequently basified. He shows that the matrix between the xenoliths is richer in mafic material than the normal portion of the sill. This is marked by the presence of abundant large hornblende prisms, and he remarks that the matrix thus recalls certain appinites of the Scottish Highlands. Gindy (1951B) later described a coarse amphibole rock from Cor and suggested that they had been formed in

limestone together with other skarns by the diffusion of trondhjemitic material along the contact of metadolerite and limestone, the trondhjemite having obtained a considerable amount of material from both. This coarse amphibole rock would, no doubt, be considered as an appinite and bears a striking resemblance - as a rock type - to one of the writer's appinitic types (p.410).

Pitcher and Read (1952) have described an appinitic intrusion-breccia from Kilkenny consisting of a minor part made of quartzite fragments in a scanty granophyric matrix and a major part formed of a hornblendic (appinitic) rock containing fragments of calc-silicate flags. They suggest that the two matrixes are predominantly made of re-constituted quartzite and calc-silicate rock respectively. In other words, that the appinitic matrix is of calc-silicate origin and "that no magma in any usual meaning of the term has been involved" .... but "that a sodic fluid, probably gas charged, was the operative medium".

Iyengar, Pitcher and Read (1953) describe rather briefly an appinitic amphibolite complex at Mulnamin More near the previous district. This consists of coarse appinitic amphibolite with inclusions, many of which are of calcareous origin, and a southernly part composed of streaky biotite-hornblende-plagioclase-diorite devoid of enclaves. An association of appinitic amphibolite (with evidence that

much calcareous material has entered into its composition) and mixed dioritic rocks form a composite body, the components of which "were evidently not manufactured at the present level of exposure". The case of the Meenalargan Complex will be considered separately in the next section.

The following observation from the writer's area is relevant to a discussion of Gindy's example, where an appinitic rock is formed in place from a limestone, and also in the case of the Mulnamin More body, where the appinitic rock is formed largely from calcareous material at a lower level. At the south-easternly corner of the metadolerite mass situated to the left-hand side of the drive to Ardlougher House, the metadolerite suddenly acquires a very coarse texture and becomes appinitic. The hornblende is recrystallised into stumpy idiomorphic crystals about 8 - 10 m.m., apparently as a result of a later introduction of quartzo-felspathic material. This rock is a perfectly normal metadolerite, yet once it is recrystallised into a coarser rock with coarse idiomorphic hornblende it is termed 'appinitic'.

It appears therefore, that in all the Donegal examples so far described, the appinitic types are dioritic in nature and are ultimately hybrid rocks produced by the interaction of soda rich material on one hand and calc-, calc-amphibolite or amphibolitic material on the other hand. It is rather difficult to state the exact nature of the soda-rich component,

Gindy refers to it as trondhjemitic in one case and shows that it is lamprophyric in another (lamprophyres are usually sodic in Donegal). Pitcher and Read refer to "sodic fluid, probably gas charged" as the operative material, and the writer infers in the present case that it is oligoclasic in nature, rarely accompanied by excess silica. Meanwhile, the other parent of these rocks can be either a calc-silicate rock, amphibolite after calc-silicate, the metadolerite or even the amphibolite resulting from the alteration of a peridotite. The importance of the point about the sodic emanation of fluid being gas charged, as stated by Pitcher and Read, is strongly confirmed by the appinitic types in the Mill Ponds complex.

It seems that the sodic emanation, fluid or material, etc., is the so called trondhjemite involved in the early migmatisation and granitisation of country rock to produce the Older Granites (Gindy 1952) (Pitcher 1952).

VII. A Comparison of the Mill Ponds Complex and the Meenalargan Complex.

Iyengar, Pitcher and Read (1953) have demonstrated the production, at the present level of exposure, of coarse appinitic amphibolite from calcareous rocks of the Mulnamin Calc-silicate Flags in more than one locality in the Meenalargan Complex especially at Lough Laragh. They also state that at

several localities conspicuous hornblende porphyroblasts are developed in fine-grained metadolerites to produce a rock superficially resembling the usual appinitic amphibolite thought to be of calc-silicate origin ; in other words, that the metadolerites have also contributed towards the appinitic types in the complex.

The study of the Ardara Pluton (Chapters 6 and 7) has shown that the coarse tonalite forming the outer mantle of the pluton was originally the mobilised derivative and ultimate product of a deep seated complex very similar to the Meenalargan Complex. This rock consisted originally of large plagioclase crystals, hornblende and biotite, and a large part of the potash felspar and quartz was secondary and related to the main core of the pluton. Thus, as already stated by the writer in the discussion on the above paper, the migmatisation in the Meenalargan Complex appears to have occured at a lower level prior to the emplacement of the pluton. This early migmatisation was effected by the introduction of sodic material which was generally active at that early stage. The migmatisation, mobilisation and differential movement of the diverse rock units shown by the above authors to be connected with the flow of magma during the emplacement of the Ardara pluton, is most probably a continuation of the earlier migmatisation.

On the other hand the Amphibolitic Complex of Mill

Ponds is but the upper part of a large buried complex now revealed on the southern side of the Ardara Pluton and consisting of rocks having peridotite as one parent. The central core of the complex represents a plug-like offshoot of the original buried peridotite mass which has managed to survive and retain its identity due to its reaching its present high level. Meanwhile, the rocks of the lower part of the ultrabasic mass were completely metamorphosed 'dioritised' and migmatised. These were, at a later date, affected physically by the emplacement of the Ardara Pluton and were rendered more plastic and mobile ; but there has been certainly no addition of potassic material from the main bulk of the pluton as witnessed by the marked lack of potash in the mixed rocks of Mill Ponds.

The Meenalargan Complex and the Mill Ponds Complex are now represented by the south-eastern part of the Ardara pluton, the shortest distance between them being about ¾ miles 250yds. The two complexes could have been continuous at a certain stage in the history of the area but essentially prior to the emplacement of the pluton.

Assuming the succession suggested by the writer (p.15) to be correct and that the Glenties Series followed after the Rosbeg Group and Maas Succession (not necessarily a stratigraphically continuous succession), then the Mill Ponds Complex could well represent the <u>roof</u> of a considerable

amphibolitic complex, a large part of its rock being derived from a peridotite. The middle part of the presumed complex would have been cut by the Glenties Thrust while part of its base is represented by the Meenalargan Complex. In the latter, the original peridotite would have been completely altered, migmatisation having begun early in the history of the area. The Mulnamin Calc-silicate Flags running straight into it would naturally show transformation to amphibolites.

However, the following two points seem to strengthen the view that the two complexes had been at one time continuous :-

(i) The coarse dioritic rock found in the northern parts of the Mill Ponds Complex at Kilrean (p.396), and in the mixed rocks in the centre of the Complex, is identical with other occurrences in the Letterilly area. This rock is undoubtedly the direct parent of the tonalite in the pluton.

(ii) It seems most unlikely that the immense quantity of basic amphibolitic material constituting the rocks of the Meenalargan Complex, as well as the considerable quantity of basic rocks already incorporated by the Ardara pluton have all been derived from the Mulnamin Calc-silicate Flags and the metadolerite bodies in that lithological group.

VIII. Appinitic Types and Lamprophyre Dykes.

At the present stage of this thesis and in the light of the detailed history of the present area, it is intended to draw certain conclusions concerning the relations, if any, between the two suites of lamprophyre dykes on one hand and the mixed dioritic rocks and appinitic types on the other.

Bailey (1916) in defining the appinites which he named after the local parish of Appin, states that they are "the plutonic equivalents of the hornblende vogesites and spessartites" .....

Reynolds (1936) demonstrated the formation of appinite together with micropegmatite and syenite by the replacement of quartzite xenoliths engulfed in hornblendite magma, the process involving the differential diffusion of various magmatic constituents into the quartzite. Later (Reynolds 1938) produced evidence of metasomatic felspathisation of quartz xenoliths in the Kircubbin and Newmains lamprophyre dykes and the later rheomorphism of the felspathic material. Quoting other cases of apparently similar transfusion phenomena in other lamprophyre dykes, she infers that the rock types in the Kircubbin dyke are examples of the individual heterogeneous members of the Ards swarm and their Scottish continuation. She therefore suggests that the process of metasomatic transfusion and rheomorphism seen in individual dykes may be "small scale replicas of the main process which was active in the generation of rock types associated together in the various Caledonian dyke

swarms".

Pitcher and Read (1952) make the following statement as a result of both their general experience of Donegal and their study of the intrusion-breccia of Kilkenny :- "The appinites are grouped with the lamprophyres and the whole group seems notoriously prone to hybridization, contamination and all kinds of processes that are not consonant with straight crystal-fractional differentiation".

The foregoing statement is further confirmed by evidence from the present area. The lamprophyre dykes have already been dealt with in detail in chapter 4 of this thesis, and the following points are of special significance:-

(i) The lamprophyre-felsite dykes were intruded during the period between the final phases of the main orogeny and the emplacement of the Ardara pluton. This is the time in which the migmatisation in the amphibolitic complex was apparently taking place by the invasion of soda-rich emanations. Gindy has shown that, although trondhjamitic and oligoclase-rich material first appeared in the country rocks before, during and after the tectonic maximum, <u>active migmatisation</u> of the country rocks was mainly <u>post tectonic</u> i.e. after the main orogeny.

(ii) The lamprophyre-felsite dykes are all <u>sodic</u> in nature and very rich in oligoclase, the main variation in composition being in the proportion of the ferromagnesian components.

Potash felspar is either entirely absent or else present in insignificant amounts; the lamprophyres are decidedly trondhjemitic in nature.

(iii) The amphibole of the spessartites bears a similarity to that of the hybrid diorites and appinitic types, in the fact that a brownish hornblende possesses outer rims of greenish actinolite. The same relation is seen in the amphibole of the basic lamprophyre dykes of the second suite.

(iv) It has been shown (pp.54 and 63) that the lamprophyre-felsite dyke suite is concentrated mainly in the south-western part of the area and that the generalised trend of the dykes is entirely independent of planes of structural weakness at the present level and the different movements taking place during their emplacement. It appears therefore that the lamprophyre-felsite dykes are the products of a buried complex of migmatisation and granitisation involving the introduction of trondhjemitic material.

(v) The swarm of basic lamprophyre dykes includes coarse- and medium-grained hornblendic rocks containing up to about 75% mafic constituents and of Sp.gr. 2.93 as well as more leucocratic types, the only difference being a variation in the proportion of oligoclase felspar. This bears some resemblance to the mixed dioritic rocks in the amphibolitic-appinitic complex. The intermediate members of this swarm are identical in field occurrence, morphology and compositic

with other lamprophyre dykes in adjacent areas which are xenolithic and associated with calc-silicates rocks. Moreover, the amphiboles of this swarm are decidedly actinolitic. The basic lamprophyre dykes are most probably mobilised products of hybridisation of amphibolites and/or calcareous material, hence their relation to the appinites.

Chapter FIFTEEN.

C O N C L U S I O N.

The foregoing has dealt with the geology of the area in detail mainly on a time basis, and the sections of the work contain a brief summary and conclusion. An outline of the geological history of the area has already been given at the beginning of the thesis. It is intended in this present section, first, to outline briefly the chronological sequence of events with special emphasis on the three phases of movement, and secondly, to give the main points contributing to the geology of West Donegal, followed by the new ideas contributing to general petrological knowledge.

I. General History of the Area.

Subsequent to the geosynclinal phase of sedimentation and intrusion of doleritic bodies, the history of the area is that of a series of distinct tectonic movements each associated with a definite metamorphism and closely followed by the emplacement of granite, probably all part of one long plutonic episode (Fig.7).

First, early orogenic fold movements from the south and south-south-west were closely associated with a regional metamorphism of the Dalradian sediments with the attainment of the 'garnet grade'. This was immediately followed by the activity of lamprophyre-felsite dykes, minor granite bodies - which sometimes appear as the roofs of larger buried masses -

and finally, basic lamprophyre dykes.

Second, post-orogenic thrust movements from the south-east were associated with a regional retrograde metamorphism and were followed by the emplacement of a sheet of tonalite along a subsidiary thrust plane ; the general structure of the area was now suitable for the emplacement of the Ardara Granitic Pluton, this causing the contact metamorphism of its envelope of country rocks.

Third, late thrust movements causing the retrograde metamorphism of parts of the contact aureole of the pluton and the mylonitisation of the tonalite sheet, were closely followed by the emplacement of granite across the 'neck' of the pluton.

Thus, it is clear from the accompanying chart (Fig.7) that the geosynclinal phase has been followed by a lengthy episode of orogeny and plutonism embracing three distinct phases of movement.

II. Contributions to the Geology of Donegal.

The outstanding points considered to contribute to the knowledge of the geology of Donegal can be summarised briefly as follows :-

1. The area south of the Ardara pluton was mapped for the first time since 1890, and a succession established, the lithological groups of which are separated by major structural breaks :-

Slieve Tooey Quartzites
---------- Carbane Thrust
Monargan Psammitic Group
---------- Monargan Thrust.
Strawoaghter Semi-pelitic Group
----------Strawoaghter Thrust.
Glenties Series
----------Glenties Thrust

This discontinuous succession is suggested to be above the Rosbeg Semi-pelitic Group and the Maas Succession.

2. The 'Ardara Limestone Group' with the boulder bed described by Anderson (1952) and stated to follow conformably below the Slieve Tooey Quartzites, was found to be a predominantly psammitic group of rocks in the form of an exotic thrust slice emerging from beneath the Quartzites and lying discordantly over the rocks of the Glenties Series. A boulder bed was found to lie at the northern face of the thrust slice.

This thrusting marks the second phase of movement as stated above.

3. Unlike other areas of West Donegal, the time relations of the lamprophyre-felsite dykes and minor granite bodies in the present area are known precisely. The lamprophyre-felsite dykes began their activity immediately after the main orogeny and have continued till after the emplacement of the Ardara Pluton. The minor granite bodies were later than the earliest members of the lamprophyre-felsite dykes and were followed by a small swarm of basic lamprophyre dykes. At

least the lamprophyre-felsite dykes and minor granite bodies were earlier than the thrust movements and regional retrograde metamorphism.

4. The basic lamprophyre dykes form a separate swarm in the northern part of the area quite distinct from the lamprophyre-felsite dyke suite. In no other part of W.Donegal have lamprophyre dykes reached this basic composition.

5. The regional retrograde metamorphism, of wide distribution in W.Donegal, is found to be connected with considerable thrust movements from the south-east, by which the Glenties Series and Slieve Tooey Quartzites are thrust against the Maas Succession on the Mulnamin anticline. These thrust movements are earlier than the emplacement of the Ardara Pluton.

6. The Ardara Granitic Pluton, as a distinct member of the Donegal Granite Series, has been emplaced by the forceful displacement of the metasediments in contrast to the Rosses Ring Complex, the emplacement of which was shown to be controlled by a mechanism of cauldron subsidence, (Pitcher 1953B).

7. The mode of emplacement of the Ardara Pluton - which is the south-western extremity of the main Donegal Granite - essentially by the movement of magma along the structural break between the Glenties Series and the Mulnamin anticline, throws much light on the problem of the emplacement of the main body of the Donegal Granite, since this may be bounded on its south-eastern side by the north-eastern continuation of the great thrust of Glenties.

8. The Ardara Pluton also demonstrates the production of new rock types in considerable quantity by interaction with and resorption of basic amphibolitic country rocks, by one of the members of the Donegal Granite Series.

9. Investigation of the Amphibolitic Complex of Mill Ponds has shown that some appinitic types are the ultimate result of hybridisation of altered ultrabasic peridotite rocks.

III. Contribution to General Petrology.

The contribution to petrology in general can be summarised as follows :-

1. The Ardara Pluton provides an example of a diapir emplaced by the upward movement of magma along an older structural break and later swelling into a circular mass.

2. The Ardara Pluton is possibly the first case in which a mobilised derivative of a migmatitic complex is intruded together with a purely magmatic granite, the latter not having directly taken part in the formation of the migmatitic rock. The migmatitic rock has travelled for some distance alongside the magmatic granite.

3. The Ardara Pluton provides a clear case of a diapir emplaced in the form of two upwellings of magma with a short lapse of time in between. The second upwelling was later than at least part of the hydrothermal phase of the first.

The information so far available concerning other

plutons such as the Northern Granite of Arran (Bailey 1926, Tyrrell 1923) does not postulate any lapse of time between the components ; the two rock-types might have been emplaced together in the same manner as the xenolithic quartz-diorite and tonalite of the first phase of the emplacement of the Ardara Pluton.

4. The effect of the second upwelling of magma was to impress late structures in the pluton including the plastic deformation of the earlier granitic members and the formation of boudinage structures in the xenoliths in the granite.

5. The effect of the second upwelling of magma upon the contact altered country rocks is also recorded as a mineralogical readjustment due to variations in temperature and pressure.

6. The tectonics accompanying the emplacement of the composite granitic diapir are clearly elucidated. By mapping the lithological groups and marker horizons on the 6" scale, and the use of large and small scale structures in the surrounding country rocks, the mode of emplacement of the diapir by the forceful displacement of the country rocks is fully demonstrated.

7. The planar distention of the country-rocks in the immediate vicinity of an inflating diapir during the later phases of its emplacement is demonstrated for the first time.

8. The lamprophyre-felsite dykes - which mark the earliest

igneous manifestations within the lengthy episode of orogenisis and plutonism, and which continue until after the emplacement of the Ardara Pluton - retain their N.W. - S.E. trend even after the second phase of movement, in which the movements were different from those of the first phase. They do not appear to be controlled in trend by local planes of structural weakness or by a direction of crustal tension at right angles.

9. At the foot of the Slieve Toogy Quartzite thrust blocks, the Mylonitic Gneiss of Carbane is reeded and lineated in 'b' parallel to the thrust. The 'ac' plane shows the rolling movement meanwhile the banded mylonitic structure - which is rather localised - is only seen on the 'bc' plane.

10. The prolonged episode of orogenisis and plutonism following the geosynclinal phase has been resolved into three phases of movement, the first and second of which have totally different movements and effects.

A P P E N D I X.

TERTIARY DOLERITE DYKES.

I. General. A set of twelve dolerite dykes occur in the present area and appear to be entirely independent of the prolonged igneous activity associated with the three-phase orogenisis dealt with in full in this thesis. The Survey Memoir (1890 p.98) refers to these dykes as "the youngest eruptive rocks of Donegal" and as "part of the volcanic phenomena of older Tertiary time in the British Isles". Their great similarity to the Tertiary dykes of Antrim has been noted by other workers. As regards composition, they are usually olivine dolerites, less often augite dolerites occasionally amygdaloidal. The dykes vary in width from 1½ft. to 45ft., usually vertical and trend N.N.W.- S.S.E. to N.W.-S.E., rarely N.E.-S.W. These dykes usually possess a columnar type of jointing normal to the place of the dyke. They have been seen in several places to occupy fault planes.

II. Occurrences and Morphological Description.

Out of a total of twelve dykes in the whole area, two occur within the Ardara pluton, the remaining cutting the country rocks. Nine of the dykes are found on the southern side of the pluton.

The largest dolerite dyke in the area is that at Odogherty ; it outcrops mainly on the western side of the mountain road to Donegal Town. It is about 45yds. wide and

is exposed over a distance of about 650yds. in a N.W.-S.E. direction. The dyke is massive and is traversed by two sets of joint planes normal to the plane of the dyke and dipping at about 40° on either side.

The second largest dolerite dyke is also found near this locality, at Cronkeeran, situated between the row of farm houses and the foot of the Ardvalley thrust block. It is about 35ft. wide and 300yds. in length, trending N.W.-S.E.

At Kilrean Upper, due south-east of the Amphibolitic Complex of Mill Ponds, three dolerite dykes cut the pelitic and semi-pelitic rocks of that area. The largest of these dykes is about 12ft. wide and trends vertically in a direction a few degrees west of north. The second dyke outcrops about 100yds. to the west. It is about 6ft. wide and possesses six-sided columnar jointing normal to the plane of the dyke. The hexagonal cross sections of these joint blocks are about 6 - 9 inches across. The third dolerite dyke in Kilrean Upper is seen in one of the streams flowing down the face of the Crockbrack Quartzite thrust block. It trends N.W.-S.E.

In the bed of the Owentocker river at a point ¼mile south-west of Drumnacross School, a 10ft. wide dolerite dyke crosses the stream in a north-westernly direction. The rock is very fresh and contains spherulitic amygdales about 1 c.m. in diameter filled with zeolites. Another dolerite

dyke also rich in spherulitic amygdales is found in a stream at a point just by the boundary of the Amphibolitic Complex ; the stream flows south through Mill Ponds.

Two dolerite dykes were found in the locality of Carbane Hill. The first crops out in the gulley of the stream flowing rapidly from the Drumnasilla Quartzite thrust block, the second dyke alongside the path leading to the peat-cutting area at a point near the outer margin of the mylonitic gneiss. This dyke shows crude six-sided jointing.

The only dolerite dyke occurring in the area north of the Ardara pluton cuts the Lower Limestone member of the Upper Portnoo Limestone along the coast near the western boundary of Drumshantony. This dyke is about 1½ft. wide and stands vertical in a direction N.25° E. The dyke is cut by a conjugate system of joints normal to the plane of the dyke and consisting of two sets of joints dipping roughly at 45° either way along the length of the dyke, The latter thus seems to be formed of prismatic blocks with rhombic sections. The rock contains pipe amygdales in addition to the usual amygdaloidal cavities of these rocks.

As already stated, only two dykes are found to occur within the Ardara pluton. One of these dykes is seen at a point about 200yds. due north of Garvegort School and appears to follow the northernly trending fault in the tonalite. The dyke is about 3ft. wide and is exposed in discontinuous

outcrops for a distance of about 150yds. The other dolerite dyke is found at Letterilly at a locality about 500yds. south-west of the Maas-Glenties road. It is not particularly well exposed but reappears once more at the foot of the large ledge-like crags of xenolithic quartz-diorite. The dyke is 6ft. wide and trends in a north-westerly direction.

III. Petrography.

These dolerite dykes are mainly olivine dolerites and sometimes augite dolerites completely lacking in olivine. The rocks of the larger dykes are usually medium-grained while the thin dykes are decidedly finer grained.

The large dyke at Odogherty (slice 813) is a typical olivine dolerite, consisting of olivine, titaniferous augite and bytownite with accessory iron oxide. The rock is medium-grained and shows a well developed ophitic texture. Colourless olivine, with inclusions of iron oxide, occurs in crystals up to 2 m.m. across, sometimes these crystals occur as aggregates with interstitial plagioclase and some pyroxene. The augite is slightly pleochroic light tan to pale yellowish grey and occurs as grains up to 2 m.m. across. It shows well developed ophitic texture. The plagioclase is bytownite (An.72-74) in laths up to 3 m.m. long. Iron oxides occur mainly as ilmenite and are present in notable quantities.

The dolerite dyke cutting the granite at Letterilly

(slice 536) consists of olivine, augite, plagioclase, chrysotile, antigorite and iron oxide. The olivine which is by far subordinate to the pyroxene occurs as sub-rounded grains 0.3 m.m. across, usually 2 - 4 crystals together, between which some antigorite is found. The augite is dark buff to brownish tan, feebly pleochroic and occurs in crystals about .9 m.m. across with a sub-ophitic texture. The augite is partly breaking down to antigorite. The plagioclase forms slender laths up to 1½ m.m. long and has the average composition of An.75. Chrysotile occurs in small patches, pleochroic in yellowish green to greenish yellow, usually with a fibrous form sometimes bundles and shreds with a decussate structure. It is occasionally associated with antigorite, the latter forming clear yellowish green borders around the chrysotile patches. The rock contains occasional amygdales about 0.7 m.m. in diameter and filled with a fibrous zeolite.

The dolerite dyke along the north-eastern coast of the area is an augite-bytownite-dolerite entirely lacking in olivine. It is fine grained and possesses a sub-ophitic texture. The augite is notably pleochroic, dark tan to purplish brown, suggesting a titaniferous nature. The plagioclase has the composition of An.73-77 and occurs as slender laths up to 0.4 m.m. long. The finer grained matrix of the rock consists of iron oxide, antigorite and subordinate chrysotile. The rock has abundant spherical amygdales as

well as pipe amygdales. A typical pipe amygdale is about 6 m.m. in diameter with an internal lining of siderite ½ m.m. thick. The siderite is in the form of curved lenticular crystals with a flat base in contact with the wall of the amygdale. This siderite is succeeded by an anular band consisting of a spherulitic zeolite (Tomsonite), the centres of the spherulites usually lying along the circumference. A small area in the centre is occupied by a neat mozaic of quartz grains. The rock shows a remarkably higher degree of crystallisation in a zone 2 m.m. in width, surrounding the pipe amygdales, and contains curved crystals or aggregates.

Slice 123 shows the chilled edge of this dyke against the limestone host. The chilled edge appears as a margin 1½ m.m. wide and consisting of a black isotropic matrix with very minute twinned microlites. This followed by a zone 2 m.m. wide slightly lighter in colour and containing minute laths of plagioclase and incipient crystals of a dark ferromagnesian mineral.

There is hardly any thermal effect upon the limestone.

Acknowledgement.

I wish to express my gratitude to Professor H.H. Read and Dr. W.S. Fitcher for their guidance, helpful criticism and encouragement during the progress of the work and the preparation of this thesis.

The work was sponsored by a scholarship from the Egyptian Ministry of Commerce and Industry, which I deeply acknowledge.

BIBLIOGRAPHY OF PREVIOUS LITERATURE.

Andrew, G. 1923 The Contact relations of the Donegal Granite. I.F.S. Fem.Proc.Manchester, Lit.Phil. Soc., p.211.

Blake, E.H. 1861 On the primary rocks of Donegal. Jour. Geol. Soc.Dublin. Vol.9, -.295.

Callaway, C. 1885 On the Granitic and Schistose rocks of Northern Donegal. Q.J.G.S. Vol.41,p.221.

" 1887 On the alleged conversion of crystalline schists into igneous rocks in County Galway. QJ.G.S. Vol.4-, p.617.

Cole, G.A.J. 1900 On Metamorphic rocks in Eastern Tyrone and Southern Donegal. Trans.Royl.Irish. Acad. Vol.31, p.431.

" 1902 On Composite gneiss in Boylagh, West Donegal. Proc.Roy.Irish.Acad, Vol.24, Sect.B. pt.2, p.263.

" 1906A On a hillside in Donegal "A glimpse into the great earth cauldrons". Proc.Irish Soc.

" 1906B On the marginal phenomena of granite domes Geol.Mag. Vol.3 (abstract) p.80.

" 1914 Illustrations of the formation of composit gneisses and amphibolites in N.W.Ireland. Rep.Inter.Cong.12th Session, p.311-312.

Cole, G.A.J.	1915	Presidential Address.Bri.Assoc. for Adv. Sc.
Forbes, D.	1871	Structure of Rock Masses (Foliation). Popular Science Review.
"	1872	On the Geology of Donegal. Geol.Mag. Vol.9, p.12.
Geikie, A.	1891	Presidential Address. Q.J.G.S.
Green, A.M.	1871	Notes on the Geology of part of Co. Donegal, Ireland. Geol.Mag.Vol.8,p.553.
Griffith, R.	1852	Notices of the Geology of Ireland. Brit. Assoc. Rep. p.47.
Harkness, R.	1860	On the metamorphic rocks of the North of Ireland. Brit.Assoc.Rep.p.79.
Harte, W.	1865	Crumpled granite beds in the County Donegal. Jour.Roy.Soc.Ireland. Vol.4, p.144.
Haughton, S.	1862	Experimental researches on the Granites of Ireland, pt.III. On the Granites of Donegal. Q.J.G.S. Vol.18. p.403-407.
"	1863	Experimental researches on the Granites of Ireland, pt.IV. On the Granites and Syenites of Donegal with some remarks on those of Scotland and Sweden. Q.J.G.S. Vol.20. p.271.

Haughton, S. 1870 On the Constituent minerals of the Granites of Scotland as compared with those of Donegal. Jour.Roy.Soc.Ireland, Vol.2, p.232.

" 1871 The Granites of the County of Donegal. Trans.Roy.Irish. Acad.Vol.24, p.213.

Hull, E. 1831 On the Laurentian beds of Donegal and of other parts of Ireland. Rep.Brit. Assoc. p.609.

Hull, E. & others. 1890 Memoirs Geol.Surv. accompanying sheets 1,2,5,6, and 11.

" 1891. Memoir of the Geol.Surv.Ireland.

Hunt, J.S. 1863 On the Chemical & Mineralogical relations of metamorphic rocks.Jour. Geol.Soc.Dublin. Vol.10, p.85.

Kilroe, J. 1891. In Memoir of the Geol.Surv.Ireland.

Kinahan, G.H. 1869 In Memoir of the Geol.Surv.Ireland.

" 1831A On the Laurentian rocks in Ireland. Rep.Brit.Assoc. p.610.

" 1831B Possible Laurentian rocks of Ireland. Geol.Mag.Vol.p.429.

M'Adam, J. 1834 On the Geology of the district of Fannad in the County of Donegal. Jour. Geol.Soc.Dublin, Vol.2, p.128.

Scott, R.H.	1861	On the Granitic rocks of the S.W.of Donegal and the minerals therewith associated. Jour.Geol.Soc.Dublin,Vol.9, p.286.
"	1863	On the Granite rocks of Donegal and the minerals therewith associated. University Press, Dub., Second notices.
Scott, R.H., Griffith,R. & Haughton, S.	1863	On the Chemical and Mineralogical Constituents of the Granites of Donegal and the rocks associated with them. Rep. Brit. Assoc. p.43.
Westrop,W.H.S.	1867	The origin of Granites. Geol.Mag. Vol.41, p.522.

R E F E R E N C E S.

Anderson, J.G.C.	1948	The Occurrence of Loinian Rocks in Ireland. Q.J.G.S. Vol.CIII.pp.171-190.
"	1952	The Pre-Carboniferous Rocks of the Slieve League Promontory, Co.Donegal. Proc.Geol.Soc.Lond. No.1491.
Bailey, E.B.	1916	Geology of Ben Nevis and Glen Coe. Geol.Surv.Scot.Mem.53, pp.167-169.
"	1926	Domes in Scotland and South Africa ; Arran and Uredefort. Geol.Mag.Vol.LXIII. No.XI.pp.481-495.
Balk, R.	1937	Structural Behaviour of Igneous Rocks. Mem.5, Geol.Soc.Amer.
Billings, M.P.	1937	Introduction of Potash during Regional Metamorphism in Western New Hampshire. Bull.Geol.Soc.Amer.Vol.49,pp.289-302.
"	1942	Structural Geology. Prentice Hall, Inc.New York.
Charlu, J.G.K.	1951	A note on the Development of Large Garnets in Sutherland Migmatites. Geol.Mag.Vol.LXXXVIII.pp.185-191.
Cheesman,R.L.	1951	The Geology of Loughros Peninsula. M.Sc.Thesis London, Univ.
Cheng, Y.C.	1942	A Hornblendic Complex, including Appinitic Types, in the Migmatite Area of North Sutherland,Scotland. Proc.Geol.Assoc.,Vol.LIII,Part 2, pp.67-85.
Cloos, E.	1934	The Loon Lake Pluton, Bancroft area, Ontario, Jour.Geol.Vol.XLII. No.4, pp.393-399.
Friedman, G.M.	1953	Olivine Amphibolite of Blackrock Island, Ontario, Amer.Jour.Sci. Vol.251, No.9, pp.661-673.

Gindy, A.R. 1950 The Country-Rock and Associated Granites, N.E. of Gweebarra Bay, Co. Donegal. Ph.D. Thesis, Lond.Univ.

" 1951A A Xenolithic Sill at Tallabrista, Co. Donegal, Ireland. Geol.Mag.Vol.LXXXVIII pp.55-59.

" 1951B The Production of Amphibolic and other Skarn Rocks from Limestone at Cor, Co.Donegal. Geol.Mag.Vol.LXXXVIII. pp.103-112.

" 1953 The Plutonic History of the District Around Trawenagh Bay, Co.Donegal. Q.J.G.S. Vol.CVIII. pp.377-412.

Grout, F.F. 1937 Criteria of Origin of Inclusions in Plutonic Rocks. Bull.Geol.Soc.Amer. Vol.48, pp.1521-1572.

Hadley, J.B. 1949 Preliminary report on Corundum Deposits in the Buck Creek Peridotite, Clay County, North Carolina. U.S. Geol.Surv.Bull. 948 E.pp.103-128.

Hills, E.S. 1940 Outlines of Structural Geology. Methuen & Co. London.

Hurlbut, C.S. 1935 Dark Inclusions in a Tonalite of Southern California. Amer.Mineral. Vol.20, No.9, pp.609-630.

Iyengar,S.V.P. 1949 The Geology of the Dalradian Schists and Donegal Granite in the Maas Derry-loghan area, Co.Donegal. Ph.D.Thesis, Lond.Univ.

" , Pitcher,W.S. & Read, H.H. 1953 The Plutonic History of Maas Area, Co. Donegal. Proc.Geol.Soc.Lond. No.1501, p.cvi.

Johannsen, A. 1938 A Descriptive Petrography of the Igneous Rocks Vol.IV The University of Chicago Press, Chicago, Illinois.

Judd, J.W. 1885 On the Tertiary and Older Peridotite of Scotland. Q.J.G.S. Aug.1885 pp.354-418.

Karpoff, R. 1946 Sur la Presence de Disthene dans une Pegmatite a la frontiere Algero-Sudanise. Compt. Rend. Acad. Sci. Paris. Vol.223, pp.1154-1155.

Leith, C.K. 1923 Structural Geology. Constable & Co.Ltd. London.

Lindgren,W. 1900 Granodiorite and other intermediate rocks. Amer.Jour.Sci., IX.

Macdonald, G.A. 1938 Andalusite in Pegmatite from Fresno County, California. Amer.Mineral. Vol.23, pp.588-594.

Martin, N.R. 1953 The Structure of the Granite Massif of Flamanville. Manche. N.W.France. Q.J.G.S. Vol.CVIII. Part 4, No.432 pp.311-337.

McCall,G.J.H. 1951 The Geology around Cressleugh,Co. Donegal,Eire. Ph.D. Thesis. Lond.Univ.

" 1953 The Dalradian Geology of the Cressleugh area. Proc.Geol.Soc.Lond.,No.1501, p.civ.

Mead, W.J. 1940 Folding, Rock Flowage and Foliate Structures. Jour.Geol.Vol.XLVIII.p.1008

Mithal, R.S. 1952 The Geology of Portnoo District, Co. Donegal. Ph.D. Thesis Lond.Univ.

Nockolds,S.R. 1932 The Contaminated Granite of Bibette Head, Alderney. Geol.Mag.Vol.LXIX. No.820. pp.433-452.

Pitcher, W.S. 1953A The Migmatitic Older Granodiorite of Thorr District, Co.Donegal. Q.J.G.S.Vol.CVIII.pp.413-446.

" 1953B The Rosses Granitic Ring - Complex County Donegal, Eire. Proc.Geol.Assoc.Vol.64,Part 3,pp.153-182.

" & Read,H.H. 1952 An Appinitic Intrusion-Breccia at Kilkenny, Maas, Co.Donegal. Geol.Mag.Vol.LXXXIX. No.5,pp.328-336.

Read, H.H.	1923	The Geology of the Country round Banff, Huntly and Turriff. Expl.sheets 86 and 96, Mem.Geol.Surv. Scot.
"	1927	Igneous and Metamorphic History of Cromar, Deeside, Aberdeenshire. Proc.Roy.Soc.Edin.Vol.55.
"	1931	Geology of Central Sutherland. Geol.Surv.Scot.Mem.
"	1933	On Quartz-Kyanite-Rocks in Unst, Shetland Islands, and their bearing on Metamorphic Differentiation. Min.Mag.Vol.XXIII.No.140, pp.317-328.
"	1936	The Stratigraphical Order of the Dalradian Rocks of the Banffshire Coast. Geol.Mag.Vol.LXXIII. No.868 pp.468-476.
Reave, W.H.	1938.	Explanation of the Geology of Degree Sheet No.29 (Singida) Tanganika Territory. Dept. of lands and mines. Geological division, Bull.No.11
Reynolds, D.L.	1936	Demonstrations in petrogenisis from Kiloran Bay, Colonsay, I. The Transfusion of quartzite. Min.Mag.Vol.XXIV,No.155,pp.367-407.
"	1938	Transfusion Phenomena in Lamprophyre Dykes and their bearing on Petrogenesis Geol.Mag.Vol.LXXV, No.884,pp.51-76.
Suzuki, J.	1930	Petrological Study of the Crystalline Schist System of Shikoku, Japan. Jour.Hokkaido Imp.Univ.Ser,IV,Vol.I, No.1
Turner, F.J.	1943	Mineralogical and Structural Evolution of the Metamorphic Rocks. Geol.Soc,Amer.Mem.30.
Tyrrell, G.W.	1923	The Geology of Arran, Mem.Geol.Surv.Scot.

Wilson, G.	1946	The Relationship of Slaty Cleavage and Kindred Structures to Tectonics. Proc.Geol.Assoc.Vol.LVII, Part 4, pp.263-302.
"	1952	Ptygmatic Structures and their Formation. Geol.Mag.Vol.LXXXIX. No.1 pp.1-21.
Wiseman,J.D.H.	1934	The Central and South-West Highlands Epidiorites. Q.J.G.S. Vol.XC, pp.354-417.

GEOLOGY OF GLENTIES ARDARA AND CLOONEY, Co. DONEGAL

LEGEND

- Foliated Tonalite
- Central Granodiorite
- Xenolithic Quartz-diorite
- Newer Granite of Doocharry
- Mylonitic Gneiss of Carbane
- Minor Granite bodies
- Quartz-diorite of Owenea Lough
- Coarse Olivine-bearing Amphibolite
- Coarse Amphibolite
- Altered Amphibolite and associated Diorite
- Appinitic types
- Metadolerite
- Pelite
- Semi-pelite
- Alternately banded Semi-pelite and Pelite
- Graphitic and Micaceous Phyllite
- Quartz Flags
- Quartz Granulite
- Quartzite
- Limestone
- Calc-granulite
- Breccia
- Blown Sand
- Dolerite dyke
- Dip of bedding plane
- Horizontal beds
- Vertical beds
- Foliation in Tonalite
- Vertical foliation in Tonalite
- Foliation in Granite
- Vertical foliation in Granite
- Lineation or mullion in Granite
- Lineation on foliation plane in Granite
- Thrust
- Presumed thrust
- Line of dislocation
- Fault
- Boundary of pegmatitic fringe in Granite

N

GWEEBARRA BAY

INISHKEEL · AUMINISH · GRABBINDOO · CARRICKFAD · OPINISH · BOYLE'S ISLAND · TRAMORE STRAND · PORTNOO HARBOUR · PORTNOO · CASTLEGOLAN HOUSE · BOLEYMORE · CASHELGOLAN HILL · DRUMSHANTONY · WHITE STRAND · ROSHIN POINT · CLOONEY LOUGH · CLOONEY HILL · NARIN · CLOONEY · CLOGHERNASHARCH LOUGH · BLACK STRAND · STILL · NARIN HILL · BALLYHAISTON BRIDGE · BOON LOUGH · BINWEE · BALLYENNA · BONNYGLEN · MAAS UPPER · MOLLOY'S HOTEL · MAAS · SURDIES · LOUGH FAD · LOUGH NAMANLAGH · LOUGHDERRYDUFF HILL · KILCLOONEY · ABOOEY · LOUGH NACURRACH · SUNNY LOUGH · LOUGH DERRYDUFF · LOUGHFAD HILL · LOUGH NAGARNAMAN · MEENALARGAN HILL · CROCKARD · LEARAGH · CROCKANADREEVARN · LET TIMLEY HOUSE · GOBNAGROW · TIEVEBRACK HILL · SHEEBEN MORE LOUGH · ABERBRACKSIN · LOUGH ADERRY · LOUGH KEERAN · LOUGH MACNEAN · WARVANEILL LOUGH · LOUGH NAMANNA · GLENNACANNIVE · STRACASHEL BRIDGE · GLENTIES · CARBANE · DRUMNASILLAGH HILL · DESERTNESS POINT · TULLYMORE SCHOOL · LOUGH MACHUGH · TULLYCLEAVE BEG · CORN HILL · PRIEST MOUNT · MOUNTAIN ROAD TO BALLYBOFEY · OWENEA RIVER · DERRYNESS ISLAND · LONGFIELD · L. LAUB · OWENEA BRIDGE · KILREAN · MEENACMALLOW · MEEN LOAD · PORTAWAUD · TO LOUGHROS POINT · L. SHANAGHAN · CROCKBRACK · DRUMNACROSS · CARVEGORTCLEE · DOOCHLYNORTH · GORTNACART SCHOOL · CASHEL · ARDARA · KINNOGHTY · WOOD HILL · STORMHILL · MONARGAN · ENBOROUGH · DOOGHNAMEEN · ARDVALLY · TULLYHONWAR · STACKANILLER · STRAWCAGHTER GLEBE · CARRY · BRACKY HILL · GLENGESH HILL · NOGUMNA HILL · ARDLOUGHER · CRONKEERAN · NOGUMNA MOUNTAIN · OWENBEG RIVER · LOUGH MILLAN · TO DONEGAL TOWN · TO STRANORLAR · TO PINTOWN · STRABOY HILL · HILL PONDS

One Mile

M. KAMAL AKAAD
1952

MAP No 2

STRUCTURAL MAP OF THE ARDARA PLUTON

GWEEBARRA BAY

N

SAND DUNES

PORTNOO

CLOONEY

NARIN

MAAS

GLENTIES

ARDARA

STRIKE AND DIP OF FOLIATION

VERTICAL FOLIATION

STRIKE OF FOLIATION OF UNKNOWN DIP

SECONDARY LINEATION

STRIKE AND DIP OF LATE SHEAR PLANES

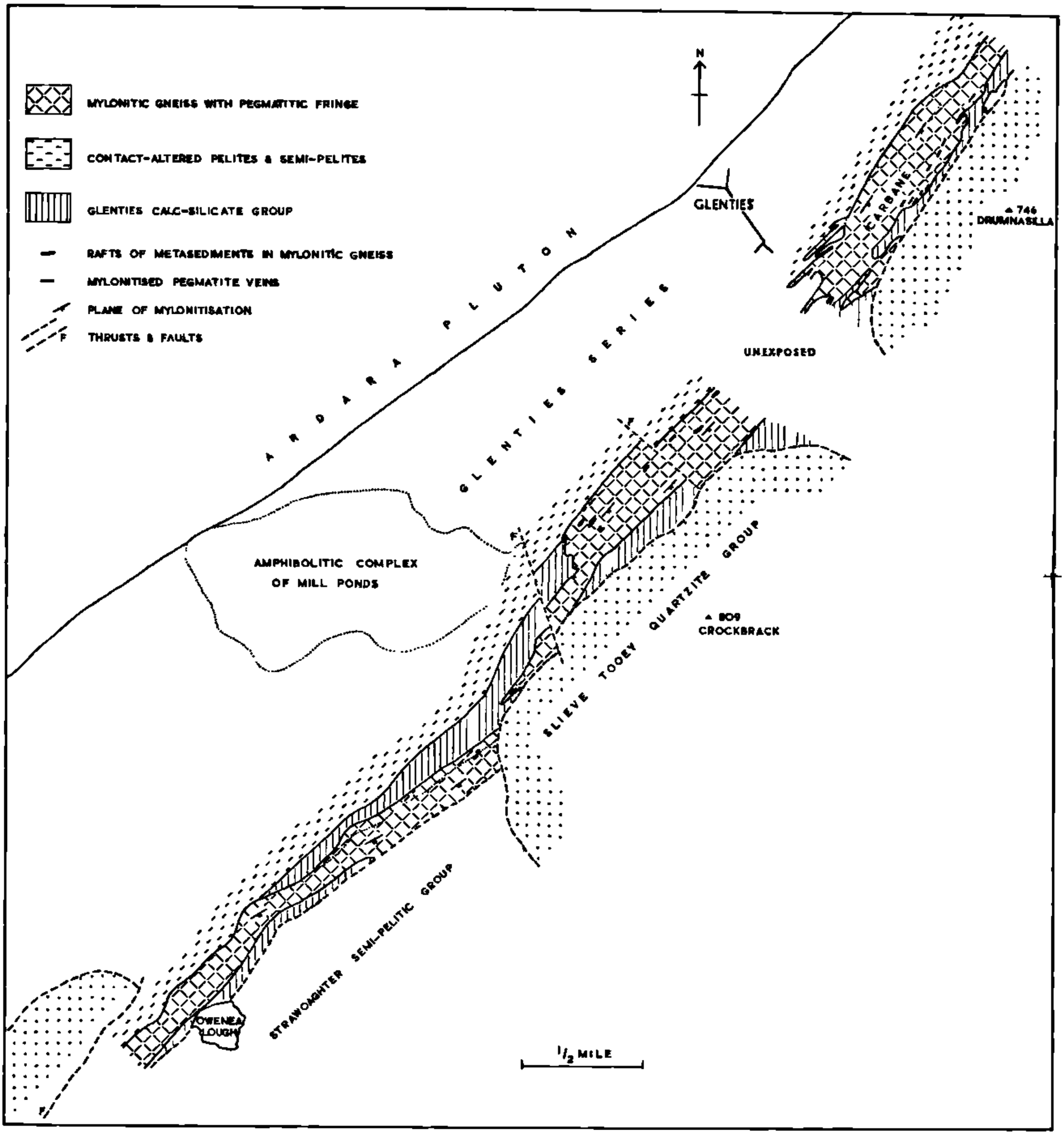
MAJOR AND MINOR THRUSTS IN COUNTRY ROCKS

FAULTS

PRESUMED DISLOCATION

½ MILE

MAP No.3


MYLONITIC GNEISS WITH PEGMATITIC FRINGE
CONTACT-ALTERED PELITES & SEMI-PELITES
GLENTIES CALC-SILICATE GROUP
RAFTS OF METASEDIMENTS IN MYLONITIC GNEISS
MYLONITISED PEGMATITE VEINS
PLANE OF MYLONITISATION
F THRUSTS & FAULTS
N
ARDARA PLUTON
GLENTIES SERIES
GLENTIES
CARBANE
▲ 746
DRUMNASELLA
UNEXPOSED
AMPHIBOLITIC COMPLEX
OF MILL PONDS
SLIEVE TOOEY QUARTZITE GROUP
▲ 809
CROCKBRACK
STRAWOMINTER SEMI-PELITIC GROUP
OWENEA
LOUGH
1/2 MILE