BODLEIAN LIBRARY OXFORD
DEPOSITED
THESIS
17·XII·56

ABSTRACT

The area of Dalradian rocks under investigation lies at the S.W. extremity of the narrow 60 mile ridge of the Ox Mountains, and is situated immediately N.W. of Castlebar, the county town of Mayo, Eire. It has not been studied in detail since the original mapping of the Geological Survey of Ireland between 1860 and 1870 by R.G.Symes.

This work is mainly concerned with the stratigraphy and petrography of the Dalradian schists together with a less detailed account of their structures and their relationship to the main metamorphic rocks of the Ox Mountains which are regarded as Moinian in character.

No stratigraphical sequence for the Dalradian rocks as a whole has been found possible because they are divided up into fault blocks by post Old Red Sandstone movements which are sinistral in character. Each fault block has distinct lithological, metamorphic, and structural features. The general character, however, of the schists of the area as a whole is similar to that of the Upper Dalradian of the Scottish Highlands.

The rocks have therefore been divided into groups named after the more important townlands of each fault block. They are Glenisland, Raheenbarr, Windy Gap, Derryharriff, Commauns-Shanvoley, and Ardvarne. They are generally soda rich, a fact revealed by the abundance of albite feldspar. Thick series of pebbly grits showing repeated graded bedding are characteristic of the Glenisland, where slump structures also occur, Raheenbarr, and Ardvarne groups. Detailed petrographic studies show the schists to be extremely variable in composition and to include alumina rich chloritoid schists, green bed facies, and tourmaline bearing albite schists. These features lead to the conclusion that the rocks are the metamorphosed derivatives of a greywache type of sedimentation of a subsiding geosynclinal

region.

Obervations are made on the origin of albite schists on the basis of the field occurrence, petrography, and the comparison of a new analysis of an albite schist from Raheenbarr with other soda rich metasediments and unaltered sediments. In this region the rocks are regarded as the simple recrystallization products of an original sediment with only small scale migration of ions and no introduction of material from outside sources.

The Glenisland, Raheenbarr, and Windy Gap groups are intruded by epidiorites, of which the main type is fine grained; coarse grained areas also occur. They are frquently sheared and show lenticular structures with slickensided surfaces. Along the margins of the fine epidiorite with the coarse areas small spherical or nearly spherical structures are found composed largely of epidote (pistacite) and albite. It is suggested that they represent original amygdals. A new chemical analysis is presented together wiht comparable analyses of epidiorites from the Scottish Dalradian and also unmetamorphosed dolerites.

The line of junction of the Dalradian rocks with the Moine type rocks of the Ox Mountains is one of considerable dislocation and is termed the Conloon Fault. It is essentially sinistral in character and possesses a band of crushing and contortion up to 200 yards in width. As this line is approached from the Dalradian side (west), there is evidence of increased shearing, especially in the northern part of the Commauns-Shanvoley group.

The lowest grade of metamorphism is seen in the Ardvarne group which lies within the chlorite zone. The Glenisland and Commauns-Shanvoley groups belong to the biotite zone, while the Raheenbarr group just reaches the garnet isograd. Garnet is also abundant in the Derryharriff and Windy Gap groups.

Three distinct periods of movement are recognized, all of post regional metamorphic age. The earliest stage is demonstrated by shearing in the Commauns-Shanvoley group, which from the evidence of slickensiding took place in a N.E.-S.W.direction. This was succeeded by thrusting in a N.W.-S.E. direction which has brought the Windy Gap, Raheenbarr, and Glenisland groups to rest on top of the groups to the east. The last episode was post Old Red Sandstone and pre Carboniferous Limestone sinistral faulting in a N.N.E.-S.S.W. direction which cut the region up into fault blocks. The age of the Conloon Fault is known for certain, but is definitely pre Carboniferous Limestone. It cuts off one post Old Red Sandstone fault and may represent a late stage of the same movement.

The Ox Mountains consist of psammitic and semi-pelitic schists with intercalated pelitic bands lying within the sillimanite zone of regional metamorphism flanking the central core of the diapiric Ox Mountain Granite Gneiss with its associated Hornblende Orthogneiss.

STRATIGRAPHICAL AND TECTONIC INVESTIGATIONS

IN THE

SCHISTS OF CO. MAYO, EIRE.

by

Arnold Edward Currall B.A., F.G.S.

Keble College.

Thesis submitted for the degree of D.Phil. in the University of Oxford.



Dalradian Schist country looking north from Ardvarne. To the west (left) Burren, O.R.S., to the centre Sheeans Hill, epidiorite, and to the east (right) Farbreiga, Shanvoley Schists, with Nephin, quartzite, in the distance.

TABLE OF CONTENTS.

		Page.
	Acknowledgements.	1
	The grid.	2
I.	Introduction.	3
II.	Previous investigation.	6
III.	Castlebar Dalradian Rocks.	8
A.	Field Occurrence and Petrography of metasediments.	8
	1. Introduction.	8
	2. Glenisland Group.	9
	3. Raheenbarr Group.	28
	4. Windy Gap Group.	48
	5. Derryharriff Group.	63
	6. Commauns - Shanvoley Group.	70
	7. Ardvarne Group.	86
B.	Field Occurrence and Petrography of meta-igneous rocks.	98
	1. Introduction.	98
	2. Epidiorites.	98
C.	Metamorphism of Castlebar Dalradian Rocks.	116
D.	Observations on the origin of albite schists.	119
E.	Tectonics of Castlebar Dalradian Rocks.	124
IV.	Conloon Fault Zone.	129
V.	Ox Mountain Succession.	132
A.	Paragneisses.	132
B.	Orthogneisses.	150
VI.	Old Red Sandstone.	153
VII.	Carboniferous Limestone.	159
VIII.	Post Carboniferous Igneous Rocks.	161
IX.	General Structure and Metamorphism.	163
X.	References.	166

ACKNOWLEDGEMENTS

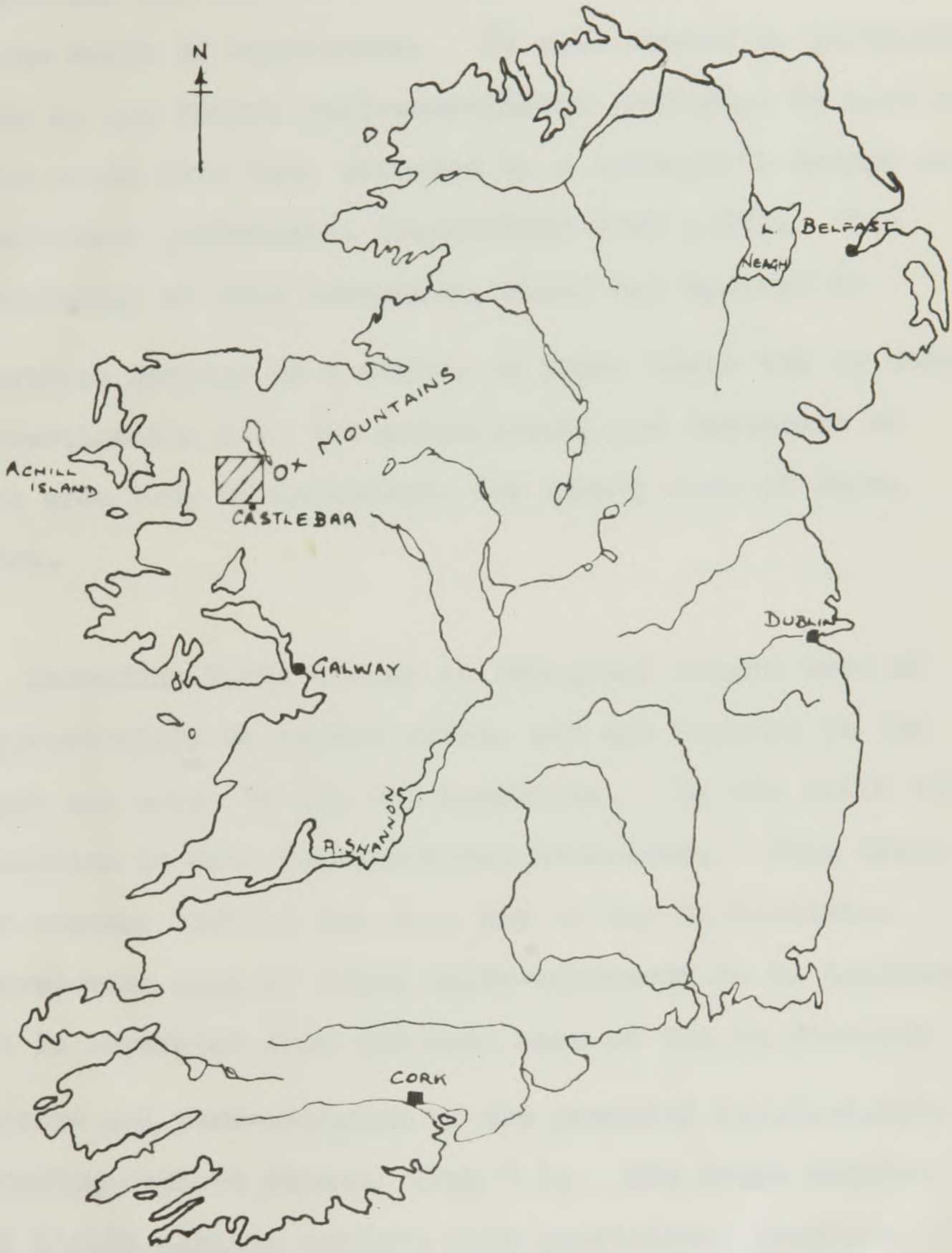
The writer wishes to record his thanks to his supervisor Professor L.R. Wager, F.R.S., who at all times has given constructive criticism and guidance. To Professor J.G.C. Anderson, he is indebted for first suggesting this region as an area of investigation, and to Dr. E.A. Vincent, for two new analyses.

Thanks are also due to Professor L.R. Moore, who has freely given encouragement and facilities for study, and to Emeritus Professor B.M. Laing, for reading and suggesting improvements to the manuscript. Acknowledgement is also due to many others, especially the writer's father, Mr. E.P. Currall, who has redrawn all the maps, and the Director of the Geological Survey of Ireland for facilities to examine field maps.

The initial part of the investigation was carried out in the Dept. of Geology and Mineralogy, University of Oxford, and completed in the Dept. of Geology, University of Sheffield. The work has been made possible by the award of a Burdett-Coutts Scholarship of the University of Oxford, and by grants from the Research Fund of the University of Sheffield, which are gratefully acknowledged.

THE GRID

The general absence of useable place names apart from those of the townlands on the 6" ordnance survey maps, made the use of a grid reference system necessary for the accurate location of exposures. The National Grid System of England, Scotland and Wales has its point of origin S.W. of Land's End. It was found inconvenient to extend this grid westwards, because of the resultant distortion between the lines of longitude and the N-S grid lines. Therefore a local grid for the area was constructed on the 6" scale, having its point of origin 5.25 miles bearing 237° from Christ Church tower in Castlebar. The grid is based on 1 mile squares, which are divided into tenths. It has been found serviceable, but suffers from the defect that, not being based on the metric system, the smallest squares are 176 yards square, an inconvenient unit in field estimations.



GENERAL MAP OF IRELAND. 1:2,500,000.

INTRODUCTION.

Dalradian rocks have attracted workers since Macculloch's challenging remarks 'the rocks are few, and it is easy to learn to recognise them; there is nothing which any man may not attain on this narrow subject, with a few weeks of experience. It will confer no particular fame on any future self-constituted geologist to have done what could have been effected by a surveyor's drudge or a Scottish quarryman'. (Macculloch 1836 p.17). The inaccuracy of this statement, which was applied to Scottish geology as a whole, is amply borne out by this investigation into the stratigraphy and tectonics of the area N.W. of Castlebar, the county town of Mayo, Eire.

Dalradian rocks occupy an irregular shaped area of approximately 20 square miles, and are bounded to the west and north by Old Red Sandstone. To the south the junction is with Carboniferous Limestone. This tract of country lies at the S.W. end of the Ox Mountains stretching some 60 miles north-eastwards to Co. Leitrim. It is separated from the main mass of the Ox Mountain ortho- and para-gneisses by the powerful N.N.E.-S.S.W. trending Conloon fault. (Map 4). The rocks consist of highly albitic schists with quartzites, graphite schists, quartzo-feldspathic schists, thin limestones, and pebbly grits and phyllites, which range in their degree of alteration from the chlorite to the garnet grade of regional metamorphism. They are similar to the Dalradian of the South-West Highlands of Scotland

and will therefore be known as the Castlebar Dalradian Rocks. They are distinct from the Ox Mountain Series which on account of their predominantly psammitic and semi-pelitic character with associated calc-silicate ribs are tentatively regarded as Moinian. (c.f. Anderson 1947).

Structurally the region is one of some complexity. N.E.-S.W. and N.N.E.-S.S.W. trending faults of post-Old Red Sandstone and pre-Carboniferous age split it up into fault blocks which are both lithologically and structurally dissimilar. An earlier episode of movement is demonstrated by the presence of sheared schists in the northern half of the area, together with evidence of thrusting in a N.W.-S.E. direction in the Windy Gap region.

The dating of the earth movements is possible by mapping of the Old Red Sandstone and Lower Carboniferous rocks which overstep or show a faulted relationship to the Dalradian.

The field evidence suggests that the Ox Mountains represented a landmass in Lower Carboniferous time against which thin basal quartzites passing up through sandy limestones into normal crinoidal limestones were laid down. This is also supported on palaeontological grounds (George in discussion of Oswald 1955).

Immediately N.W. of Castlebar the ground occupied by the Old Red Sandstone and Dalradian rocks rises steadily to 1400' from the Carboniferous Limestone lowland to the south. The topography is irregular due to glaciation, and below 500' the ground is covered by drumlins, moraines, and

glacial drift. The line of the Conloon Fault marks the western edge of a southward retreating ice-lobe, which has resulted in the Lough Conn depression occupied by the Ox Mountain Series. (Charlesworth, 1928, p.105).

The region, although surveyed by Symes in 1870, has not been since re-investigated, except for two revisions by the Geological Survey as mentioned in the next section. The original survey shows considerable accuracy and tribute is due to Symes' pioneer work of the period before petrological studies were shown to be of assistance in mapping metamorphic terrain.

PREVIOUS INVESTIGATION.

The earliest account of the geology of this part of Co. Mayo is to be found in the Explanatory Memoir of the Geological Survey of Ireland accompanying Sheet 75, by Richard Symes (1872). The account is largely superficial and confined to a description of a few striking rock types. He suggests that the main structure of the metamorphic rocks of the area is a basin with the quartzites of Raheenbarr hill forming the uppermost beds (p.24). No serious attempt is made to formulate a succession. However it is noteworthy that Symes recognised the presence of a powerful N.N.E. trending fault separating the less metamorphosed rocks on the western side from the more highly altered successions to the east. Geikie (1893)however was of the opinion that this junction was the outcrop of an unconformity between the Dalradian and the underlying Ox Mountain gneisses, which he considered to be Lewisian in character. He also considered these to be comparable with the Lewisian of Sutherland and Ross-shire, and to represent "an ancient axis of eruptive rocks which have undergone more or less mechanical deformation".

Kinaghan in his Geology of Ireland regarded the Ox Mountains as being metamorphosed Cambro-Silurian (Ordovician). By "Ox Mountains" he is referring not only to the Ox Mountain series, but also to the Castlebar Dalradian rocks.

This opinion was also put forward by M'Henry (1903) who supported the contention by claiming that the black schists are similar to fossiliferous Llandeilo. He acknowledged that "the metamorphism may be due in part to dynamic metamorphism", because he found that "quartz pebbles have been crushed and drawn out -- --- into riband-like forms". p. 373.

In addition M'Henry recognised the importance of post Old Red Sandstone movements, in the Windy Gap region where Old Red Sandstone is thrust over metamorphics with the formation of a 40' crush breccia of fragments of both series. He goes on to comment that "in the Fanad area, Donegal, to the north of Knockalla Mountain, we find metamorphosed sediment (quartzite) overthrust onto Old Red Sandstone with a zone of crush breccia along the line of movement, the direction of the overthrust being to the N.W., here again proving the occurence of great earth stresses in post Old Red Sandstone time". p. 376.

Kilroe (1907) critically analyses previous conclusions. In particular he expresses disagreement with Geikie on the nature of the junction between the Dalradian and the Ox Mountain gneisses. Nevertheless it may be pointed out that Symes on his original field map, mapped the junction as a fault.

It is to be regretted that some of the conclusions of the earlier workers were spoilt by a controversy, which as Bishopp (1950) says "has never been ventilated". Symes mapped the conglomerates bounding the schists as Old Red Sandstone but described them in his memoir (1872) as Silurian. They were also represented on the 1" map published in 1870 as Silurian. Kilroe (1907), however, without explanation "tacitly substituted Old Red Sandstone for Silurian", on his map. Bishopp (1950) discussed the age of these sandstones and conglomerates and on tectonic grounds supports Symes' original conclusion that they are Old Red Sandstone.

III. CASTLEBAR DALRADIAN ROCKS.

A. Field Occurrence and Petrography of Metasediments.

1. Introduction.

The metamorphic rocks of this area lying west of the Conloon fault are for the most part of sedimentary origin. In their diversity of type they may be compared with similar rocks from the South West Highlands of Scotland. They can be divided into six main groups separated by major faults or thrusts, all following a N.E.-S.W. trend. Each group is distinct in its lithology, structure, and degree of metamorphism indicating that the powerful movements initiating these dislocations are post-metamorphic and post-folding in age. It has therefore not been possible to correlate the metasediments of the individual groups, nor to deduce a stratigraphical order for the area as a whole.

The groups are as follows, from west to east, see map No. 2.

GLENISLAND GROUP.	(Glenisland quartzites and mica schists. Green Beds Brockagh grits and chloritoid schists. Lough Cashel schists.)	stratigraphical order based on current and graded bedding.
RAHEENBARR GROUP.	(Albite granulite Raheenbarr quartzite Albite schists Raheenbarr grits)	stratigraphical order based on current and graded bedding.
WINDY GAP GROUP.	(Black schist Limestone Garnet mica schist.	

DERRYHARRIFF GROUP.	Derryharriff mica schists.	
COMMAUNS- SHANVOLEY GROUP.	(Commauns schists) (Shanvoley schists)	stratigraphical order uncertain.
ARDVARNE GROUP.	(Ardvarne grits and (phyllites.	

The groups have been named after the more important townlands.

The absence of traceable horizons, and evidence of repetition due to folding, make any determination of thicknesses in the Greenans-Derryharriff, and Ardvarne groups difficult.

2. GLENISLAND GROUP.

Glenisland quartzites and mica schists.	Stratigraphical
Green Beds	order based on
Brockagh grits and chloritoid schists.	current & graded
Lough Cashel schists.	bedding.

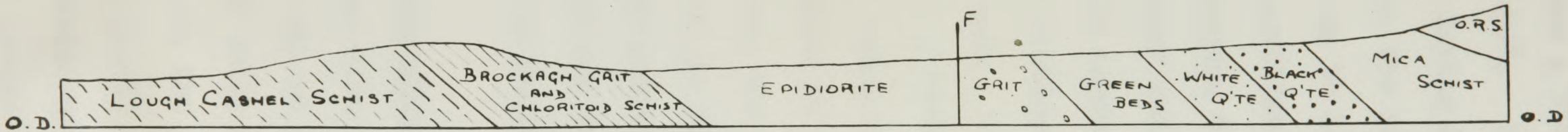
Field occurrence.

The Glenisland group is comparatively well exposed on the higher ground round Drumminaguncan and Monagarraun. The lower part of the group is also well exposed in a section of the Brockagh river (between G.R.058468 and 088492), whilst another stream section a mile east of Glenisland post office shows the upper part (between G.R. 100623 and 125633). The intervening areas are concealed by peat bog which overlies glacial debris.

The sequence dips steadily to the east and contains a thick sill like mass of Epidiorite, the eastern margin of which is faulted against grits. (section 1).

S.W.
033515

N.E.
145600



SCALE: 6" TO 1 MILE

SECTION THROUGH GLENISLAND GROUP.

SECTION 1.

Lough Cashel schists.

The best exposures of The Lough Cashel schists lie immediately to the west of the Lough Mallard-Glenisland road, where they show a NNW.-SSE. strike, dipping eastwards at between 35° and 55°. They are predominantly feldspathic with abundant mica giving a well developed schistosity, and are characterized by the presence of abundant black tourmaline needles up to 1cm. in length. The group varies from a semi-pelitic schist showing the sporadic development of feldspar, to a highly micaceous schist with abundant feldspar and a good strain slip cleavage, with thin grit bands occurring with the semi-pelitic parts. These are of local development and are rarely traceable for more than 100 yds. Within a steep bank beside a track (G.R. 049497) a semi-pelitic schist outcrops with micaceous bands 1" thick which are rich in tourmaline. It is crumpled because of the variable competence of the two parts on folding, and forms a useful horizon for about a ¼ mile after which it passes laterally into a more normal schist. Irregular quartz veining is present throughout but particularly in the Brockagh river section where the Old Red Sandstone is faulted against the schists.

Brockagh grits and chloritoid schists.

Their junction with the Lough Cashel schists, although not actually seen may be plotted with some accuracy in a narrow steep sided gully running parallel with the road (G.R. 170503), where the grit bands appear to follow conformably. This highly siliceous grit group shows considerable variation in grain size, from a fine grained rock to a coarse, pebbly grit consisting of roughly equidimensional grains set in a fine grained and micaceous matrix. The quartz grains are mostly white although grains of a bluish colour are not uncommon. Feldspar is invariably present among the larger grains. There are two

course bands traceable in the Drumminaguncan region separated by finer siliceous sediments which are often interbedded with bands of pelitic material. Repeated graded bedding from coarse to fine grits occurs showing the beds to be the right way up. Current bedding gives further evidence of "way up" (G.R. 072549).

Other structures of probable sedimentary origin are to be seen in a bluff of fine grits (G.R. 062528) (see fig. 1) where over folds and cut off structures are cut across by the schistosity which elsewhere is coincident with the bedding. They are interpreted as slump structures. At the same horizon nearby detached fragments of coarser material up to 2"-3" long are found set in the finer matrix of the rock. Similar structures less well developed occur throughout the series. Although not so extensive these structures may be compared with similar structures described by Sutton and Watson from the Upper Dalradian of Banffshire (1955). There they have described such contortions, similar to those ascribed by Kuenen and his workers, to slumping, and movement of unconsolidated sediments on a shelving floor accompanied by turbidity currents.

Upwards the series becomes increasingly micaceous and green in colour. A 50' scarp facing east, 200 yards west of the small lake (G.R. 180550), and dying out southwards, marks the passage from the grits into these more schistose rocks, in which minor folds are present whose axes plunge SE. These greenish schists represent the highest beds of the western part of the Glenisland succession. They are followed without signs of transgression, except in the south, by a thick mass of an albitic epidicrite, a description of which will appear later in this work. The relationship of this mass to a small exposure of a quartz mica schist south of the Brockagh river at 117495 indicates





Strike view of bluff
containing slump
structures.



Fig. 1.

Slump structures in Brockagh Grits (G.R. 062528).

possible transgression, but absence of any exposures northwards makes the further determination of field relationships impossible. To the north round Monagarraun, in a narrow gully running NNW-SSE (G.R.095695) evidence of crushing in coarse grits suggests that the eastern limit of the epidiorites is a fault boundary.

A band at least 200' thick of pebbly grits showing a similar range in grain size to those around Drumminagucan, and with the same easterly dip of 45° is exposed in stream sections and in the peat bog to the east of the epidiorite (G.R. 105572 - 108585) where one example of graded bedding shows fine grits passing upwards into coarser grits. In the absence of other examples, this case is not regarded as reliable. (Shrock 1948 p.81).

Green Beds.

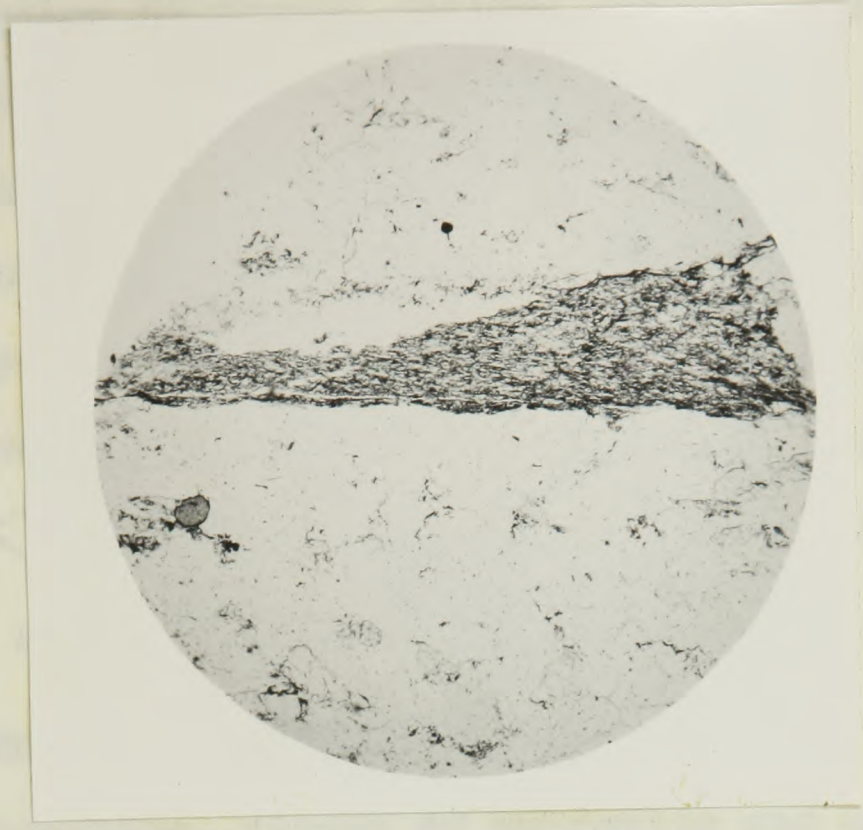
Highly epidotic and chloritic green schists succeed the Brockagh grits and are exposed in the stream section G.R. 100623 - 125633, together with a few isolated exposures in the bog to the south. The evidence for terming these green schists, Green Beds after the Scottish terminology will be discussed under their petrography. The strike of the beds is N - S, with a dip varying from 30° - 80° E. They are compact rocks in which quartz, feldspar and mica are conspicuous.

Glenisland Quartzites and Mica Schists.

20 yards upstream from the Green Beds a micaceous, flaggy quartzite, dipping 45° E outcrops at the base of a series of waterfalls. It consists of alternating layers of quartz, usually ¼" thick, with very thin laminae of a greenish mica. This passes upwards into a more compact white quartzite practically devoid of mica. There is a total thickness of some 300' of quartzite which varies in colour between white and black depending on the

amount of finely divided graphite which is present. In one thin band towards the top small parallel sided structures occur with black edges, at least 1cm. in length and probably longer. In thin section (M 212) their margin is seen to be marked by a thin line of fine, clear quartz, while the interior consists of an aggregate of fine angular quartz grains, muscovite flakes, and graphite. (Fig. 2). It is suggested that these may represent burrows of worms or boring organisms infilled by a fine silt.

The top of the sequence is marked by a grey conglomeratic band containing subangular to rounded fragments of grey quartzite set in a similar matrix. Its upper junction is sharp, and is succeeded by an extremely fissile and soft graphitic schist, which in turn passes into graphitic feldspar schists which are seen in a small stream (G.R. 125622). Further up the same stream section these pass into biotite bearing schists (G.R. 129615), which are also exposed in isolated patches on the higher ground half a mile south. These represent the uppermost part of the Glenisland succession.



Ordinary light x 10



Crossed nicols x 10

Fig. 2.

Worm burrows in Glenisland quartzite (Specimen M212).

Petrography.

Lough Cashel Schists.

These medium to coarse grained schists are composed largely of albite feldspar, muscovite, biotite largely altered to penninite chlorite, quartz and tourmaline. Bands in which feldspar is particularly abundant are more compact and poorly schitose than the more siliceous or micaceous bands. The feldspar lies within the albite range (R.I. < R.I. Canada Balsam, optically positive) and normally has develcped as porphyroblasts with ragged edges up to 2mm in diameter, in which lines of inclusions of quartz, magnetite, flakes of muscovite and chlorite are arranged parallel to the schistosity. In a few cases there is evidence, given by lines of dusty inclusions, of rolling during formation. This rolling seems to be particularly associated with the more siliceous bands in which thin layers of quartz, rarely more than 1mm thick, are separated by micaceous laminae.

In material M337 from the tourmaline rich band (G.R. 049497) two distinct layers are present, one consisting entirely of muscovite and square grains of albite and tourmaline, with a little biotite going to chlorite, the other consisting of quartz, irregular shaped grains of albite with inclusions of muscovite, chlorite and quartz, biotite, scattered rods of tourmaline, apatite and sphene. The junction between them is sharp, and characterized by a messy fine grained matrix of quartz, biotite altering to chlorite, and large tourmaline rods. Lines of fine dusty inclusions run through the grains of tourmaline and albite in this band and may be traced with difficulty into the surrounding muscovite flakes. (Figs. 3A,3B,&4A). The majority appear dark and opaque, but some may be seen to be dark, yellow-brown, rounded ended rods, or circular blobs. (Fig. 4B.). Their high relief makes them stand out in the feldspar, whereas they are



Fig. 3A. Zig-zag carbonaceous inclusions in albite indicating pre-crystallization deformation. Lough Cashel Schists. Specimen M237. Ordinary light x 20.



Fig. 3B. Carbonaceous inclusions passing through albite into tourmaline indicating pre-crystallization deformation. Lough Cashel Schists. Specimen M237. Ordinary light x 20.



Fig. 4A. Carbonaceous inclusions in albite showing post-crystallization movement. Lough Cashel Schist. Specimen M237. Ordinary light x 20.

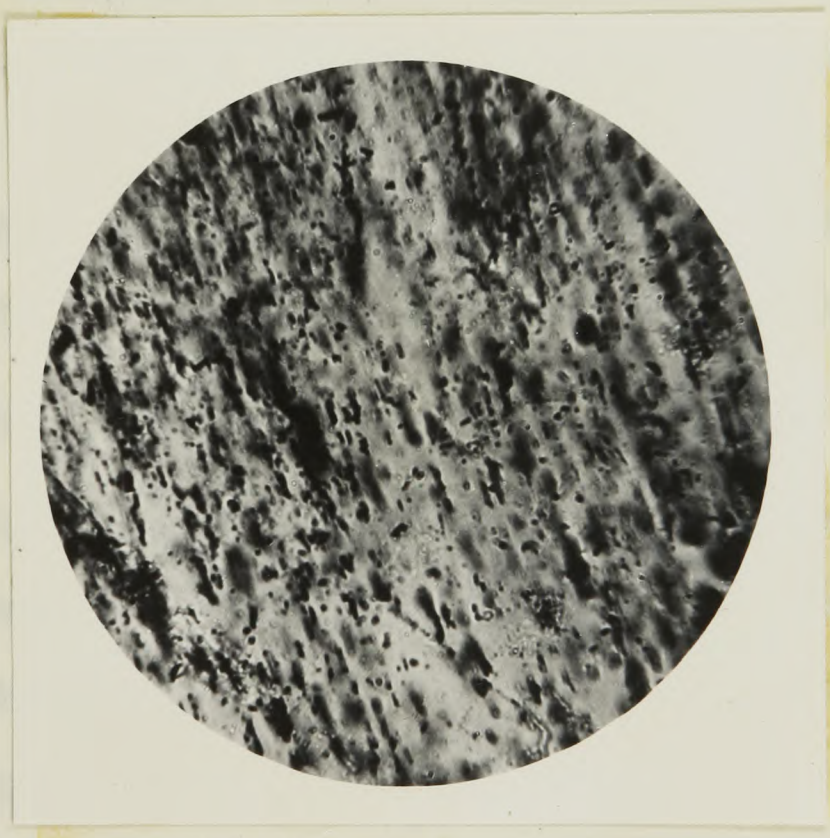


Fig. 4B. Carbonaceous inclusions in albite. Lough Cashel Schist. Specimen M237. Ordinary light x 300.

partially obscured in the muscovite owing to its combination of high relief and cleavage. Despite this they do not appear to be as numerous within the muscovite. Their identity has not been determined but similar inclusions in the Glenisland quartzite are almost certainly carbonaceous. Their arrangement is unrelated to the schistosity and often shows sharp folding. (Fig. 3A). They have clearly resulted from pre-crystalline deformation. In some cases, however, these lines of inclusions pass from one albite grain into another or into grains of tourmaline, whilst in others the lines show sharp junctions across grains as a result of post crystalline deformation. (c.f. Turner and Verhoogen 1951 p.525). This feature may be observed in the hand specimen where a thin quartz vein is seen to be sheared.

Throughout these schists tourmaline is found in association with a variety of other minerals, muscovite, quartz, and albite, and does not show any evidence of having been formed at their expense. It is distinctly zoned, with a bluish-green core, becoming brown towards the outside, and it is strongly pleochroic , blue to green and yellow-brown to very pale straw. Harker (1932) p.117 notes that "blue colours in tourmaline are probably related to a noteworthy content of soda, and are much less common in metamorphised rocks than in granites". Although no analyses have been made of these tourmaline feldspar schists it would seem reasonable to suggest that the abundance of albite indicates a percentage of soda greater than that normally associated with argillaceous sediments, and as a result one might expect tourmaline also to reflect this property. Tourmaline has been noted as a common accessory mineral in many of the schists of the S.W. Highlands and also in Northern Ireland. Clough (1897)

remarks on the association of albite and tourmaline in Cowal and says (p.45) "tourmaline prisms are more common in the albite and more micaceous schists than in the quartzose, but they do occasionally occur in the latter". This observation is fully borne out by the Lough Cashel schists, although in some thin sections of albite schists from Lochgoilhead (Argyllshire) seen by the writer, tourmaline is present in very much smaller amounts. In the tourmaline schists of Glenelly in the Sperrin mountains of Northern Ireland Hartley (1935) records abundant tourmaline in association with albite and muscovite, and suggests (p.152) that it is "of definite stratigraphical value" as he considers it to be "inherent in the composition of the original mud from which these schists were derived".

In the case of the Lough Cashel schists, since igneous activity is absent from the region as a whole, there seems to be no reason to doubt that the original sediment was sufficiently rich in boron to account for the development of tourmaline from it.

Biotite is a common constituent right through the series and although in the more pelitic bands it shows a preferred orientation, this is absent in the semi-pelitic parts. It is a dirty brown in colour and invariably shows signs of alteration to a penninite chlorite, (pleochroic Y=green, Z=very pale yellow green, anomalous interference colours, +ve with small 2v). In many cases the alteration is complete.

The uniformity of the interference colours of the muscovite, e.g. M237, shows that in addition to the high degree of preferred orientation of the flags, there is also a high degree of preferred optical orientation.

Quartz, in addition to occurring as thin layers, also occurs as small lenses e.g. M235, probably representing

relics of the more arenaceous part of the original sediment.

Brockragh grits and chloritoid schists.

The grits as a whole are poorly sorted both with regard to grain size and mineral constituents. Quartz pebbles ranging in size from 2 to 10mm make up the main part of the large fragments. Amongst the quartz there is a small proportion of a blue opalescent variety which in thin section contains abundant minute inclusions. The occurrence of a similar type of quartz from various parts of the Upper Dalradian of the Scottish Highlands has been noted by several workers (Anderson 1947, Hill 1905, Sutton and Watson 1955). Sutton and Watson comment (p.129) that the Lewisian pyroxene gneisses of the N.W. Highlands, the petrography of which has been described by Teall (1907), are the only known British rocks in which blue quartz is found. The next most abundant pebbles are of a feldspar, which although showing multiple twining, is usually in an advanced state of serecitization. Maximum symmetrical extinction angles of 6^{o} indicate oligoclase. These pebbles are clastic and are set in a fine grained matrix of recrystallized quartz, muscovite, and biotite, in the main altered to penninite chlorite (pleochroic green-pale straw, 2v small, +ve). Their margins have been in part crushed due to shearing. The shear planes are marked by limonite staining and run obliquely across the schistosity.

The green micaceous chloritoid schists which succeed the pebbly grits proper show greater evidence of recrystallization. Original small quartz pebbles have recrystallized as small quartz lenses 1-2mm in length, composed of up to a dozen grains. These are scattered throughout a matrix composed of thin bands of quartz separated by a felt-like mass of short muscovite flakes forming approximately a quarter of the rock, and giving it its schistosity. Penninite chlorite (pleochroic light-dark

green, with anomalous blue and purple interference colours) is also abundant. Scattered flakes of chloritoid, irregularly oriented with respect to the schistosity, up to .6mm long and with ragged terminations, are found throughout the series (M219 and M223) (Fig. 5). Where the flakes are thick enough a good basal cleavage is seen. The mineral is pleochroic:- X= pale green-blue, Y= blue, Z= colourless or pale yellow. There are a few small grains of albite enclosing fine grains of quartz. Biotite is noticeably absent. Pyrite also occurs. The presence of chloritoid indicates "an abundance of alumina, sufficient iron, and a dificiency in magnesia, lime, and potash". (Harker 1952, p.213). The development of chloritoid is thus dependent on a peculiar chemical composition of the original sediment. Its presence is not common in the Dalradian in Scotland, but has been described by Barrow from a 22 mile belt of chloritoid schists running parallel to the Highland Boundary fault, S.W. from near Stonehaven. "It occurs in a highly chloritic green greywacke consisting of a felt of white mica and chlorite, associated with considerable quartz and very little feldspar". The associated beds are schistose pebbly grits. Thus the general character and association of the Kincardineshire rocks is similar to that developed here.

Green Beds.

Schists whose chemical composition suggests derivation from basic igneous rocks have long been known from the Dalradian of Scotland and termed Green Beds (Clough 1897).

Mineralogically they show considerable variation even within the same zone of metamorphism. In the chlorite zone they are essentially chlorite-albite-epidote schists, in which the amount of epidote is the biggest variable. Quartz is normally present and frequently occurs as lenticular



Fig. 5. Chloritoid schist.

Specimen M223. Ordinary light x 20

patches representing original quartz pebbles (Phillips 1930, p. 244). Phillips also notes that biotite makes its appearance in a green form well before the normal biotite isograd of pelitic beds. This with increase in grade becomes brown. He further observes that chlorite may persist in the more pelitic type of rock but is rare in the more gritty varieties. "Yellow epidote, forming granular aggregates and well formed crystals tend to occur between the more quartzose patches". Albite is also an abundant mineral, forming rounded porphyroblasts.

Beds of essentially this character occur in the stream section G.R. 108023, and are termed Green Beds. They are medium grained, compact, green rocks, showing a variable development of albite feldspar, and may be called chlorite-biotite-albite-epidote-schists. Some parts are definitely more siliceous than others. The more micaceous parts show a poorly defined lineation, but a well marked schistosity due to the orientation of muscovite and chlorite flakes. Specimen M1084 (G.R. 108023) is a highly micaceous type. Albite is developed as abundant rounded porphyroblastic grains enclosing quartz, epidote, and apatite. It is mainly untwinned although occasional simple twins do occur, while some irregular shaped grains possess a cloudy central area of fine inclusions. The amount of quartz shows considerable variation in different parts of the single slice, but it is not arranged in any definite bands, although small lenticular patches indicate probable original pebbles. Where present as inclusions in the albite it frequently appears elongate parallel to the schistosity. Yellowish epidote is very abundant as long, thin laths in the case of the inclusions in Albite, or as larger stumpy grains showing strong interference colours in the ground mass. Muscovite is restricted

mainly to the ground mass either as large individual flakes or as aggregates, but small flakes are present in the albite. There appear to be two varieties of chlorite present both pleochroic light straw to dark green. The first is slightly cloudy, and a slightly darker shade than the other. It contains small inclusions of iron, shows anomalous blue interference colours, and is optically +ve with small 2v. Frequently biotite is still preserved in the same flake, indicating that it is retrograde chlorite. The second is clear and contains no inclusions of iron. Its interference colours are anomalous brown-greens. It is probably original chlorite. Both muscovite and chlorite show a high degree of preferred orientation.

In the more siliceous Green beds (M263) epidote is not so abundant and is associated with lenticular patches of quartz consisting of recrystallized aggregates representing original quartz pebbles.

Glenisland quartzites and mica schists.

Flaggy quartzite

The lowest beds of this series are siliceous schists consisting of thin layers of quartz (up to 2mm in thickness), laminated by thin wafer bands of white and greenish mica.

The green muscovite has the following optical properties :-

Pleochroic X colourless
Y very pale green
Z very pale green

(-) 2V c. 30°

R.I. N_X 1.560 $N_Z - N_X$ = 0.037
N_Y 1.592
N_Z 1.597

The values for N_X has been interpolated from that of N_Z by use of the Berek compensator to determine the maximum

interference colours in sections at right angles to 001. According to Winchell (1951) on the basis of the above optical properties it is rich in the picrophengite molecule.

Phillips 1930 p.244 comments on the presence of a very pale green mica in the chlorite zone of the Green Beds. The remainder of the rock is composed of a roughly equigranular aggregate of quartz with scattered grains of apatite, sphene, and pyrite which occurs as single, subhedral grains, or as irregular aggregates.

White and Black quartzite.

Mention has already been made of the small parallel-sided structures occuring in the graphitic part of the quartzite succession, which are regarded as worm burrows. In thin section (M212) the main mass of the quartz has been recrystallized with the original bedding shown up by lines of graphitic inclusions. These frequently occur as bands .25mm thick. In addition, graphitic material is also associated with small micaceous aggregates which are present throughout the rock. The association is similar to that within the worm burrows, and represents small mud blobs scattered through an otherwise pure quartz sand. Both the white and black quartzite consists entirely of quartz with variable small amounts of muscovite. Feldspar is noticeably absent.

Graphitic-quartz-albite-muscovite schist.

These beds are essentially quartzose schists in which a strain slip cleavage is developed (M213). Small irregular lens shaped patches of quartz, which is clear or crowded with graphitic inclusions, representing recrystallized pebbles, are set in a fine grained matrix of muscovite, quartz, and abundant subhedral grains of pyrite. Running through are lines of graphitic inclusions

showing considerable folding. Small rounded albite porphyroblasts in varying stages of development also occur in the matrix showing the lines of graphitic inclusions. The development of a strain slip cleavage together with some shearing is expressed in the alignment of the graphitic inclusions as well as in the orientation of the muscovite.

In the more feldspathic bands strain slip cleavages are absent and the bedding is clarified by parallel lines of inclusions of quartz and graphitic material running through the albite porphyroblasts, which frequently compose the main part of the thin section (M214). These show no evidence of rotation during growth. A few remnant flakes of biotite are also present but for the most part it is completely altered to penninite chlorite.

Micaceous green feldspathic schist.

These rocks, which succeed the graphitic schists, are similar to them, with the exception that there is very little graphitic material present. Albite porphyroblasts having irregular margins and showing poeciloblastic texture with respect to quartz and muscovite are present.

Two types of chlorite are present as in the case of the green beds. The first is a penninite chlorite, pleochroic pale brown-green to medium green, and showing anomalous blue interference colours. It has a very small 2v and may be either +ve or -ve. Small iron ore inclusions are abundant. Biotite frequently forms part of the same flake and this form is therefore regarded as retrograde after biotite. The second type is clear and free of inclusions, being pleochroic, colourless to very pale green, and showing anomalous brown interference colours. This form is regarded as being primary chlorite.

3. RAHEENBARR GROUP.

Albite granulite.

Raheenbarr Quartzite.

Albite schists.

Raheenbarr grit. stratigraphical order based on graded bedding.

Field occurrence.

The Raheenbarr group which lies immediately east of the Glenisland group is bounded to the west by the Lough Boy fault along the line of which a south west flowing stream has cut a steep sided gully, and to the east by the southward continuation of the Sheeans thrust whose boundary is marked by a slight change in slope just west of another south west flowing stream. The structure at this eastern margin is further complicated by a roughly parallel fault running through the steep gully along the east of Raheenbarr Hill.(Fig. 6A, B, & C.).

The main strike of the sediments is from 5° E. of N. to 5° W. of S. except in the north east corner where the strike becomes N.N.W.-S.S.E.. Evidence from the grit series shows that the dip and strike of the schistosity is coincidental with that of the bedding. The area is best exposed on the southern slopes of Raheenbarr Hill. Further south the succession is obscured by peat bog and thick glacial drift through which the streams do not cut. The western half of the Raheenbarr group consists of an albitic epidiorite, which will be discussed later in the section on Epidiorites.

Raheenbarr Grit.

The relationship between these pebbly grits and the albitic epidiorites lying apparently structurally below them is uncertain and will be discussed under the structure. The boundary is however transgressive to the bedding of



Fig. 6A. Raheenbarr Hill from the south.



Fig. 6B. Raheenbarr Hill from the south.



Fig. 6C. Raheenbarr fault line, running through steep sided gully, immediately east of Raheenbarr Hill.

the pebbly grits, and mapping on the scale 18" to 1 mile shows that the junction is most likely to be a faulted one since there are signs of brecciation occurring in the steep edge of the epidiorite bordering the boggy hollow separating the two rock types.

A thickness of approximately 800' of Raheenbarr grit is exposed. The main body of the succession is a series of medium to fine grained arenaceous sediments with an invariably micaceous matrix in which coarse pebble bands are common. These are characterized by the presence of opalescent blue, disc shaped quartz pebbles up to 5 m.m. across, which lie parallel to the bedding, and whose long dimension is twice the short. They form a very small proportion of the pebbles, the remainder, in order of abundance, being, white quartz, white feldspar, and quartzite. Quartz forms approximately 75% of the pebbles. The coarse bands are traceable over a considerable distance and form useful mapping horizons. Several occurrences of graded bedding (e.g. G.R. 203525) show that the grits young towards the S.E., thereby indicating that the group is the right way up. Occasional thin bands of pelitic material are present though of little lateral extent. The most prominent of these occur towards the bottom of the sequence (G.R. 195583) and approximately 300' above. (G.R. 212553). The sequence does not show any steady decrease in grain size upwards. It is essentially a series of repeated graded beds whose individual thickness shows considerable variation. From the scattered outcrops between the stream sections which run parallel to the strike it would appear that the beds vary from between 6' - 15' in thickness.

Prominent jointing, either vertical or steeply dipping S.W., is present in a N.W.-S.E. direction, whilst a second

set of joints, less well developed, runs approximately at right angles to the first. (Fig. 7A & 7B). Small scale movement has occurred along many of these joints. Thin discontinuous quartz veins are to be found throughout. Zones of brecciation 2' - 3' in width occur parallel to the strike (G.R. 299525 and G.R. 206528), but are not traceable further owing to cover.

In the region round G.R. 2255 a small boss of albitic epidiorite rises steeply from the grits. The schistosity developed in it shows the same direction as that of the grits. Its exact relationship is not certain but is discussed later.

Albite schists.

Albite schists overlie the Raheenbarr grit and show a sharp junction with them which may be traced with accuracy for a short distance 150 yards west of the summit of Raheenbarr Hill. The lowest schist is a micaceous rock in which large porphyroblasts of albite feldspar up to ¼" in diameter are developed parallel to the schistosity, and which show up distinctly on the weathered surface. The lithology is not constant throughout the series and discontinuous lenses of more siliceous albite rocks are found. The more highly micaceous parts show a strain slip cleavage which is responsible for a prominent lineation plunging 50° in a direction 130°, G.R. 245524. (see Fig. 8). This cleavage is absent in the siliceous bands but these have developed minor folds whose axes plunge in the same direction. (G.R. 242526).

Within the upper part of the series a 100' thick band of a compact biotite schist occurs, the schistosity of which can only be distinguished on the well weathered surface. The succeeding albite schist is much more siliceous and less micaceous than the preceeding albite



Fig. 7A. Bedding and cleavage in Raheenbarr Grit. (G.R. 214529).



Fig. 7B. N.W.-S.E. & N.E.-S.W. joints in Raheenbarr grit. (G.R. 214529).



Fig. 8. Strain slip cleavage in albite schist, south slope Raheenbarr Hill. (G.R. 245585).

schist, resulting in a more compact rock better described as an albite granulite. An obliquely transcurrent fault cuts off the top of the series so that the maximum thickness of the albite granulite exposed is approximately 75'. Vertical jointing in a N.W.-S.E. and N.E.-S.W. direction becomes much more pronounced towards the fault.

Beneath the main east facing scarp, Albite granulites also occur above the Raheenbarr quartzites which form a prominent east facing scarp. Within the granulites there is a band of dark green quartzose schist showing the development of an amphibole traceable for some distance. (G.R. 274577). To the east the granulite is cut off by the Raheenbarr fault running N.E.-S.W. up a boggy hollow, which, towards the south, converges on the main mass of the Raheenbarr quartzites, making a prominent N.W. facing fault scarp, resulting in a steep sided gully. (see Fig. 6C). Within this hollow (G.R. 2755), and intruded into the albite granulite is a small felsite boss, running N.E.-S.W. and approximately 200 yds x 50 yds in size. It is poorly exposed and its margins are not seen. There is considerable evidence of disturbance in this area, with isolated outcrops showing much variation in dip and strike. East of the fault there is a small isolated synclinal sheet of pebbly grit similar to that at the base of the Raheenbarr succession (G.R. 2652). It is on the grounds of similar lithology and strike directions, coupled with the fact that epidiorites are not elsewhere associated with the Greenans-Derryharriff group to the east, that this narrow strip is regarded as essentially part of the Raheenbarr group.

Raheenbarr quartzites.

The prominent feature, Raheenbarr Hill, 805', (see

Figs. 6A & 6B), is made up of approximately 1000' of quartzites varying in colour from white to black, depending on the amount of graphite present. These dip 15°-60° eastwards, with a strike which varies between just west of north and just east of north. It is only within the more micaceous parts that distinct minor fold structures are found, and in those that are poorly micaceous the folds are not only less pronounced but have a shallower amplitude. Immediately east of Raheenbarr summit the axes of these plunge 40° N. of E.. Mullion structures are also present (G.R. 249857), lying in the same direction. The quartzite throughout is feldspathic with the feldspar grains weathering to a milky white in the glassy white of the quartz. Vertical joints are well developed, particularly those striking N.W.-S.E. together with a second less prominent set lying at right angles to these. Secondary quartz veins up to 4"thick are common. In the more graphitic parts of the succession these veins have bleached the quartzite for about 6" on either side.

The eastern side of Raheenbarr Hill is marked by a vertical scarp 75'-100' high, striking N.E.-S.W. At the southern end (G.R. 263535) is a large isolated block of black quartzite, 50 yds x 30 yds. in size, whilst to the north east of the main scarp face there is a series of vertical scarps facing 30° west between the 600' and 700' contours. Although these slopes are well covered by heather and bracken, it may easily be shown that they constitute a screelike slope of large quartzite boulders.

Petrography.

Raheenbarr Grits.

The Raheenbarr grits are petrographically similar to those of Glenisland. In the coarser bands however the pebbles tend to be disc shaped rather than equidimensional.

Specimen M1046 from an exposure on the west bank of the stream (G.R. 203525), is typical of the coarse bands. In hand specimen disc shaped quartz and feldspar are set in a finer grained micaceous and chloritic matrix. In the thin section the pebbles show sharp margins with the matrix, this being invariably laminae of pale green muscovite or of dark brown biotite in varying stages of decomposition to penninite chlorite. The quartz pebbles are frequently single crystals showing good strain shadows, together with slight shearing and some recrystallization. Individual pebbles of opalescent blue quartz which have been sectioned all show the presence of minute inclusions which are either round or slightly elongate. The former appear to be predominantly reddish, the latter greenish, and they show no particular orientation. Their nature is of uncertain and comment on their significance will be made later. The few pebbles of elastic feldspar examined also show sharp margins. Despite their advanced state of sericitization multiple twinning can be recognised and maximum symmetrical extinction angles about the 010 twin plane of 9° indicate oligoclase.

The matrix consists of a recrystallized inequigranular mass of quartz, with thin laminae of pale green muscovite biotite, or chlorite.

The finer grained material of the series shows a far greater degree of recrystallization than the coarse. Specimen M1044 from the stream exposure beside a small waterfall ½ ml. S.W. of Raheenbarr Hill (G.R. 205538),

is a pale green schistose rock with thin quartzose bands approximately 1mm thick, separated by micaceous laminae. The slice shows the rock to consist of roughly equidimensional grains of quartz with thin, short laths of pale green muscovite lying in definite layers, as well as scattered throughout. Small patches of feldspathic material 1mm. in diameter are also present, but they are strongly sericitised and their nature is indeterminate.

The pelitic beds belong to the Green Bed type of facies. Typical material (M277) from a small bluff at grid reference 194524 is a medium to coarse grained grey green rock containing white feldspathic blebs. In thin section the rock is distinctly banded, due to layers rich in albitic porphyroblasts separating those containing predominantly quartz, albite, zoisite, biotite and garnet. The albite porphyroblasts of the feldspathic layers are clear, irregular growths containing small inclusions of biotite and zoisite. Twinning is absent and relief is poor as the refractive indices are just below that of Canada Balsam. The margins of the porphyroblasts are marked by thin flakes of dark brown biotite altering to chlorite. These bands grade into the more quartzose layers in which the feldspar is also albite but which is poeciloblastic, enclosing rounded quartz grains, short stubby laths of zoisite, and flakes of muscovite, biotite or chlorite. The colourless grains of zoisite, apart from those in the feldspar porphyroblasts, are irregular in outline and rarely more than 0.25mm. long. They are scattered throughout fairly abundantly. Tourmaline is locally abundant in rods of .5mm. diameter, showing a marked degree of preferred orientation. Dark brown biotite is prominent as aggregates or as individual flakes. Some decomposition to penninite chlorite has occurred. Small hexagonal or square garnets approximately .25mm.

in diameter are abundant. Frequently they are altered to chlorite, the pseudomorphs being easily recognised.

The pebbly grits from the fault breccia exposed along side the wall, ½ mile S.W. of Raheenbarr Hill (G.R. 198535) show fragmentation in which the angular fragments range from 2cms. downwards. The thin section shows the groundmass to be very fine grained, dirty brown and indeterminate. There has been no recrystallization, and the schistosity displayed by each fragment shows random orientation with respect to that of every other.

Albite schists.

Schists rich in albite, occurring mainly on the south west slopes of Raheenbarr hill, show the feldspar weathering out as rounded, pinkish-brown grains, up to 5mm. across, set in a green micaceous matrix.

Specimen M321 from beside the track ½ml. S. of Raheenbarr hill (G.R. 243528), represents typical material of the group. Abundant feldspar porphyroblasts are aligned in roughly parallel rows giving a rude schistosity, and are set in a finer grained matrix, consisting essentially of quartz, penninite chlorite, and muscovite, with small amounts of epidote, apatite, tourmaline, and iron ore. The feldspars are clear, without sign of decomposition, and they contain lines of inclusions which are mainly thin laths and tablets of quartz, epidote (pistacite) and chlorite. Frequently these tend to be located at the centre, a feature noted by Teall, 1897, from the albite schists of Cowal. In contrast to the Cowal rocks however, rotation of the porphyroblasts during growth has not been observed. Their stress nature is shown by the partial forcing out of the micaceous matrix. The composition has been determined by refractive index determination on 001 and 010 cleavage flakes, using the method of Tsuboi (1923). These gave a N_x' value of

1.5295, which indicates a composition of An_{2-4}. Optic axis figures show a high value of 2v and a positive sign. Twinning is normally absent, but when present is simple. (Fig. 9).

The development of quartz is sporadic. Apart from small inclusions in the porphyroblasts it is present as subangular grains in the matrix, either scattered or as local segregations. It is in close association with muscovite and chlorite. The chlorite, which belongs to the penninite series, is pleochroic colourless to pale green, optically positive with a small 2v, and it shows anomalous green-brown interference colours. A small amount of biotite decomposing to chlorite is also present. Pistacite epidote occurs as lozenges of varying size scattered through the rock. Small quantities of irregular grained apatite and subhedral grains of pyrite, decomposing to haematite round their margins, are also present. Scattered small pale pink or colourless garnets, rarely more than 0.25mm. in diameter, occur, and show some alteration to penninite chlorite.

Interbedded with the albite schists, particularly towards the top of the succession, are quartzose bands showing a poor schistosity. Specimen M1050 from a 100 yards north east of M321 is from one such band. It is a medium-fine grained, light grey rock of slightly flaggy appearance. This is confirmed in thin section where it is seen to consist of short sub-lenticular patches of granular quartz separated by thin layers of short muscovite plates. Small pyrites cubes occur throughout, in recrystallized quartz.

The Quartz- albite- chlorite- biotite- garnet- schist occuring as bands within the albite schists, is a medium grained rock with a variable development of quartz. Specimen M1049 from 50 yards E. of M321 (G.R. 246531), is



A. Ordinary light x 5.



B. Crossed nicols x 5.

Fig. 9. Photomicrograph albite schist, south slope Raheenbarr Hill. Specimen M321.

typical. In thin section quartz is seen to occur in small lenticular patches made up of several grains showing undulose extinction, and frequently bounded by thin folia of muscovite or biotite. These are set in a groundmass of fine grained granular quartz and poeciloblastic albite enclosing small flakes of muscovite and chlorite in addition to quartz. The muscovite and biotite are both abundant and intimately intergrown, giving the rock a fairly prominent schistosity. The biotite is in varying stages of decomposition to penninite chlorite and frequently encloses zircon. Idioblasts of garnet up to 0.5mm. in diameter, and showing square or hexagonal outlines occur as small nests associated with quartz and micas. Few of them are completely fresh, some being completely replaced by chlorite. Skeletal crystals of ilmenite now in the form of leucoxene are abundant together with occasional grains of epidote (pistacite) and apatite.

The more siliceous albite granulite from the east side of Raheenbarr hill are composed mainly of albite full of irregular inclusions of quartz, muscovite and pistacite epidote. Their arrangement within the grains is entirely random which is in contrast to the Albite schists further west. Small lenses of quartz are scattered throughout the rock, representing original pebbles. The schistosity is due to small flakes of muscovite and chlorite and short stumpy grains of pistacite which all lie parallel to the long direction of the quartz lenses. A few small subhedral grains of garnet, in some cases altering to penninite chlorite are scattered throughout.

Bands and discontinuous lenses of Green Bed type schists (Specimen M117) are fine grained and show a poor schistosity, which results from the arrangement of albite in roughly parallel layers separated by a fibrous mass of

amphibole largely altered to chlorite, calcite and ilmenite. Albite is either devoid of inclusions or shows a poeciloblastic texture with inclusions of quartz, apatite, pistacite, sphene and chlorite. Twinning is rare, but is simple when present. Chlorite after hornblende is faintly pleochroic in shades of pale yellow-green, and shows brown-purple anomalous interference colours. Pistacite is abundant, but the succession shows considerable variation in the amount present. If there is only a small amount present then calcite is abundant. There does not appear to be any essential distinction between those which are calcite rich and those which are pistacite rich. Iron ore, mainly ilmenite or leucoxene is found as black aggregates scattered throughout the rock, while pyrite shows square or sixsided outlines.

The affinities of the Albite schists.

An analysis of specimen M321 is contained in Table 1 (Anal 1), together with analyses of comparable rocks from other areas. If this is compared with the analyses of the albite schists of Cowal and Loch Lomond (Anal 2 & 3) the total alkali is seen to be similar although in the case of the Cowal rocks potash exceeds soda. In fact all seven analyses show similar values for total alkali.

The essentially sedimentary nature of the rock is shown by the high percentage of corundum given in the calculated norm. (Holmes 1921).

It is of interest to compare anal 1 with anal 7 of a Silurian greywacke from the southern uplands of Scotland (Walton 1955). It is taken from the Queensberry group of the Lower Silurian near Innerleithen, between Peebles and Galashiels. The sequence found is one of fine to medium grained massive greywackes containing occasional thin coarse bands and exhibiting occasional slump structures and poor grading, together with fine

	1	2	3	4	5	6	7
SiO_2	62.89	63.40	63.11	57.06	64.70	68.17	62.96
Al_2O_3	16.57	18.10	15.58	19.66	15.45	15.02	15.38
Fe_2O_3	2.97	)6.70	)6.49	2.19	1.56	2.60	0.53
FeO	3.59	)	)	4.27	4.18	1.39	5.52
MgO	2.84	1.90	1.95	2.47	1.48	1.46	2.54
CaO	1.12	0.90	1.34	1.67	2.92	1.52	2.52
Na_2O	3.37	3.20	2.49	2.92	3.99	4.09	3.76
K_2O	2.57	3.20	3.97	4.14	3.46	2.25	2.83
H_2O+	2.50	)	)	)	1.82	)	2.54
H_2O-	0.11	)2.8	)1.41	)4.09		)2.90	0.40
CO_2	-	)	0.39	tr.	0.85	tr.	-
TiO_2	0.85	tr.	0.83	0.98	0.59	0.60	0.74
P_2O_5	0.04	-	0.25	0.23	0.19	0.15	0.05
MnO	0.10	-	0.24	0.09	0.50	0.06	0.16
BaO	-	-	-	0.08	0.10	0.06	-
SrO	-	-	-	0.07	-	0.02	-
S	-	-	0.14	0.25	0.05	tr.	-
C	-	-	-	0.02	-	0.10	-
TOTAL	99.82	100.20	100.39	100.19	100.44	100.19	99.91

1. Albite schist, Raheenbarr, Castlebar, Co. Mayo, Eire. Anal. E.A.Vincent.
2. Albite schist, Head of Stuck Burn, Cowal. Anal. J.J.H.Teall 'Geology of Cowal'. Mem. Geol. Surv. Scot. p.39.
3. Albite Gneiss, Ben Ledi Grit and Schist, Rudha Ban, Loch Lomond. Anal. W.Pollard. E.H.Cunningham Craig. Q.J.G.S. 1904 vol.60 p.23.
4. Qtz.-Alb.-Chl.-Epi.-Ser.Schist, Trig.EE, Upper Taieri Survey District, New Zealand. J.H.Williamson, Geology of the Naseby Survey District, New Zealand, Bull. 39, N.Z. Survey 1939.
5. Mean of 6 porphyroblastic Albite Schists, Stavanger, Norway Anal. O.Roel. V.M.Goldschmidt, Vidensk. skr. Mat.-Naturv. Kl. No.10 p.110.
6. Semi-schist, Trig Y, Rock and Pillar Survey District. J.H.Willis mson, Geology of the Naseby Survey District, New Zealand. Bull. 39 N.Z. Survey 1939.
7. Silurian Greywache, Firn Quarry, Peebles-shire. Anal. W.H.Herdsman. E.K.Walton, Proc. Roy. Soc. Edin. 1955 vol.65 p.344.

CALCULATED C.I.P.W. NORM.

	1	2	7
qu.	25.38	25.74	17.40
or.	15.57	18.90	16.68
ab.	28.30	27.25	31.96
an.	5.56	4.45	11.68
co.	6.63	7.85	1.84
hy.	10.00	9.02	15.01
mt.	4.41	4.41	0.70
il.	1.51	-	1.57
ap.	0.34	-	0.34

APPROXIMATE MODE

	1
quartz	19
albite	33
muscovite	31
chlorite	11
biotite	0.5
epidote	4
apatite	1.5
iron ore	1

MICROMETRIC ANALYSIS

	7
quartz	22.9
siliceous fragments	10.6
basic fragments	9.2
feldspar	6.4
matrix (material less than 0.02 mm. diam)	50.9

TABLE 1. CHEMICAL ANALYSES OF ALBITE SCHISTS AND RELATED ROCKS.

grained silty shales. In his discussion Walton admits that the micrometric analyses (table 1) does not reflect the true mineralogical composition because the siliceous and basic fragments are frequently composite. The low percentage of feldspar is therefore apparant, not real, a fact which is reflected in the calculated norm.

This comparison indicates that the matrix, which consists of fragments whose grain size is less than 0.02mm. diameter, is composed largely of feldspathic mud.

In the work of Goldschmidt (1921) it has been shown that schists rich in albite may result from soda impregnation derived from a Trondyhemitic magma , of phyllites (Table 1 anal 5). However in the case of the Castlebar rocks, no igneous rocks are exposed within the Dalradian sequences, - a feature noted by both Clough and Cunningham Craig in the S.W. Highlands of Scotland.

From the Naseby area of New Zealand Williamson(1939) has described albitic schists (Table 1 Analysis 4) which may be traced through lower grades of metamorphism into a very little altered semi-schist (Table 1 Analysis 6). Turner in his report on the petrography of these schists is of the opinion that from a consideration of their mineralogical and chemical composition they are the metamorphic derivations of a sedimentary series predominantly psammo-pelitic.

More recently Taylor (1955) in a study not only of major elements but also of trace elements has shown that the quartz-albite-biotite schists of the Arahura series in the Alpine schist Belt of South Island, New Zealand are of sedimentary origin and that the parent rock was of greywacke character. From his study of individual samples he finds that they all point to the same conclusion, and on this basis makes the important statement that while

producing a completely recrystallized rock, the metamorphic processes have not in this case altered the primary element distribution to any appreciable extent. At most they have caused migration of major and trace elements over distances of a few centimetres.

The complete recrystallization that has taken place suggests that the original sediment was comparatively fine grained with scattered quartz pebbles which have recrystallized as elongated areas of quartz. This conclusion fits in with descriptions given by Walton for much of the Silurian greywackes.

Raheenbarr quartzites.

The Raheenbarr quartzites show some variety in rock type resulting from the varying amounts of muscovite, feldspar, and graphite present. In the main the quartzite is a hard, compact, white or grey rock, with the more micaceous parts becoming distinctly flaggy.

The white quartzite shows dead white blebs of feldspar 2-3mm in diameter, lying in roughly parallel lines, e.g. specimen M1051 from a bluff on the south slope of Raheenbarr Hill, 400 yards from the summit. In thin section quartz, with a few small scattered muscovite flakes, displays great unevenness of grain size together with highly irregular outlines. Any evidence of original pebbles has been obliterated by recrystallization. Small irregular areas of albitic feldspar occur throughout, and show a fine grained granulated margin.

The grey quartzites are normally more micaceous than the white, and do not contain feldspar. Specimen M1056, from a few yards east of the summit of Raheenbarr hill, is a dark grey compact rock devoid of schistosity

in hand specimen. The thin section however, shows lines of graphite inclusions running through the micaceous partings and the granulose ground mass of quartz, which surrounds small lenticular pebbles of clear quartz. The rock is a pebbly grit with a siliceous cement. The small percentage of dirty muscovite present shows a fairly high degree of preferred orientation parallel to the long axes of the pebbles. At right angles to this direction thin lines of granulation of the quartz show evidence of incipient shearing although there is no apparent displacement.

Thin black patches, visible on much of the grey rock, are seen in M1058, from the same place as M1056 to be due to small micaceous and graphitic areas which having formed in between highly competent surroundings have been squeezed and compressed to produce drag folds.

The most micaceous beds are also the richest in graphitic material. In M107, from 500 yards due south of the summit of Raheenbarr hill, it is a black dust associated with the micaceous areas, either disseminated between the laths or as aggregates. The lines of graphitic inclusions, and muscovite flakes show up minor folding. The black aggregates and dusty lines have been shown to be carbonaceous in character in specimen M107. Finely powdered material was heated in a platinum crucible until it was a constant weight, during which period any carbon present was oxidised and driven off as CO_2. A further sample was then heated in a Penfield tube to determine the $H_2O + 110^{\circ}C$ content. Examination of the powdered material after heating showed all the original minerals to be still present, with the exception of the black aggregates. There being no

additional new minerals, the inclusions are regarded as carbonaceous.

summary of results.

%age loss in wt. after heating in platinum crucible to constant wt. = 2.74%

%age loss in wt. due to H_2O $^{+110^{\circ}C}$ by heating in Penfield tube. = 1.165%

difference 2.74 - 1.165% = 1.58%



Fig. 10. Panorama taken from above Burren P.O. looking north.

4. WINDY GAP GROUP.

Black schists.
Limestone.
Garnet mica schist.

Field occurrence.

The Windy Gap Group is part of a thrust sheet whose metamorphism lies within the garnet zone. The gently undulating thrust plane dips W.N.W. at between 5° - 15°, and although not seen, is marked by an extremely sharp change of slope which runs round the south and east sides of Sheeans Hill and thence northwards to where it is cut off by the N.E. - S.W. Burren fault of post Old Red Sandstone age, which brings the metamorphic rocks of both the Windy Gap thrust sheet and the Greenans-Derryharriff group against the Old Red Sandstone conglomerates of King's Hill. The base of the thrust, which is termed the Sheeans thrust, at this northern end follows the line of the rough track to Cuilmullagh. (Fig. 11, 12 & 13). On the west side of this track the faulted masses of white saccharoidal limestone and epidiorite rise precipitously.

Garnet mica schist.

The main group of metasediments in the Windy Gap area which strikes N.W. - S.E. and swings towards N. - S. at the northern extremity, dips S.W. at angles varying from 35° - 65°, and consists of a series of garnet mica schists intercalated with quartz bands. The pelitic parts of the series show the development of large garnets up to ¼" in diameter, which frequently occur in thin bands in the mica schist. In the north, towards the base of the



Fig. 11. Windy Gap with Nephin (2020') in distance across glacial Glen Nephin.



Fig. 12A. Windy Gap from the south.



Fig. 12B. King's Hill in the distance beyond Windy Gap, and west slope Sheeans epidiorite, from the south.



Fig. 13A. O.R.S./schist fault scarp N.E. of Windy Gap.



Fig. 13B. Line of emergence of Windy Gap thrust plane on N.E. side Windy Gap mass looking north towards Cuillmullagh.

group, there are two white quartzite bands approximately 20' in thickness which emphasize the general strike. Small scale open folds in the region east of King's Hill (G.R. 405930 to 405940) also strike N.W.-S.E., and associated with these, and in fact occurring throughout the garnet mica schists, are minor folds which are clearly defined by thin quartz layers (up to 1" in thickness). The axes of these folds give a lineation plunging 25° in the direction 160°. 200 yards due south of King's Hill, (G.R. 387985) there is evidence of brecciation in a more quartzose part of the series, and movement of ½" to 1" has taken place along joint planes running in the direction 200°, whilst 50 yards S.W. (G.R. 383992) small scale faulting, involving a downthrow to the N.W. has occurred along joint planes in the same direction. The rocks of this part are shattered and rotten due to the post Old Red Sandstone movements of the Burren fault. Poor though visible fold axes which plunge 25° in a direction 315° are also present.

Limestone.

Apparently overlying the Garnet mica schist is a 50' band of a pure, white, saccharoidal limestone with occasional thin micaceous bands, which appears as a series of disconnected fault blocks running through the N.W.-S.E. gully of Sheeans Hill. The limestone is faulted against the Albite Epidiorite and is well exposed in a north facing bluff on the western side of the road at Windy Gap, (G.R. 370962). The limestone shows folds which strike in a direction 215° with a plunge of 60°. (Fig. 14A & B). Immediately above the faulted junction and parallel to it, sheer planes, along which the epidiorite has moved, frequently have calcareous matter associated with them. The strike of the schistosity in the epidiorite does not follow these sheer planes. The epidiorite above the limestone in the Sheeans gully is often talcose. Limestone



Fig. 14A.



Fig. 14B.

Faulted junction between epidiorite and limestone at Windy Gap. (G.R. 370962).

is also to be found in a faulted block at the northern end of the Windy Gap thrust sheet, and here also it shows a similar relationship to the epidiorite. At the southern end of the group in the stream section (G.R. 364840) there is a further white saccharoidal limestone, frequently micaceous, which shows an intimate relationship with mica schist. In addition it shows evidence of small scale fault movements (Fig. 15A & B), which strike north - south, together with signs of squeezing round randomly orientated brecciated blocks of schist. The junction with the Old Red Sandstone which is also exposed in this stream section is in part brecciated and rubbly.

Black schist.

An exposure of black micaceous and siliceous schist outcrops in the road side at 363842, dipping 40 N.E. The beds seen are :-

black siliceous schist	top not seen.
black micaceous schist	18"
black feldspathic schist	base not seen.



Fig. 15A. Blocks of schist in limestone stream section 1 mile south of Windy Gap. (G.R. 364840).



Fig. 15B. Small scale N.-S. fault movements in banded limestone 1 mile south of Windy Gap. (G.R. 364840).

Petrography.

Garnet Mica schists.

These schists may be described petrographically as quartz - muscovite - chlorite - albite - garnet schists. There is a variation from a predominantly micaceous variety to one which is highly siliceous, with the former type being the most common. Some schists show a small development of biotite, and three main classes of schist may be distinguished :-

a. quartz- muscovite- chlorite -albite- garnet schist.
b. quartz- muscovite- chlorite- biotite- albite- garnet schist.
c. quartz- orthoclase- biotite-garnet schist.

With the exception of c. which is highly siliceous, they all contain abundant muscovite and chlorite. The other minerals present besides garnet and feldspar are apatite, sphene tourmaline and iron ores.

a. These are best developed in the immediate vicinity of Windy Gap. Specimen M150 from a north facing bluff at grid reference 371966, shows thin bands of reddish garnets up to ¼ inch in diameter. On the cut surface these show up the minor folding of the rock. (Fig. 16).

In thin section the garnet is seen to be associated with a thin band of quartz, albite and muscovite. The garnet is almost entirely fresh and tends to form irregular grains, sub-hexagonal in outline, with a few inclusions mainly of quartz.

The non-garnetiferous parts consist of an intimate intergrowth of bent muscovite and flakes of penninite chlorite (+ve, with purplish-brown interference colours), together with irregular poeciloblastic feldspar. In a few cases the feldspar shows multiple twinning which gives a maximum symmetrical extinction angle of 15°. This, together with the following properties:- an R.I. less than 1.54, and a positive biaxial figure, indicates albite.

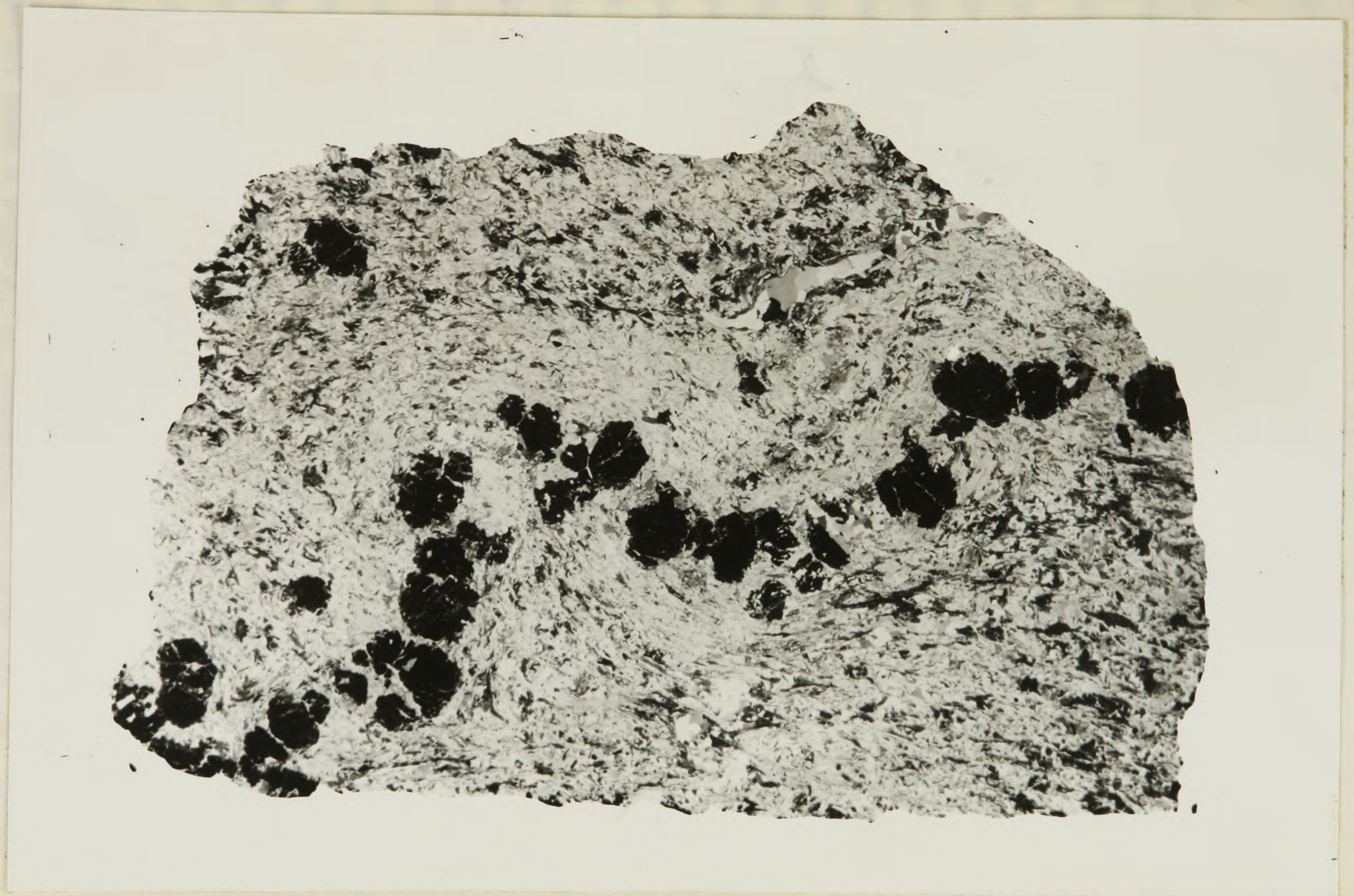


Fig.16. Garnets showing up minor folding in garnet mica schist, Specimen M150 Ord. light x2½.

Inclusions of chlorite, muscovite and quartz are common, and show evidence of rotation during formation. (Fig. 17). There is also a small amount of alteration to sericite. Accessory minerals present are apatite, epidote and leucoxene.

A fairly well developed strain slip cleavage is associated with the minor folding, and is revealed by the micas, which are frequently bent, showing the shear planes and indicating the sense of movement. Biotite is noticeably absent from these rocks. The fresh appearance of the garnet, together with the absence of iron ore or rutile inclusions in the chlorite suggests that it has never been present. It is however abundant in the other two types.

b. These biotite bearing garnetiferous rocks structurally underlie type a. The bulk of the rock is made up of muscovite often highly sheared, and slickensiding occurs frequently. Specimen M310 from the south facing slope of the Sheeans hill (G.R. 376962) is typical. Fairly abundant fresh biotite in shortish flakes and a small amount of chlorite are associated with the sheared and broken muscovite. The Feldspar, which is Albite, is not particularly plentiful, and occurs as small irregular or angular, clear, untwinned grains. A few thin lines of black inclusions show evidence of some rotation during growth. A small amount of quartz may be present and tends to occur as isolated lenticular patches, possibly representing original pebbles. Idioblastic grains of garnet show a square, or hexagonal outline and are rarely more than 1.5mm in diameter. Decomposition to chlorite is common and frequently the alteration may be complete. Greenish brown Tourmaline, showing a secondary growth in optical continuity with the earlier one, but of slightly



Fig. 17. Lines of inclusions of chlorite, muscovite and quartz showing up evidence of rotation during growth in albite. Garnet mica schist specimen M150. x 10 ordinary light. Bluff on the west side of Windy Gap. (G.R. 371966).

different colour, occurs in thin section M314.

c. These siliceous schists occur at a lower structural level than either a, or b, and are typically represented by specimen M309 from the north-facing slope of the Sheeans hill (G.R. 380979). In hand specimen it shows a marked lineation due to the dark micas. In thin section quartz, showing undulose extinction, forms a highly irregular network of grains of all sizes up to 1.5mm, associated with an interstitial development of orthoclase, in part decomposed to sericite. In addition, clear, fresh albite with small inclusions of muscovite, tourmaline and chlorite are present. Small aggregates or isolated short flakes of biotite, in part altered to chlorite, are abundant throughout, together with some thin muscovite flakes. Irregular shaped grains of garnet, up to 1mm in diameter are poeciloblastic, containing grains of quartz, and showing a small amount of decomposition. A small quantity of apatite and sphene are also found. Pyrite, with a square outline, is common throughout the rock in the form of small grains.

Limestone.

The limestone is remarkably pure and appears in hand specimen as a white saccharoidal rock. The thin section shows an interlocking granular network of calcite in which there are occasional rounded quartz grains and thin flakes of muscovite.

Black schists.

These are dark coloured because of the presence of black opaque inclusions of carbonaceous matter. They are shot through with calcite veining of post-regional metamorphic age. Petrographically three types may be distinguished :-

a. quartz- feldspar- graphite schist.
b. quartz- albite- muscovite- chlorite- graphite schist
c. feldspar- muscovite- chlorite- graphite schist.

The only outcrop where they occur is on the roadside at southern end of the Windy Gap area (G.R. 363842).

a. In hand specimen this type (M297) is compact, medium grained and dark grey in colour, with patches, up to 3mm. in diameter, of weathered feldspar. Quartz is seen in thin section to be granular with feldspar forming isolated poeciloblastic blebs of irregular outline. The feldspar is in an advanced stage of serecitization. Its R.I. is less than that of Canada Balsam, but its exact nature is unknown. Thin flakes of muscovite are scattered throughout and a brown chlorite (pleochroic from dirty brown to pale straw, optically negative, and with low interference colours, frequently grey brown) forms short, stumpy flakes. There is no evidence of shearing but thin stringers of calcite cut across feldspar and quartz and thus is clearly a secondary effect. (Fig. 18A).

b. Specimen M298. This soft, highly micaceous black schist shows minor folding with the development of thin white lenticular patches of feldspar. The thin section shows quartz occurring in small lenses, or as isolated grains in the intimate intergrowth of bent muscovite and brown chlorite that forms the main part of the rock, or poeciloblastically within the serecitized albite. A few grains of this show a multiple twinning which gives a maximum symmetrical extinction angle of 15°. The R.I. is less than that of Canada Balsam. Secondary calcite occurs in irregular areas as well as in the veins. (Fig. 18B).

c. Specimen M299. The hand specimen is a compact micaceous feldspathic rock, which, in thin section, is seen to be composed entirely of irregular poeciloblastic feldspar separated by small flakes of muscovite and brown biotite similar to that in M298 and M297. The feldspar although highly serecitized appears albitic. Tourmaline is also present in this type of schist.



Fig. 18A. Calcite infilling tension cracks in quartz. Specimen M175. x 10 crossed nicols. Roadside 1 mile south of Windy Gap. (G.R. 363842).



Fig. 18B. Limestone enclosing black schist. Specimen M298. x 10 ordinary light Roadside 1 mile south of Windy Gap. (G.R. 363842).

5. DERRYHARRIFF GROUP.

Field Occurrence.

As with the preceeding groups the Derryharriff group is separated from the other parts of the metamorphic succession by lines of dislocation.

In the south the group consists of a series of mica schists and grits, in whose more pelitic bands small garnets occur. Bog and glacial cover is thin except where the ground slopes down to the Carboniferous Limestone. Here drumlins are numerous, giving a highly irregular topography in which exposures are isolated and difficult to relate to one another. Extensive bog also covers the ground to the west and north of Lough Rusheen, towards where the Lough Boy fault cuts the Derryharriff group off from the Commauns schists.

The main anticlinal and synclinal structures tend to lie in a general north-south direction although they are complicated immediately east of the Sheeans thrust. Evidence of "way up" of the group is unsatisfactory.

Derryharriff mica schists.

In the Tully Commons area just west of a ford (G.R. 277366) a fine grained, micaceous schistose grit outcrops in a steep limbed synclinal structure pitching E. of S. If these grits are traced laterally along their strike they pass into quartz mica schists, which with similar schists containing feldspar, form the main rock type of the southern end of the group. Although it cannot be demonstrated in the field, the general evidence indicates that many of these rock types are lenticular in their development, a feature upon which comment is made in the section on the origin of the sediments. Only rarely is it possible to trace any consistency in both grain size

and lithology for more than a hundred yards along the strike. The variations are due to differing percentages of mica, quartz, and feldspar. It may be argued that this is the result of the dip and strike of the bedding differing from that of the schistosity, but although this may be true in some cases, examination of a few distinct horizons, such as the micaceous quartzite underlain by a more micaceous schist at G.R. 283385, indicates that schistosity and bedding have the same dip and strike.

Pelitic bands about 1' thick in the quartz mica schists of the Derryharriff region show small garnets on the weathered surfaces. The micaceous and siliceous parts of these schists show minor folds, the axes of which plunge consistently S.S.E. at between 10° and 30°, and which are in the same direction as the main anticlinal and synclinal structures exposed on the east-facing slopes along the N. - S. grid squares 27 and 28. The siliceous parts are usually in the form of quartz lenses, as a result of stretching, with the production of platey rods, which are parallel to both the minor and the major fold axes. (Fig. 19A & B). The more competent beds, essentially siliceous granulites and micaceous quartzites do not show the development of minor fold structures or rodding, but there is not infrequently a poorly defined lineation in the same direction as the rodding and minor folds.

Between Derryharriff and the section exposed in the Clydagh river a ¼ mile S.E. of Burren Post Office, exposures are few because of the glacial deposits of an ice eroded channel between the Old Red Sandstone of Derrynadivva, on the N.W., and the high ground made up of the Ardvarne grits at Ardvarne and Conloon, on the S.E. Where exposed the schists are dominantly siliceous and



Fig. 19A. Minor fold axes in Derryharriff mica schist dipping 60° S.W. Roadside exposure at Derryharriff. (G.R. 283407).



Fig. 19B. Quartz segregations in quartz mica schist. (G.R. 481734).

feldspathic with fewer pelitic bands. These, however, continue to show the presence of small red garnets. The general strike in this narrow belt is still dominantly N.W. - S.E.

Petrography.

Derryharriff mica schist.

The main rock type of this group is a quartz - albite muscovite- chlorite- biotite-garnet schist. Muscovite, although normally abundant, may only be present in small amounts. Chlorite occurs both as a primary mineral and also as a decomposition product of biotite or garnet. As in the case of the Raheenbarr rocks the secondary chlorite is normally associated with iron ore inclusions or needles of rutile, and it also shows a much paler anomalous blue interference colour. In the majority of cases the alteration of the original mineral is not complete. Garnet is of very variable occurrence, being restricted to the more typically pelitic beds.

Specimen M 250 from the roadside exposure at G.R. 220432 is characteristic of the pelitic bands. In hand specimen it is a greyish green compact rock with a poor schistosity. Small irregular patches of feldspar show up on the weathered surface. The thin section shows a fine grained mosaic of irregular quartz grains and an interlocking network of primary chlorite, (dark blue-purple interference colours and optically positive) together with developing feldspar porphyroblasts of poeciloblastic habit. The feldspar shows no twinning, has an R.I. $<$ R.I. of Canada Balsam and is optically negative. It is probably orthoclase. This is the only occurrence of orthoclase as a dominant feldspar in the series. It indicates a type of development unusual in the sequences of the region as a whole. The inclusions

responsible for the poeciloblastic habit are almost entirely quartz and they frequently constitute as much as 50% of the grain. The grain boundaries are invariably highly irregular, in contrast to the sharp outlines normally associated with albite.

Scattered thin flakes of biotite occur throughout the section together with rounded garnet, whose average grain size is approximately .5mm. Neither biotite nor garnet show signs of decomposition. Small rods of a green tourmaline, and irregular grains of apatite are also found. There is very little muscovite. Calcite occurs in small irregular areas and it appears to be of late development. In some patches of quartz individual grains are marked out by a line of iron ore giving an hieroglyphic effect which is closely associated with squarish skeletal crystals of leucoxene after ilmenite.

In more micaceous material (specimen M285, G.R.256425) small irregular or sub-rounded grains of albite (R.I. < R.I. Canada Balsam and optically positive) have developed in a groundmass of a felted network of muscovite and chlorite with some quartz, which occurs either as individual grains or as small lenticular areas up to 3mm. in diameter, both cases showing strain shadows. The muscovite is frequently slightly bent and shows up small scale folding and shearing.

The rocks towards the north east show an increasing degree of shearing and in the more micaceous beds a strain slip cleavage. Micro folds show an irregular development as in specimen 1034 from a roadside exposure at G.R. 285468; they are shown up in thin section by muscovite and thin plates of leucoxene after ilmenite, as either tight or open shallow structures. This variation can be shown by specimen M98 from the stream section (G.R. 282536) to be due to subsequent shearing. Thin bands of quartz are

frequently overturned against shear planes which show up as a line of granulitized quartz and broken muscovite flakes. Most minerals show some stage of decomposition. Ragged flakes of biotite going to chlorite are abundant throughout, except in bands rich in muscovite. The feldspar is in an advanced state of sericitization. There are also present squarish patches consisting of a mosaic of chlorite which may be pseudomorphs after garnet. Two distinct rock types occur in a small bluff beside the road at grid reference 295545. In hand specimen they appear similar, as feldspathic and micaceous grey green schists with a well marked strain slip cleavage. The structurally lower band is a quartz- albite- muscovite- chlorite- apatite schist. (specimen M122). In thin section it shows an interlocking felted network of muscovite, chlorite (very dark brown interference colours, optically positive), with some small grains of quartz together with roughly rounded albite porphyroblasts, showing little or no rotation during growth. Although in the main free of inclusions, these when present consist of epidote (pistacite), apatite, quartz, tourmaline, and muscovite, which lie in straight lines across the grains. In the non-albitic bands a strain slip cleavage is prominent with bent muscovite. Apatite, as subhedral grains lying parallel to the general banding is extremely abundant throughout and forms approximately 10% of the thin section.

The abundance of apatite indicates the presence of a high percentage of phosphate. Owing to the fact that this richness is unrecognisable in the field it is not possible to trace the horizon nor to say with certainty its actual form. Phosphatic beds either as definite bands or as lenses are however a frequent characteristic of some parts of a greywacke sequence and imply a pause in the rate of sedimentation. (Pettijohn, 1949).

The rock lying structurally above M122 is a quartz-feldspar- muscovite- chlorite- garnet schist (specimen M123). It is a fine-medium grained rock with a distinct strain slip cleavage, defined by alternating quartz layers and micaceous bands. Some quartz layers contain a plagioclase feldspar which is largely sericitized. Remnants of pericline and multiple twinning occur but no determinations are possible. The micro folds associated with the strain slip cleavage are picked out by bent muscovite and penninite chlorite (dark blue interference colours and optically positive) flakes, and also by abundant thin straight plates of leucoxene after ilmenite. These plates are occasionally bent. Pyrites and tourmaline are also present, and garnet is also seen developing from chlorite as elongated grains enclosing quartz. These are altered to chlorite where they form part of a fold crest.

A few thin flakes of chloritoid occur in a quartz-muscovite-chlorite- albite schist, from the hillside ½ mile north of Lough Mallard (G.R. 272358) intercalated with the more normal schists. The rock is affected by slight shearing with small interstitial areas of calcite lying along the shear planes.

6. COMMAUNS - SHANVOLEY GROUP.

Commauns schists) stratigraphical order
) uncertain.
Shanvoley schists)

Field occurrence.

These two series of schists which are lithologically similar are classed separately because of the different degrees of shearing which they have suffered. The Shanvoley schists are more highly sheared than are the Commauns schists to the south of them.

The group is dominantly siliceous and feldspathic with variable amounts of mica present. In the absence of pelitic bands the grade of metamorphism is uncertain, although biotite occurs frequently in the micaceous parts. Occasional thin white quartzites, feldspathic bands and gritty bands are useful locally as marker horizons, but the majority of the group shows repeated minor folding and overfolding. There is so little lithological variation that it is not possible to obtain any estimate of thicknesses.

Bog covers the area between the two series, and exposures are restricted to a few poor ones in stream sections.

Commauns schist.

In the Commauns region no satisfactory stratigraphical succession has been worked out owing to the folding, which although in most cases is simple with gently sloping limbs, is, in the more micaceous parts of these essentially quartz schists, interpreted as overfolded if not isoclinal. The section upstream from G.R. 432715 shows well the reaction of the various lithological types to the deformation that they have suffered. The chloritic quartz schist at G.R. 432715 is interbanded with layers of more quartzose material, and shows no evidence of minor structures. The same is true of the slightly more

chloritic rocks between G.R. 413742 and G.R. 413757 which also dip southwards, but which show changes of strike suggesting overfolded structures plunging westwards. (see map). The next well exposed part of this stream section is between G.R. 426768 and G.R. 421799 where there is a noticeable increase in the amount of mica present. Here minor folds are well developed, plunging S.W. at 20°, together with a series of fairly tight, open anticlinal and synclinal folds.

On the rising ground immediately to the north of this series of stream exposures, feldspathic bands occur in a dominantly coarse quartz-mica schist containing large mica flakes. Minor folds are common throughout, although poor in the more feldspathic parts. Quarts bands are also common and where involved in minor fold structures show thickening towards the crests and troughs. Some irregular quartz veining occurs traversing the schistosity. It is of very local development and rarely more than ½" thick or more than 2'-3' in extent. These micaceous rocks are frequently sheared along apparently horizontal planes, and show fine slickensided surfaces which run N.E.-S.W., i.e. parallel to the direction of the minor folding. (specimen M268). These shear planes vary from 1-5 mm apart and possess an undulating surface. In the thicker shear sheets the minor folds structures are preserved, a fact which indicates the influence of two periods of movement, an earlier one, probably associated with the original metamorphism, and later, post-metamorphic one. The relationship of these two movements and its implications will be dealt with later.

In the parallel stream section half a mile to the east, a similar set of rocks also shows minor folding plunging S.W. at up to 20° in the micaceous groups, together with slickensiding and shearing in the same

direction in the slightly more siliceous bands. Quartz rodding, semi-circular or elliptical in cross-section, frequently occurs where there are definite thin quartz bands, and where association with minor folds shows thickening at the apices of the folds. Thin stretched quartz lenses, further accentuating the structural plunge to the S.W. occur in beds in which thin quartz veins are closely packed, as at G.R. 500710.

The hint of overfolding found in the stream section between G.R. 413748 and G.R. 413757 is confirmed on the well exposed rough ground alongside a track at G.R. 476738. Here whole folds plunging at 25° S.W. and closing to the N.W., can be traced. But these overfolded beds dip in the opposite direction to those further west - a fact which raises some difficulties in their interpretation.

It is to be noted that the formation of close minor folds seems to be inhibited where there is any appreciable development of feldspar. The amplitude of the folds remains the same while the wavelength is many times greater. This is especially noticeable in an exposure beside a track at G.R. 462753, and again on the slopes above Derrylahan (G.R. 500710).

Jointing is not well developed, but where present is vertical and runs N.N.W.-S.S.E. with an occasional set running W.N.W.-E.S.E.

A tract of thick bog immediately west of Tawnykinaff separates the Commauns area of micaceous quartz schists from those of the Shanvoley and Greenans districts a mile to the north.

Shanvoley schists.

Lithologically the rocks that make up the Shanvoley and Greenans areas are similar to those of Commauns, that is to say they are mainly micaceous quartz schists. There

does, however, appear to be a greater development of quartzo-feldspathic schists, either as occasional bands up to about 10' in thickness, as in the eastern vicinity of Sheeans village, or as a predominantly quartzo-feldspathic series, interbedded with thin beds of quartz schists, as found further east.

The mapping in the N.E. part of Shanvoley and Greenans has been conducted mainly on a reconnaissance basis to ascertain the general form of the structure, the nature of the rocks, and if possible to obtain further information and evidence from the vicinity of the Conloon fault, which, despite its expression on the ground as a fault scarp for its length northwards from Conloon bridge, is very poorly exposed. Four traverses were made in a general east-west direction. The area immediately east of the Windy Gap thrust will be described first.

In the stream section a mile due south of Windy Gap, an embayment in the Windy Gap thrust mass shows a plunging synclinal structure in the Shanvoley group. Quartz schists underlie approximately 200' of a grey, flaggy quartzite, dipping S.E. at 30°, in which a faint lineation in the same direction is seen. This is succeeded by a white quartzite whose thickness is unknown because of drift cover. On the hillside 200 yards to the east the grey quartzite is again exposed dipping S.W.

The quartz schists with their feldspathic bands are well exposed around Sheeans village. In places, feldspar is also found scattered throughout the rock and weathering out on the surface (G.R. 432913). As in the Commauns region, minor folding is extremely common, plunging in a general S.W. direction at angles between 15° and 20°, and shown up by the quartz bands and by the micaceous foliae in between. Overfolding on a small scale is

present, and may occasionally be actually seen, e.g. (G.R. 446908, Fig. 20). In the main, however, it is inferred from changes in the dips, and tends to be isoclinal, closing to the north west. The trend of the strike of the series as a whole shows considerable variation over short distances, although the general direction is S.W.-N.E., swinging round to W.-E. in the north. The feldspathic bands are not sufficiently constant or distinctive to be of much use as marker horizons. There is however a white quartzite band 2' thick at G.R. 432950, which may be traced 100 yards across isolated exposures and which does bring out the fact that the series as a whole is in a highly crumpled state.

The nature of the Shanvoley structures - overfolds, minor folds and quartz rodding, is totally different from that found in the neighbouring Windy Gap succession. In the latter there is no field evidence of overfolding, the plunge of the axes of the minor folds is S.E. not S.W., and quartz rodding is not developed on any significant scale. The strike of the Shanvoley schists is always oblique to that of the Windy Gap series, the intensity of the dislocation between them being further emphasized. Discussion on the interpretation of this junction as a probable thrust plane is made later. Between Sheeans and Shanvoley the general strike swings northwards, and around G.R. 500000 it veers to its former S.W.-N.E. direction. This trend is characteristic of the Shanvoley-Greenans area as a whole. The rocks of this region are predominantly compact quartz mica schists with varying amounts of feldspar, which weathers out either white or pink. Intercalated with these are more micaceous bands showing good minor folds plunging S.E. at 10° - 20°. Overfolds closing N.W., frequently appearing isoclinal, can be inferred from the changing dips.



Fig. 20. Overfolding towards the north in Shanvoley schist 100 yards south of Sheeans village.

Two parallel gullies running N.W.-S.E., 30' wide and 20' deep, occur on the east side of a wide peat hollow at G.R. 553980. They become shallower to the S.E. There is no apparent difference in rock type or strike direction on either side, and no apparent evidence of faulting. On the continuation of this line northwards however, at G.R. 530050, a steep west-facing scarp separates similar rocks, but they have different strike directions. There are no exposures in the immediate vicinity of the scarp. The quartzite bands immediately north show no signs of displacement along this line. It would appear, therefore, that the differences in strike direction at G.R. 530050 may be explained in terms of different parts of small folds plunging S.W. Further, the general direction of minor structures on both sides of this line are similar.

Northwards from Shanvoley there is a gradual passage into quartzo-feldspathic schists which dip predominately to the north, and these in their turn pass into a compact white quartzite with micaceous partings. The dip is either northwards or southwards as a result of folding and crumpling, and the fold axes plunge N.E. at between 10° and 30° (Fig. 21A & 21B.). This quartzite band, whose outcrop is 200 yards wide, may be traced to a deep gully running N.N.E. - S.S.W. where it is displaced 50 yards to the south. It then continues eastwards and is obscured by peat cover on the slopes of Farbreiga. An indication that the succession is inverted in parts is to be seen in drag folding of micaceous beds between quartzite beds at G.R. 505041. The white quartzite passes southwards into feldspathic and micaceous quartzites which are poorly exposed round the northern slopes of Farbreiga. 400 yards



Fig. 21A.



Fig. 21B.

Folding in micaceous quartzite (Shanvoley Group) 1 mile north of Sheeans village. (G.R. 475(1)045).

further north a thick, massive, white quartzite, which laterally becomes micaceous, dips steadily southwards at 20° - 30°, and may be part of a synform if indeed the succession is inverted.

Petrography.

Commauns schists.

Shearing, noted as increasing in a north east direction in the Derryharriff area, is prominent in these rocks, with the exception of the Green Bed horizon in the stream section at G.R. 432715, which does not show the same intensity of shearing as the neighbouring beds.

The main rock type of the Commauns area is a quartz albite- muscovite- chlorite- biotite schist, which has suffered differing degrees of shearing depending on the amount of micaceous material present. Macroscopically the rock is a dark, grey-green, compact or micaceous schist, which may show feldspar on the weathered surface. Microscopically the rock consists of alternating quartzose feldspathic bands with micaceous laminae. Quartz is granulitic, with highly sutured margins and pronounced strain shadows. The feldspar belongs to the albite range and occasionally displays multiple twinning. This gives a maximum symmetrical extinction angle of 18°, and the refractive index is less than that of Canada Balsam. In the untwinned albite, strain shadows are present but they are not as pronounced as those of quartz and the grain margins are normally smooth and unsutured. These two characters help to distinguish readily two otherwise similar minerals.

In specimen M291 from a roadside exposure at G.R. 460770 the abundant muscovite flakes are often bent and they pick out a faint micro-folding. Very thin

biotite flakes and a greenish chloritic matter occur, together with abundant plates of leucoxene after ilmenite.

The most sheared and granulitized rocks are those from near the fault separating this group from that of Ardvarne to the south east. Specimen M290 from the roadside at G.R. 483734 is typical. Rounded or elongate grains of albite up to 2.0mm. in diameter, which are set in a very fine grained granular matrix of chlorite, quartz and leucoxene, have been unaffected by shearing and do not show any sign of decomposition.

The schist of Green bed character is a quartz- chlorite- hornblende- epidote- albite rock, which is dark green and poorly schistose in hand specimen. Under the microscope it shows a fine to medium grained, felted mass of chlorite with some irregular platey grains or hornblende up to 1mm. in length, the optical properties of which are as follows:-

pleochroism X = very pale yellow, Y = brown green,
Z = blue green.

Ext. angle z ^ c 16°

2v very small -ve.

Epidote is extremely abundant as small an- or subhedral grains, together with a few grains of zoisite, pleochroic pale yellow to colourless. Thin bands of quartz, approximately 1mm. thick, always show evidence of shearing. The grains are granular and have markedly sutured margins.

Albite porphyroblasts are few, and always show rounded, fairly smooth margins. For the most part they are clear, although some contain small, roughly parallel inclusions of chlorite and quartz. There does not appear to have been any rotation. Pyrite, showing sub-square outlines is the iron ore mineral present.

Shanvoley schists.-

This part of the group is more feldspathic and shows an increased degree of shearing which has affected particularly both quartz and muscovite. The feldspar, as seen in the Commaune region, is relatively unaffected except for the development of strain shadows which are less intense than those of quartz, and occasional granulitization.

Specimen M318 from just south of Shanvoley village (G.R. 432913) is a sheared albite- muscovite- chlorite- epidote schist. It contains abundant large albite porphyroblasts with curved lines of inclusions of epidote, pyrite, and muscovite. Large curved muscovite flakes, which in isolated patches are crushed and broken, with chlorite (purple-brown anomalous interference colours) together form approximately 25% of the groundmass. Also present are epidote (pistacite), large green tourmalines, and a few grains of apatite.

Shearing is mainly restricted to belts ½mm. to 1mm. wide, separating bands of unstrained feldspar 2mm. wide. The amount of movement in the shear belts is very slight since the inclusions in the feldspars, although frequently cracked, are only slightly displaced. The cracks are frequently chlorite filled.

In the less feldspathic rock M319 from 200 yards further south (G.R.438904), the quartz shows a greater degree of granularity, with small amounts of interleaved, bent laminae of muscovite and chlorite. Thin veins (0.2mm. thick) of calcite cutting across the undulose extinguishing quartz veins and following narrow parallel lines of granulation at right angles to the main shear, are clearly the last episode in the deformation of the rock.

Further east the feldspars are fragmented, but are texturally similar. In specimen M380, from a roadside exposure at G.R. 475935, these fragments may be as big as 3mm. in diameter. Where occasional multiple twinning occurs the lamellae are slightly bent or broken. The low R.I. and a maximum symmetrical extinction angle of 17° indicate albite. Inclusions are not numerous and are usually of epidote, which is pleochroic colourless to very pale pink-brown, and which is also abundant in bands with chlorite and large bent muscovites.

The increase in the intensity of the shearing towards the east is well displayed in a sequence of quartz- albite-muscovite- chlorite rocks taken on a traverse between G.R. 500(1)040 and G.R. 576(1)057, roughly along the line of the strike of the schistosity. In specimen M347 from the former spot, minor folding and crumpling is shown up on the weathered surfaces by thin discontinuous laminae of quartz between which opaque white blebs of feldspar occur. The cut surface shows these to be extremely irregular in outline and development, and up to 3mm. in diameter. The feldspar, which is albite, is poeciloblastic with irregularly sharped quartz inclusions. Occasional multiple twinning occurs but simple twins are absent. Some grains show slight sereeitization and cloudiness. They are set in a groundmass of penninite chlorite(+ve.), some of which is after biotite, and quartz exhibiting strong strain shadows and sutured margins between grains. These margins frequently have a thin line of fine granular quartz. Large flakes of muscovite are normally bent and sometimes broke, and narrow irregular zones of shear with fragmented muscovite, and fine granular quartz, cross the rock.

400 yards E.N.E., (G.R. 519(1)045), pale pink

feldspar shows a slightly more irregular development with quartz, in a chloritic and micaceous groundmass in specimen M348. In thin section the rock is seen to be more micaceous than M347. The albite feldspar contains thin straight lines of dusty inclusions, - thin chlorite and muscovite flakes and elongated grains of pyrite altering to haematite; it shows only faint strain shadows; on the other hand quartz more highly granulitized, with fine sutured margins marked by thin granulated layers, shows more intense strain shadows. Biotite is absent. Brown-green tourmaline, as small grains with a hexagonal or triangular outline, shows signs of decomposition to a medium green chlorite with dark purple blue interference colours. The decomposition starts along irregular cracks parallel to the length and works outwards. All stages from the unaltered mineral to complete chlorite pseudomorphs are present. There is also a thin band, 1.5mm. thick, of small vermicular like bodies of radiating chlorite set in a feldspathic and quartzose groundmass. (Fig. 22A & 22B.).

A further 600 yards E.N.E. specimen M349 (G.R. 548(1)056), is a finer grained and more compact rock with subangular grains of pale pink feldspar and quartz up to 1mm. in diameter. Thin section shows the subangular albite feldspar to be in a similar condition to that of M348, but forming eyes in a granulitized matrix of quartz and muscovite. The quartz is in thin ribbonlike grains with the shear planes lying parallel to the sutured margins or, where the rock is more micaceous, making an angle of 30° to their length. (Fig.23A & 23B.).

Specimen 350 (G.R. 576(1)058), 600 yards further east is similar, but the slice shows the crushed quartz to be more granular than to the west although some ribbons of

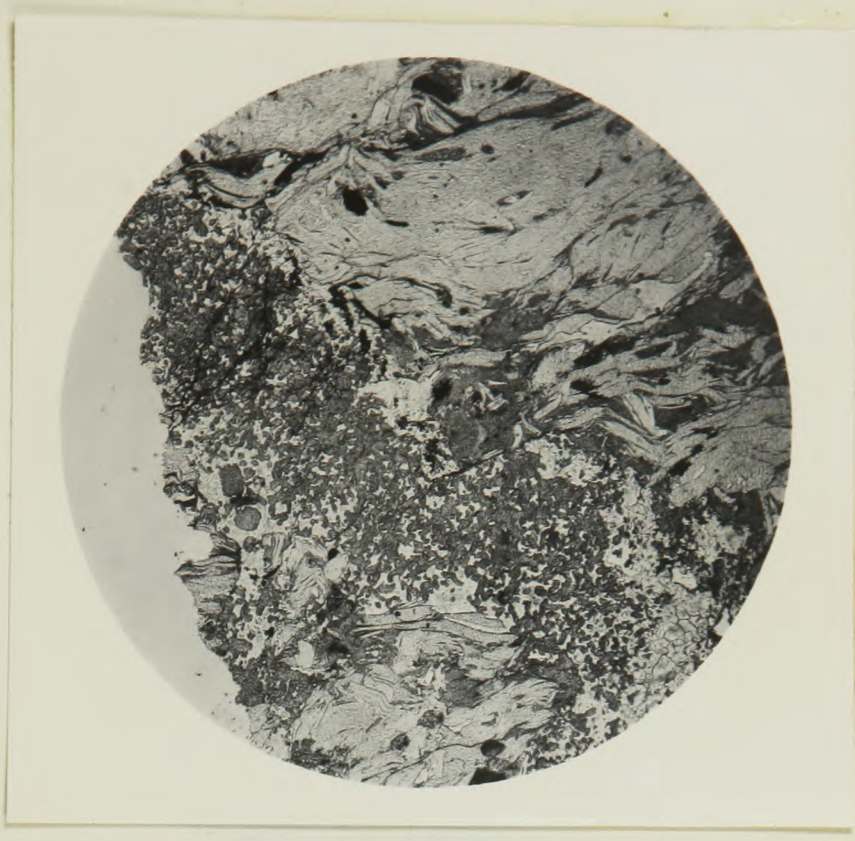


Fig. 22A. Thin vein composed of vermicular chlorite, quartz and feldspar in sheared quartz mica schist of Shanvoley group.

Ordinary light x 5. Specimen M348.

N.E. Shanvoley village. (G.R. 519(1)045.



Fig. 22B. Vermicular chlorite with quartz and feldspar in thin vein.

Ordinary light x 80. Specimen M348.

N.E. Shanvoley village. G.R. 519(1)045.



Fig. 23A. Ordinary light x 10.



Fig. 23B. Crossed nicols x 10.
Sheared quartz mica schist showing sheared margins to quartzose fragments.
Specimen M349.
N.E. of Shanvoley village. G.R. 548(1)056.

quartz are present. Bent flakes of muscovite and dirty brown unaltered biotite are abundant, frequently associated with small grains of epidote. Chlorite is locally developed along the lines of shear. In this matrix the subangular albite feldspar shows occasional multiple twins and some simple twins. It is frequently serecitized and contains some abundant elongated quartz inclusions. The stress character of albite is illustrated by the absence of strain shadows in these inclusions.

7. ARDVARNE GRITS.

The outcrop of the Ardvarne pebbly grits, running N.N.E.-S.S.W., is approximately 4 miles long by a maximum of 1 mile wide, and is cut off in the north by the Conloon fault which also forms the eastern boundary. The line of its western margin is the Lough Rusheen fault which, although nowhere exposed fully because of widespread bog, may be traced in several places where the grits are separated by boggy hollows or gullies from the quartzose mica schists of the Derryharriff succession, which shows a strike lying at right angles to that of the grits. It is however, realised that a boggy hollow does not necessarily represent a fault, but it is likely to do so where there is not only a difference of structure but also distinct variation in lithology on either side.

The succession is best seen in the river section of the Clydagh river upstream from Conloon bridge, as far as the 90° bend (G.R. 4664) where the river cuts across a glacial filled hollow, (Fig. 24A & 24B). There are also sporadic outcrops of pebbly grits on the hillside on the N.E. side of the river, but for the rest, exposures are isolated by the bog cover. In the region of the Castlebar-Glenisland road and southwestwards this cover is thinner and outcrops are better, although drumlins abound where the ground slopes down to the Carboniferous Limestone country immediately south.

The grits lie in an open series of asymmetric anticlinal and synclinal structures running N.N.E.-S.S.W., the steep limbs of which face N.W. The succession as exposed represents only part of a much thicker development, and no estimate of thickness can be given because of the folding and the lack of traceable horizons.

Lithologically the grits consist of a series of poorly sorted graded beds. The thickness of each graded



Fig. 24A.



Fig. 24B.

Falls in the Clydagh River in the Ardvarne Grits ¼ mile upstream from Conloon Bridge.

bed shows a considerable variation between 1' and 10', the majority being between 2' and 4'. The thicker beds which are found just north of the Castlebar-Glenisland road at 345453 are characterized by the coarseness of the pebbles at their base. These are mainly white quartz with smaller amounts of feldspar, occasional quartzite and mudstone fragments. A few small grains of blue opalescent quartz have been found in the matrix. They are however rare in the coarser parts of the graded beds, but are slightly more common within the medium and fine grained parts; even so they only constitute at the most approximately 1% of the total pebble content. The pebbles are elongated and flattened in a direction which lies parallel to the strike of the structure. The size of the pebbles is best seen on the weathered surfaces bleached by peat waters as at G.R. 3445. Here the coarsest quartz pebbles are approximately 2" x ½" x ¼". This relationship of axes lengths 8 x 2 x 1 is remarkably constant not only in this particular bed but also in the other coarse beds. (Figs. 25, 26A & 26B.). The long dimensions dip 20° - 27° N.E. along the bedding planes. The matrix of these coarse beds is fine grained and chloritic with smaller quartz pebbles prominent. The smaller pebbles do not show the same tendency to elongation as do the larger ones. Distinct lenses of fine grained chloritic material occur interbedded with the coarse beds, which during deformation have been squeezed and smeared into the shear planes developed parallel to the bedding. These shear planes are frequently slickensided at right angles to the direction of elongation i.e. N.W.-S.E.. The area of deformation of quartz pebbles is comparatively restricted. It is found through the Ardvarne region, but not in the Westport grits of the



Surface View

End view

Fig.25. Elongated quartz pebbles in Ardvarne Grits. x $\frac{1}{2}$. Sma ll quarry on castlebar-Glenisland road, 1$\frac{1}{2}$ miles N.E. of Castlebar.



Fig. 26A. Flattened quartz pebbles in pebbly grit, Ardvarne Group, 300 yards south of Lough Rusheen.
G.R. 323502.



Fig. 26B. Elongated quartz pebbles and jointing in pebbly grit, Ardvarne Group. North side Castlebar - Glenisland Road, 1¾ miles N.W. Castlebar.
G.R. 363446.

Westport area immediately west of Castlebar, which although separated by approximately 4 miles of Carboniferous Limestone cover are structurally a continuation of the Ardvarne grits. The Westport pebbles are rounded with a small amount of shearing in the fine grained, chloritic matrix.

Even where exposures are comparatively good, as they are south of the Castlebar - Glenisland road (G.R. 3443), it is difficult to trace any one graded bed or group of graded beds laterally for any distance. At exposures on the east side of a track at G.R. 335435, lateral variation in grain size within one bed, from coarse to medium, may be demonstrated over a distance of approximately 50 yards. The graded beds everywhere are graded upwards, indicating that the succession is the right way up.(Fig. 27A).

Interbedded with the pebbly grits are green phyllite bands (Fig. 27B). The main one, which is well exposed in the Clydagh river at G.R. 472605, may be traced southwards by means of scattered exposures as far as the stream section 100 yards east of Lough Rusheen. Minor folding in these fine grained chloritic rocks follows the general strike, with the axes plunging S.W. at angles between 5° - 25°. When more competent beds are interbedded with the phyllites, drag folding confirm that the succession is lying the right way up. A further phyllite band of local development is exposed in a roadside quarry on the Windy Gap road at G.R. 410594. In the back of the quarry 20' of phyllite, in which are developed large pyrites cubes lying edgewise to the schistosity as eyes, are exposed dipping 75° S.E., overlain by an 8' fine grit band and a dirty grey calcareous rock for the remaining 2'. Minor folding here plunges S.W. at 5°. (Fig. 28).

Several purplish grey phyllite bands of varying



Fig. 27A. Graded bedding in pebbly grits, Ardvarne Group. Roadside quarry on Castlebar - Glenicland road, 1¾ miles N.W. Castlebar. G.R. 351451.



Fig. 27B. Bedding in fine grits and phyllites, Ardvarne group. Clydagh river section ¼ mile upstream from Conloon Bridge.



Fig. 28. 'ac' joints in phyllite, Ardvarne group. Roadside quarry on Castlebar - Windy Gap road at Ardvarne. G.R. 410594.

thickness and extent occur within the succession, but nowhere has a passage from the pebbly grits been observed. One such band, which is exposed in a stream section at G.R. 354435, when traced N.E. is seen to form a narrow platform along the hillside. In lateral extent, as shown by topographical expression, it is not more than 200 yards. Further bands are exposed along the Windy Gap road.

The strike of the succession as a whole runs into the line of the Conloon fault, which transgresses the group. Haematite staining is conspicuous in the beds in close proximity to the grit succession, except at G.R. 380399, where a 2' wide band of tough brecciated rock is traceable for 20 yards in a N.E.-S.W. direction. Jointing is not common and is best developed in the coarser parts of the graded beds. It is vertical and lies at 350° and 050°. The latter is the more prominent direction being frequently infilled with secondary quartz veins up to ½" wide. The medium and fine grained pebbly grits show a small degree of movement along this direction.

This jointing represents the response of the coarser, more competent beds to compressional forces which have produced the minor folds in the phyllitic bands.

Petrography.

The rocks of the Ardvarne group show only slight regional metamorphism. They have however suffered considerable shearing and crushing with the production of elongated quartz pencils from original pebbles. The majority of the pebbles are clastic.

The main pebbly grit types are found in a small quarry beside the Castlebar to Glenisland road (G.R. 352454), and in small bluffs sticking up through the bog cover (G.R. 346457).

Specimen M1028 from the quarry is a flaggy, dark grey-green rock in which the majority of the clastic grains are angular fragments of quartz showing strain shadows.. The remainder are albite feldspar, frequently showing multiple twinning with lamellae sometimes bent or broken, together with a few grains of orthoclase. Evidence of shearing is found in the ragged margins of the quartz, and the granulation of the smaller fragments in the groundmass. The main part of the groundmass consists of very fine grained quartz with micaceous and chloritic matter scattered throughout and lying parallel, thus producing the schistosity. The coarser grained grits are essentially similar, although the large quartz grains up to 1cm. in diameter show a more ragged granulated margin with very marked strain shadows. Frequently they are partially broken with fine lines of granular material marking the break. Carbonaceous matter may occur as streaks with more serecite rich layers.

The occasional blue quartz grains that occur in the medium grained bands show minute inclusions, upon which comment was made in the Glenisland series.

Really coarse bands from the small bluffs contain pebbles of quartzite composed of small, interlocking sutured grains. In addition some of the plagioclase feldspar lies in the oligoclase to andesine range.

The fine grained green phyllite interbedded with the coarsest part of the pebbly grits shows shear structures and apart from consisting of quartz and serecite contains small square to rounded grains of limonite presumably after pyrite.

The fine grained calcareous rock from the quarry on the Castlebar to Windy Gap road (G.R. 410595), shows irregular fragments of quartz up to 1.25 mm. in diameter

set in a groundmass of calcite and small granular quartz fragments with serecitic micaceous material.

Specimen M247 from a band of brecciation (G.R. 380399) is a dark tough compact brecciated rock with fragments of quartz and schist. The matrix is of very fine grained crushed quartz and micaceous material with abundant iron ore and carbonaceous matter. Traversing the rock are long wormlike structures with a fairly constant width of 0.75mm. filled with minute granular quartz and evenly distributed dark matter. These tubes wander through the rock mass in an erratic manner and locally widen out to 1.5mm. whenever a coarser grained margin is present. In places they may intersect each other showing one tube to be younger than the other. One tube passes into a bulbous end composed of quartz grains up to 0.4mm. in diameter which have unsutured margins although they show strain shadows. (Fig. 29).

Their origin is obscure. If they are considered as worm borings then the rock is not likely to be a fault breccia. Its toughness and compact character are not in accord with other breccias definitely of fault origin elsewhere in the grit sequences. It is probably a local development of an angular accumulation.

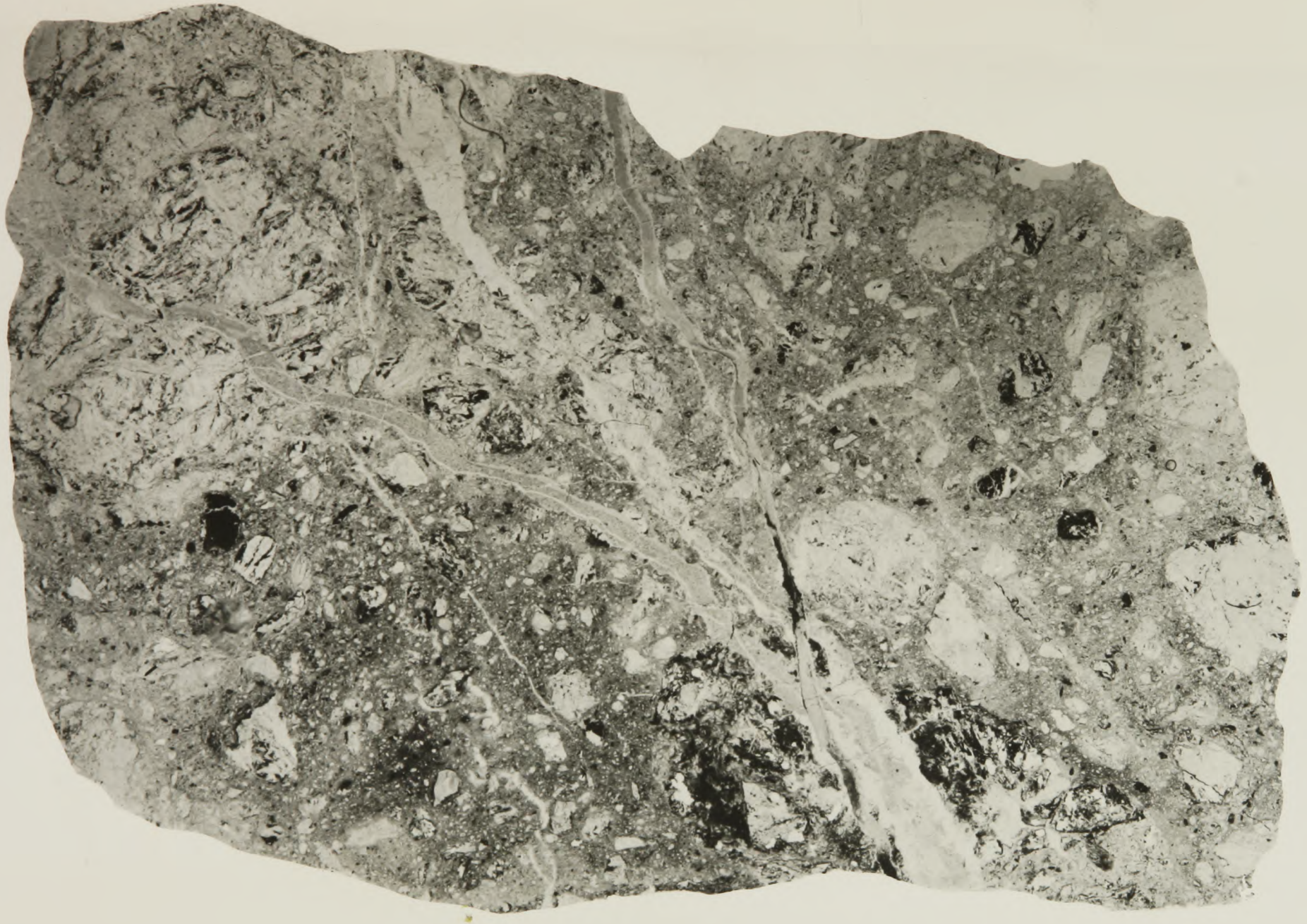


Fig.29. Brecciated quartzose schist, Ardvarne group. Specimen M 247 x 5. Black Lough.

B. FIELD OCCURRENCE AND PETROGRAPHY OF META-IGNEOUS ROCKS.

1. Introduction.

The term epidiorite was defined by von Gumbel (1874) as a metamorphosed igneous rock containing pale green fibrous hornblende, plagioclase feldspar, chlorite, ilmenite, or magnetite with occasional augite. Wiseman (1934) following the Geological Survey used it to describe metamorphosed igneous rocks of dolerite composition in which the original minerals have recrystallized as hornblende, plagioclase, and chlorite with the preservation of original textures in the lower grades of metamorphism.

More recently there has been a tendency to call these rocks meta-dolerites because of the similarity of their field occurrence and chemical composition to that of unaltered dolerites, and because of the occasional preservation of textures characteristic of dolerites. (Sutton and Watson 1951). These writers commenting on the definite mineralogical significance of the term epidiorite point out that it is characteristic solely of the metamorphosed dolerites of the Dalradian Series, and not of the other metamorphic series.

On these grounds, therefore, these altered rocks of dolerite composition are called epidiorites. In fact it is suggested that the term should be restricted to the Dalradian series.

2. Epidiorites.

Field Occurrence.

The epidiorites are normally compact poorly schistose green rocks in which small white blebs of albite feldspar, with a range in grain size from 0.5mm. to 2mm. in diameter, are frequently arranged in roughly parallel rows. This general description is applicable to the occurrences in the Glenisland, Raheenbarr, and Windy Gap areas.

In the Glenisland region the structurally lower junction with the sedimentary rocks is obscured. As

already stated the boundary appears to be non-transgressive except in the south where it cuts across the quartz mica schists. The upper junction is faulted (Section 1), and there is also evidence of brecciation of the grits in a narrow N.N.W.-S.S.E. gully (G.R. 095695). Exposures are confined to the northern part where there is little glacial drift, and in the main these exposures are small and rugged. Occasionally large feldspar blebs are developed which may be 2mm. in diameter, as in the small exposure in a steep west-facing bank ¼ mile W. of Lough Boy (G.R. 090550), (specimen M229), where the remainder of the rock is a deep green in colour due to the abundance of amphibole.

The epidiorites of Raheenbarr show a more positive relationship to the country rock. Along the line of the Lough Boy fault in a small quarry beside the road (G.R. 135520) a white saccharoidal limestone and an overlying albite schist containing porphyroblasts up to 5mm. in diameter, and dipping N.E., are folded into tight asymmetric folds, the axes of which plunge 45° towards the south east. (Fig. 30).

The eastern margin of this Raheenbarr mass and also the small isolated one immediately to the west of the summit of Raheenbarr hill rise fairly sharply from the ground occupied by the Raheenbarr pebbly grits and appear to be transgressive to them. Both the grit series and the epidiorite show a similar direction of schistosity and they both exhibit similar joint patterns running N.E.-S.W. and N.W. - S.E.. No evidence of contact phenomena or actual contacts have been observed. The exact nature of the relationship between the rocks is therefore uncertain, especially as the eastern margin of the main mass consists of a 50 yard wide band of an epidiorite of a different type from the main fine grained variety.

There is a further strip of epidiorite on the eastern



Fig. 30. Tightly folded limestone and albite schist 300 yards south Lough Boy, along the line of the Lough Boy fault.

side of Raheenbarr Hill, bounded by the Raheenbarr fault on the west and by the southward continuation of the Sheeans thrust to the east. This helps to explain the differences in the dip and strike directions and in the lithology in the north where gritty beds abut onto micaceous beds.

Along the line of the Raheenbarr fault limestones are associated with the epidiorites. In the stream section on the south side of the bridge on the Castlebar - Glenisland road at G.R. 226492, there is exposed a white saccharoidal limestone. It is entirely isolated in a region of peat cover but lies in the direction of a southward continuation of the fault. Further south along this line other exposures of a similar limestone outcrop (G.R. 205485). A few small isolated exposures of epidiorite nearby indicate the close association of the two rocks. There is also evidence of brecciation occurring not only in the limestone and epidiorite but also in the Old Red Sandstone. In the immediate vicinity of Raheenbarr hill the epidiorite is frequently brecciated and rotten especially along the steep north-facing scarp. (G.R. 263528). 150 yards further north along the fault line a brecciated association of epidiorite and limestone occurs.

Lenticular structures up to a foot in length and six inches thick occur sporadically in the main Raheenbarr mass and in Glenisland in small isolated areas. (Fig. 31). The nature of the exposures makes it difficult to determine whether they occur in belts, or indeed what is their relationship to the form of the epidiorite mass. They are clearly seen in a north-facing bank, 200 yards off the Castlebar to Glenisland road (G.R.157508). The outer margin of each lens is marked by a thin layer of

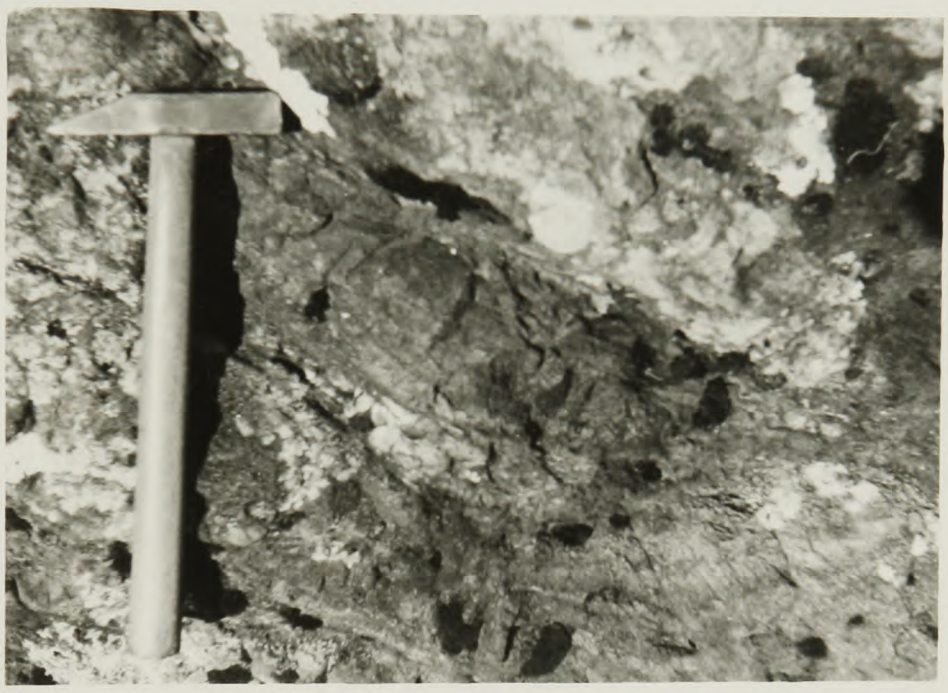


Fig. 31. Lenticular structures in epidiorite, Raheenbarr Group, 1 mile S.W. Raheenbarr Hill. G.R. 157507.

slickensided green chloritic material, but it may also be marked by thin blebs of quartz. Within the lens there is a variation in the size of the albite porphyroblasts which are set in a fine grained green matrix. This variation produces three types of lens, those with:-

1. layers of large porphyroblasts, up to 3 mm. in diameter, at the base which grade upwards into smaller ones.

2. layers of large porphyroblasts at the top which grade downwards into smaller ones.

3. Irregular distribution of large and smaller porphyroblasts.

Outside the lenses the lines of albite porphyroblasts either show swirling lines round their outer margins, or lines which are cut off at the lens margin.

The lenses occurring just off the Glenisland road (G.R. 099575) are similar in form, but are calcareous. Slickensiding occurs down the dip slope of the schistosity i.e. towards the East, and the rocks are frequently intensely sheared.

In other places, notably in the isolated mass, the lenses are marked by their thin veneer of quartz.

Structures reminiscent of graded bedding are indicated by the relative amounts of quartz and mica present and by the grain size of the feldspar. The bands are up to 2 feet thick and each is coarse at the sharply defined base, which consists of rounded or slightly elongate porphyroblasts of white feldspar up to 3mm. in diameter, together with wads of chlorite set in a dark green matrix. Upwards through the first 12 ins., there is a steady diminution of the amount of visible micaceous material together with a slight reduction in the size of the feldspar

which weathers out on the surface. For the uppermost 12 ins. micaceous material slowly becomes indistinguishable and the feldspar becomes rapidly smaller, until in the top two inches of each band it is only visible as extremely abundant white specks. Repetition of this type of band through approximately six feet of exposure is visible on small irregular bluffs (G.R. 165529). The nature of the exposures prevents their being traced laterally. The bands strike N.N.E. - S.S.W. and dip 45° E.S.E.

Two thick bands of a distinct type of epidiorite approximately 50 yards wide, occur, one at the eastern edge of the main mass, the other a third of a mile further west. They differ from the normal fine grained type of epidiorite with abundant feldspar porphyroblasts in being coarse grained and composed mainly of large blebs of amphibole up to ¼" across, with chlorite and biotite, and very little visible feldspar. There is no distinct schistosity but a prominent set of joints strike N.E. - S.W. and N.W. - S.E.. They appear to represent either a segregation of the main mass, or to be a later, although pre-metamorphic, minor intrusion.

The epidiorites in the Windy Gap region form the main part of the Sheeans hill (927 feet) (G.R. 395905), and are bounded on the N.E. by a steep sided flat bottomed gully, 75' - 100' deep and 100 yards wide, which marks approximately the shear junction with the 50' band of white saccharoidal limestone to which reference has already been made (Fig. 14A & 14B). (Another small patch of epidiorite occurs south west of Sheeans hill on the other side of the stream which cuts through the thrust plane). As in the Raheenbarr region two main types of epidiorite are recognisable in the field. Firstly the normal fine grained variety containing porphyroblasts

of feldspar of varying sizes, and secondly a coarser, more hornblendic type. The latter forms the belt, poorly exposed round the west side of Sheeans hill.

The elongate patch of epidiorite occurring in the northern part of the thrust mass is bounded on both east and west sides by steep sided narrow heather covered gullies interpreted as minor thrust planes associated with the main thrust.

Petrography of the Epidiorites.

The epidiorites of the region show considerable variation in both the mineralogical composition and in the structures present, as has already been indicated. However, they are sufficiently similar as rock types to be considered together.

The stage of alteration of these epidiorites is such that no surviving trace of original igneous textures is preserved. In fact recrystallization has been complete.

Typically they show the development of laths of hornblende (X = very pale yellow or green, Y = green, Z = blue-green, Z c = 16°), which tend to have a preferred orientation although it is not particularly marked. In some cases the hornblende occurs altering to chlorite (both positive and negative types are found, polarization colours pale greenish grey). Chlorite is also found as a decomposition product of biotite. The feldspar, which is always albite, is normally untwinned although occasional simple twins do occur. The grains, either regular in outline, or as is more usual, highly irregular in form, are crowded with inclusions of hornblende or chlorite. Short stumpy flakes of biotite are sometimes present, normally in a fresh state although

some decomposition is observed. Distinct laths of clinozoisite are the more common form of epidote present, but pistacite is found. Occasional grains of quartz are scattered throughout usually in association with spherical or ellipsoidal structures of uncertain affinity.

Fine Grained Types.

This type which forms the main epidiorite masses is usually poorly schistose in hand specimen and may, as already indicated, show a certain banding with lines of small whitish porphyroblasts of albite which weather out on the exposed surface. In thin section the schistosity is seen to be largely due to a roughly linear arrangement of the amphibole and to a lesser extent of the epidote and feldspar. In specimen M210 from just off the Castlebar - Glenisland road (G.R. 099575), the albite feldspar grains, 1 mm. in length, (R.I. < R.I. Canada Balsam, positive) tend to be elongated parallel to the long axis of the hornblende with which it shows ragged margins. It contains small inclusions of clinozoisite, ($X \wedge c = 5^{\circ}$, interference colours first order grey or yellow). Hornblende forms a felt-like mass with which is closely associated chlorite and biotite. Skeletal iron ore minerals are now in the form of leucoxene. Evidence of shearing is to be seen in the lines of dark brown staining that pass through the ferromagnesian minerals and shattered feldspar grains.

In some epidiorites the albite grains show a definite outline with evidence of rotation. Specimen M229 from the west facing slope of the epidiorites in Glenisland (G.R. 091550) (Fig. 32A & 32B) shows feldspar porphyroblasts, up to 2mm. in diameter, containing thin lines of inclusions of hornblende, sphene with some epidote, and quartz. The feldspar is set in a felted



Fig. 32A. Ordinary light x 10.

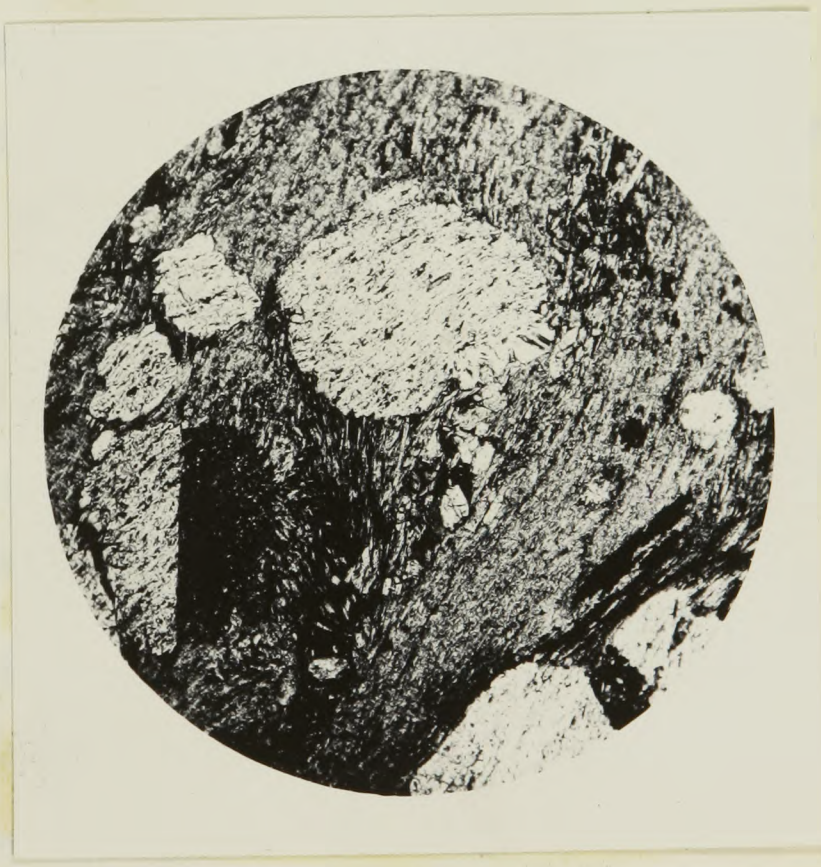


Fig. 32B. Crossed nicols x 10.

Rotated albite in epidiorite, specimen M229.

West facing slope 1 mile W. of Lough Boy.

G.R. 091550.

ground mass of chlorite and hornblende with epidote and skeletal leucoxene. The rotation of the grains appears to be the result of a post crystalline deformation since the lines of inclusions are straight and show an abrupt junction with the lines of inclusions in the main ground mass. c.f. Turner and Verhoogen 1951 p.525.

Specimen M322, from a small quarry beside the Castlebar to Glenisland road (G.R. 172516) in the Raheenbarr area, is a typical representative of the fine grained type of epidiorite and was selected for analysis. It was taken as being representative because :-

1. It does not contain any problematical structures.
2. It is free from calcite. Those epidiorites containing this mineral are almost invariably associated with a limestone and therefore the presence of calcite may indicate a migration of $Ca\ Co_3$.

Macrascopically it is a medium-fine grained green rock with small white blebs of feldspar up to 1mm. in diameter scattered throughout. Microscopically it shows the fine grained ground mass to be composed of thin hornblende laths and some chlorite, in which are set irregular shaped albite grains containing small crowded inclusions of pistacite, hornblende, chlorite, occasional clinozoisite and very small granules of sphene. In addition to the albite occasional large flakes of biotite, a few grains of quartz and a small amount of iron ore are also present. Definite elongated areas up to 3 -4mm. long are present in which the albite is clearer and comparatively free from inclusions, and the hornblende laths are larger (Fig. 33A & 33B.). Other rounded areas are found which may be composed entirely of clinozoisite or an association of chlorite and clinozoisite, their boundaries being marked by a thin line of granular sphene. These areas appear to represent some form of

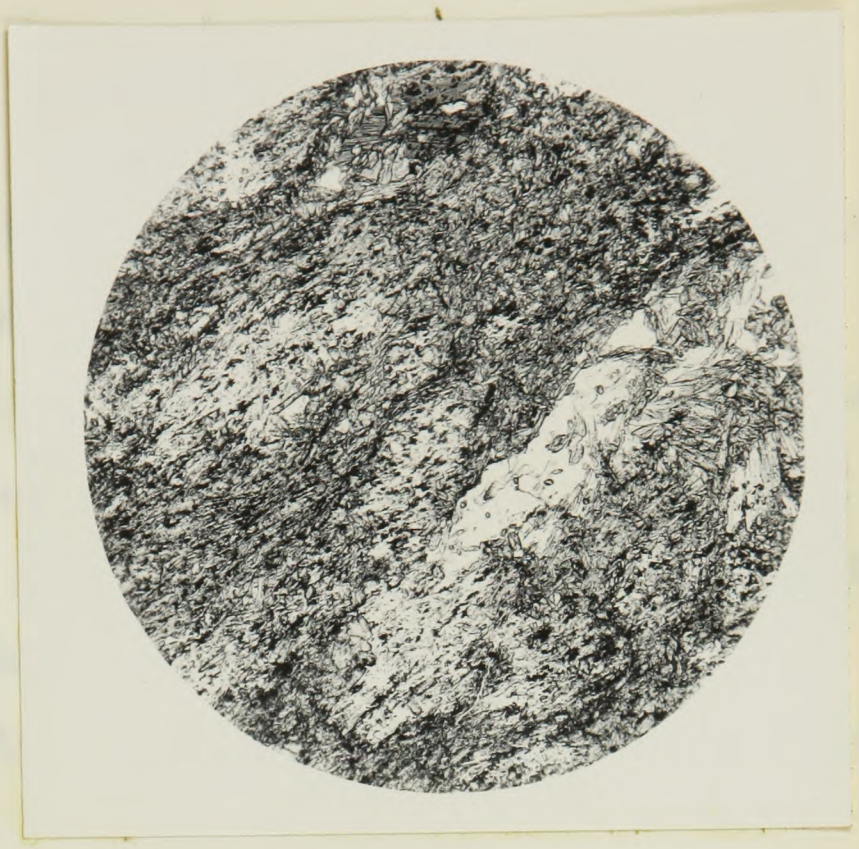


Fig. 33A. Ordinary light x 5.



Fig. 33B. Crossed nicols x 5.

Photomicrograph analysed expidiori

Specimen M322.

Roadside quarry, Castlebar -

Glenisland road, G.R. 172516.

	1	2	3	4	5
SiO_2	49.02	49.85	46.61	49.06	50.71
Al_2O_3	15.07	16.90	15.22	15.70	12.29
Fe_2O_3	1.99	1.74	3.49	5.38	1.85
FeO	8.80	11.16	7.71	6.37	9.55
MgO	7.18	3.93	8.66	6.17	7.68
CaO	10.00	8.72	10.08	8.95	10.81
Na_2O	3.30	3.45	2.43	3.11	2.15
K_2O	0.51	0.31	0.67	1.52	0.45
H_2O+	2.42	1.00	2.07	1.62	0.28
H_2O-	0.11	-	1.10		0.10
TiO_2	1.93	3.32	1.81	1.36	3.08
P_2O_5	-	0.27	0.10	0.45	0.29
MnO	0.15	0.30	0.13	0.31	0.12
TOTAL	100.28	99.95	100.08	100.00	99.96

CALCULATED C.I.P.W. NORM.

	1	2
or.	1.67	1.67
ab.	27.77	28.82
an.	25.58	30.02
di.	20.52	10.27
hy.	7.84	21.13
ol.	8.65	-
mt.	2.78	2.55
il.	3.65	4.41
ap.	-	0.34

APPROXIMATE MODE.

	1
quartz	2
albite	22
hornblende	55
chlorite	8
biotite	2
epidote	8
sphene	2
iron ore	2

1. Epidiorite, Rahsenbarr, Castlebar, Co. Mayo, Eire. Anal. E.A.Vincent.
2. Biotite-epidote-albite-amphibolite, 0.2 ml. N51E, N. end Loch-na -Craige, Acha hoish, South Knapdale. Anal. J.D.H.Wiseman. Q.J.G.S. 1934 vol.90 p.379.
3. Olivine basalt, Drynoch (Skye), Anal. W.Pollard, A.Harker, 'Tertiary igneous rocks of Skye', Mem. Geol. Surv. Scot. 1904, p.51.
4. Average of all basa lts, R.A.Daly, 'Igneous rocks and the depths of the earth', 1933, p.17.
5. Average of 28 analyses of lavas of Kilauea, and Mauna Loa, Hawaii. C.E.Tilley, Pres. Add. Q.J.G.S. 1950 vol. 106 p.41.

TABLE 2. CHEMICAL ANALYSES OF EPIDIORITES AND RELATED ROCKS.

segregation but they are not thought to be similar to the problematic spherical structures to be described shortly.

Given in table 2, are analyses of comparable rocks, both igneous and metamorphic, together with Daly's average for all basalts, and Tilley's average of 28 analyses of basalts from Hawaii. They indicate the basic igneous character of M322, although its total amount of iron is lower, and with the exception of the Hawaiin averages the lime content is higher.

Other types in the Raheenbarr region may show greater percentages of epidote (both clinozoisite and pistacite) or sphene, while some contain more albite. There appears to be a relationship between the amount of epidote mineral present and the amount of chlorite. The chlorite in these cases is often demonstrably a decomposition product of hornblende. Thus the lime has taken up silica and alumina to form epidote. Wiseman (1934), in discussing the retrograde processes of epidiorites notes that calcite is invariably associated with the retrogression of hornblende to chlorite. In these rocks however, calcite is only of sporadic occurrence and is mainly to be found along the lines of major dislocation where however they are frequently in close association with limestones.

Problematic structures in the Epidiorites.

Spherical or egg-shaped structures of variable mineralogical constitution are commonly found in the fine grained epidiorites of the Raheenbarr and Windy Gap areas. They are rarely greater than 0.5mm. in diameter

The spherical type can be seen in specimen M268 from one of the lenticular structures at G.R. 157508, in the Raheenbarr area. Photographs of sections cut (Figs. 34A, 34B & 34C.) in three directions at right angles to each other show an outer zone 1 grain thick of



Fig. 34A. Ordinary light x 10.

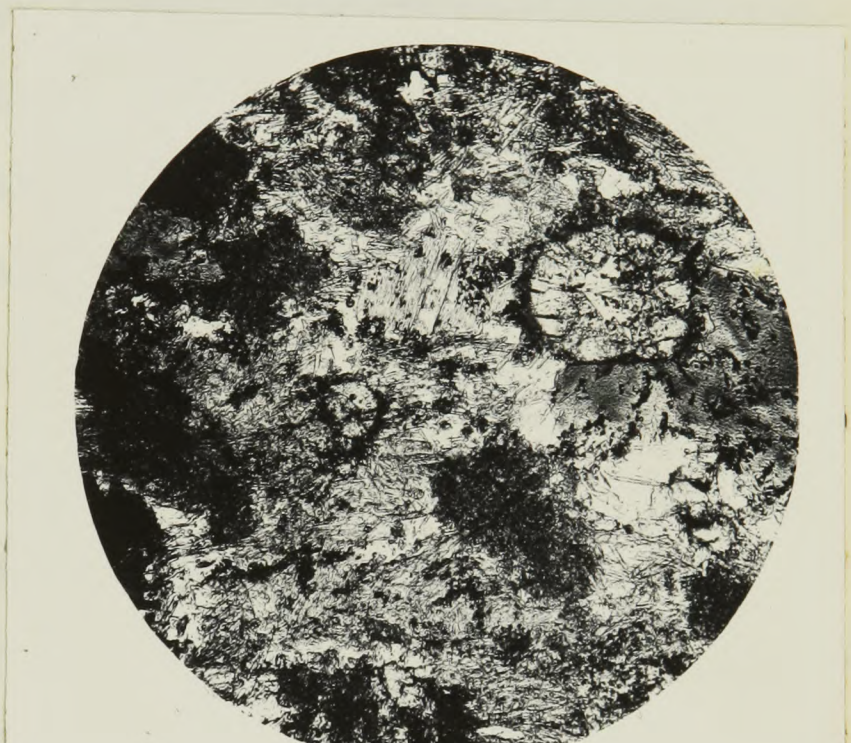


Fig. 34B. Ordinary light x 10.



Fig. 34C. Ordinary light x 20.

Spherical bodies composed of outer rim of epidote (pistacite) and a core of albite and quartz. These three sections are cut at right angles to one another.

Epidiorite, specimen M268.
1 mile S.W. Raheenbarr hill. G.R. 157503.

pistacite which consists of an outer area highly charged with minute inclusions and an inner area which is clear. The two areas are in optical continuity with a sharp junction between them which may be seen from the three sections to be a spherical surface. The central core can be either epidote (clinozoisite or pistacite) or an association of quartz and clear albite. In some cases the spheres are not as well defined as this, but have their external surface marked by a rim of very small granules of epidote.

The egg-shaped structures are best seen in specimen M203, found a few yards away from M268 at G.R. 157508. In long dimension they may be 0.75mm. The outer edge consists of a layer of fine, granular epidote which is succeeded by a thin layer of hornblende. The interior of the structure is made up of large irregular grains of pistacite or clinozoisite, hornblende, and albite, (see Fig. 35A & 35B.) . Others possess a thicker outer zone of epidote and an inner one entirely made up of albite with scattered, thin hornblende laths. In all cases these structures are set in an essentially amphibole groundmass with the hornblende laths flowing round them.

When considering the possible origin of these structures, the following points must be born in mind.

1. They occur in a rock that is wholly recrystallized, i.e. there are no relict textural structures.

2. Shearing though widespread is not intense and is confined to definite bands.

3. The epidiorites from all areas, Glenisland, Raheenbarr, and Windy Gap appear to be in a similar state of alteration.

4. The state of metamorphism of the sedimentary succession lies within the biotite zone in Glenisland, biotite and just within the garnet at Raheenbarr, and

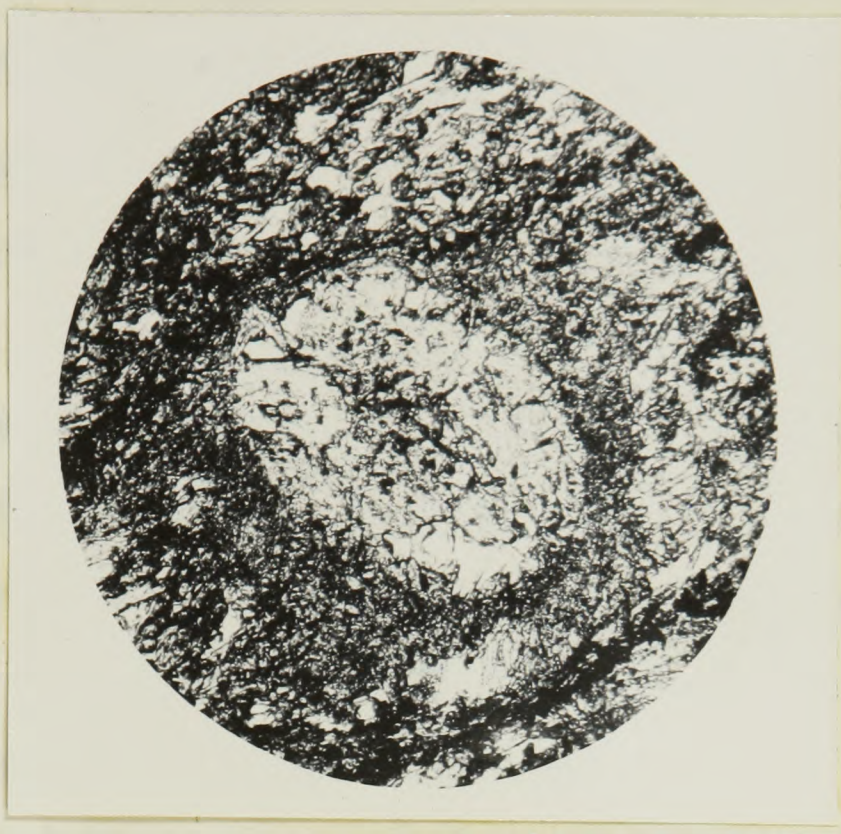


Fig. 35A. Ordinary light x 20.



Fig. 35B. Ordinary light x 20.
Egg shaped structures in epidiorite composed of an outer rim of epidote and hornblende, and a core of albite and quartz.
Specimen M203.
1 mile S.W. Raheenbarr hill, G.R. 157508.

garnet in the Windy Gap region.

5. The structures are frequently perfectly spherical. There are two main possibilities concerning their origin :-

1. That they represent an original mineral which has recrystallized to give the association of epidote, and albite and quartz. It is difficult to suggest a suitable mineral without invoking considerable metasomatism for which there is no evidence. Further the small amount of chlorite present as a decomposition product of hornblende indicates that there has not been very extensive retrogressive metamorphism. Wiseman (1934) (p.399). This is further supported by the presence of albite feldspar.

2. That they represent relict structures of original rocks e.g. amygdals or vesicles in an original dolerite or basalt. Thermally metamorphosed vesicles have been described by many workers from the tertiary basalts of the west of Scotland (in Skye by Harker 1904 p. 50) in Mull by McLintock 1918), which show a regular zonal arrangement of epidote and albite with occasional hornblende which has developed from scolecite, prehnite and augite. The mineralogy of the structures is consistent with the recrystallization of zeolite and feldspar vesicles. It may be noticed that they are always found in fairly close proximity to the bands of coarse epidiorite and never elsewhere. Although no junctions have been observed it has already been indicated that these are probably later dykes. The suggestion is therefore made that the structures represent original vesicles in a fine grained basic igneous rock which was thermally metamorphosed by later dyke intrusion which preserved the vesicles. Then on the general regional metamorphism to the biotite grade they remained essentially unaltered.

Epidiorites with vesicular margins have been recorded

by Peach (in Hill 1905 p. 70) from Glen Domhain in Argyll. The vesicles are usually globular and are set in a fine grained rock rich in chlorite, epidote, and porphyritic feldspar. From Peach's description however, it is not clear how far a comparison may be made. He does not give any indication of the degree of metamorphism nor of the nature of the contents of the vesicles.

Coarser grained epidiorites.

The coarse grained types occur only in the main Raheenbarr and in the Windy Gap masses.

In hand specimen they are coarse grained and light green in colour, showing a rude schistosity due to the size (up to 5mm. long) of the amphibole which makes up most of the rock. Specimen M311 from the western slopes of Sheeans hill (G.R. 388893) is typical. Under the microscope the large laths of fresh hornblende (X = pale yellow, Y = green, Z = blue green) are set in an albitic groundmass containing also some clinozoisite. There is very little original chlorite, and only a moderate amount of biotite. As with the fine grained epidiorites there is little evidence of retrogression except where shearing has occurred. In which case, hornblende becomes altered to chlorite with the development of calcite.

C. METAMORPHISM OF CASTLEBAR DALRADIAN SERIES.

The lowest grade of regional metamorphism occurs in the Ardvarne grits where chlorite is typically present in the fine grained phyllitic bands as well as in the matrix of the coarser grits. The main part of the alteration of this series is however, dynamic. As has already been described, the coarse pebbles show considerable elongation lying in a N.E. - S.W. direction, together with crushing of the constituent grains. (Map No. 5)

Pelitic bands in both the Glenisland and Raheenbarr groups show the presence of biotite with development of chloritoid in those parts rich in alumina and deficient in magnesia, lime and potash. Biotite does not occur in any great abundance in the soda rich albite bearing schists, in fact it may be absent. From the abundance of both chlorite and muscovite it appears that its development is to some extent inhibited or retarded by the presence of abundant soda.

In the Raheenbarr group the presence of a few small (rarely larger than 0.25 mm. in diameter) pale pink to colourless euhedral garnets in the albite schists, is noteworthy. They show a small amount of alteration to penninite chlorite. On account of their smallness of size and paucity it has not been possible to separate them to apply chemical tests to ascertain their type. The small amount of biotite present shows varying stages of decomposition to Penninite chlorite, with anomalous blue interference colours, whereas the remainder of the chlorite exhibits anomalous brown-green interference colours under crossed nicols. This distinction between the two types is regarded as significant, the former being retrograde the latter primary. The status of garnet here is uncertain.

The analysis of albite schist M321 (see Table 1 Anal. 1) shows 0.10% Mn O. Goldschmidt (1920 p.47) in the

Stavanger district of Norway has shown that spessartite garnet may make its appearance well before biotite in a rock containing 0.41% Mn O. In the Delabole slates of North Cornwall Phillips (1928) has described the occurrence of small garnets of spessartite-almandine type containing 12.5% of the spessartite molecule in a chloritic rock showing 0.15% Mn O on analysis, while Tilley (1923 p.190) comments on the early appearance of garnet containing 12.8% of the spessartite molecule in quartz- muscovite-chlorite- albite garnet schists which he describes as neither normal sediments or true igneous rocks.

Since normal pelitic rocks are rare in the Raheenbarr group it is not possible to make a direct comparison with the soda rich greywacke type of rocks to ascertain the true grade of metamorphism in terms of Barrovian zones. It is therefore necessary to look for other evidence, which for the most part is circumstantial. The coarse parts of the pebbly grits do not show any great degree of recrystallization which might have been expected in the increased pressure - temperature conditions of the almandine zone. Biotite, although in varying stages of alteration to Penninite chlorite, cannot be said to be anywhere prominent.

On this slender evidence coupled with Phillip's record of spessartite garnet in a rock containing 0.15% Mn O, the exact position of the group with respect to the almandine isograd is uncertain. In any case even if the garnet is almandine the smallness of the grains and its comparative rarity indicate that the albite schists are only just within the almandine zone.

Garnet is a prominent constituent of the mica schists of the Windy Gap group. As in the case of the Raheenbarr

albite schists it is present in rocks which are rich in albite, chlorite and muscovite with little or no biotite. The degree of recrystallization as indicated by the large grain size is regarded as implying that the garnet is almandine. The micas are invariably bent or in some cases broken while the albite porphyroblasts show evidence of rotation during growth, which indicates that the micas are of early development and have been pushed aside during the growth of albite as a stress mineral which took place during the application of stress resulting in minor folding.

The metamorphism of the Derryharriff group has reached the garnet zone which was complete before the application stresses produced minor folding. Garnet present in the pelitic bands e.g. M 123, is decomposed at the crests of the folds and is folded. These rocks are also sheared with minor folds sliced in parallel layers. Thus two tectonic episodes can be distinguished, one para metamorphic and one post metamorphic which was mainly a shearing episode.

Relics of biotite are common throughout both the Commauns and Shanvoley groups, but owing to the highly sheared state of these quartzo-feldspathic rocks little more can be deduced concerning their metamorphism. Curved lines of inclusions in some albite of the Shanvoley schists e.g. M 318 show para-metamorphic movement was taking place together with the formation of shallow open minor folds. Later shearing has bent the micas and granulitized quartz and to a lesser extent feldspar. It is noteworthy that where shearing has taken place quartz is much more liable to granulation than is albite feldspar.

D. OBSERVATIONS ON THE ORIGIN OF ALBITE SCHISTS.

The problem of the origin of the albite schists has engaged Petrologists since Dalmer described them from the phyllites of the Erzgebirge Mountains of Lower Saxony in 1881. Thought has been directed along two main lines, firstly, that soda impregnation was necessary to account for the unusually high soda content, and secondly that a simple process of recrystallization of an original sediment under suitable conditions of heat and pressure was all that was required because sediments of a composition similar to that of the albite schists were by no means uncommon.

Clough (1897) in describing the presence of albite schists in the Cowal area, indicates that they occur in the more micaceous and chloritic beds. Further, they have a sporadic development both laterally and vertically. This feature was noted by Cunninghan Craig (1904) in the Loch Lomond region. In fact he ascribed the lateral variation as being due to increasing progressive metamorphism of a siliceous grit. Bailey and McCallien (1934) in describing the continuation of the Ben Ledi and Pitlochry beds from the S.W. Highlands into Ireland, comment that a re-examination of Cunningham Craig's thin sections shows his sequence to be one of intercalated quartz schists and albite schists. A common association of albite schists are phyllites and schistose grits. In the Loch Lomond and Cowal areas albite pegmatites are common. These are not found however in the Castlebar region. The albite frequently shows evidence of rotation during growth, as indicated by the curved lines of inclusions. Most minerals present show evidence of strain, muscovite flakes are bent, quartz gives an undulose extinction, but albite does not except in areas of intense shearing.

This type of soda rich schist is now shown to extend

for at least 280 miles from Loch Lomond (Cunningham Craig 1904) in the north east, through Cowal (Clough 1897) and down the length of Kintyre (McCallien 1929), across to Antrim (Bailey and McCallien 1934, Reynolds 1942) thence southwestwards to the Sperrin mountains (Hartley 1938) and to the Mayo area where, in addition to the Castlebar region they have been described from the Nephin Beg range, and Achill Island 40 miles further west. (Trendall 1953). Some workers, notably (Goldschmidt 1920) have shown that albite rich schists may result from large scale soda metamorphism of siliceous schists in association with trondjhemitic rocks. They may also be the end product of the recrystallization of a soda rich sediment, although Reynolds (1942) makes the somewhat surprising statement that no soda rich examples of unmetamorphosed geosynclinal sediments are known. Analyses of unmetamorphosed sediments which contain more than 2% of Na_2O, i.e. those which may be considered soda-rich, are not numerous. A selection of these is given in Table 3. Bastin (1909) set out the following criteria for the identification of metamorphosed sediments:- K_2O Na_2O; MgO CaO. Inspection of these analyses shows that the criteria are not always applicable. In all except analysis 6 of the Archaean greywacke, $Na_2O > K_2O$, and in only six of the fourteen (1, 2, 9, 10, 12, 14,) is MgO > CaO. Thus although the criteria may apply in the majority of sedimentary types, there are peculiar variations in which they break down. We are here considering unaltered sediments and since these do not show any definite common chemical feature Bastin's criteria cannot altogether be expected to be applicable to altered rocks.

The sediments that show a richness in Na_2O, which may or may not be greater than K_2O are mainly of a greywacke

type.

A greywacke has been defined by Tyrrell (1931) as "essentially an impure sandstone consisting of quartz and feldspar together with variable amounts of, (a) other mineral fragments, especially basic minerals such as augite, hornblende, chlorite, serpentine and iron ore, (b) fragments of basic igneous rocks especially of the greenstone and spilitic suites, (c) silty, muddy and calcareous matter which plays the part of cement." (Pettijohn, 1949). To this the Committee on Sedimentation, (1935 - 1936) added that rapid disintegration was essential. Pettijohn further indicates that the SiO_2 content is lower than in a normal sandstone, and that Al_2O_3, CaO, Na_2O, and K_2O tend to be high owing to the amount of detrital feldspar; and because of the derivation partly from basic rocks the amounts of MgO and Fe_2O_3 are higher than in arkoses. This is indicated by the amount of chlorite which gives the rock its characteristic colour. These features are all illustrated by the analyses of Table 5.

In geosynclinal deposits argillaceous and arenaceous rocks are intimately mixed. Deposition normally appears to be continuous and bedding is usually well marked. These in fact constitute the field features of greywackes which are characteristic of the margins of geosynclines. (Jones 1938).

The greywacke sequences show several important features. The coarser particles tend to be angular, although rounded pebbles are by no means uncommon, indicating rapid transport. The sequences tend to be of considerable thickness and to show indications of having been laid down in no great depth of water. Repeated graded bedding is common together with evidence of bottom

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO_2	56.00	68.84	65.11	66.91	67.58	65.05	64.37	61.52	61.39	60.51	57.72	59.25	63.81	62.96
Al_2O_3	11.16	14.54	15.49	15.50	13.47	13.89	13.09	13.42	16.97	15.36	19.85	17.91	15.17	15.38
Fe_2O_3	0.58	0.62	0.77	0.61	1.75	0.72	0.36	1.72	0.39	0.76	2.61	2.22	1.45	0.53
FeO	4.92	2.47	3.39	2.74	5.98	2.60	4.32	4.45	5.32	7.63	2.55	4.23	3.68	5.52
MgO	3.72	1.94	1.90	1.73	1.88	1.22	2.98	3.39	3.84	3.39	2.85	3.40	3.10	2.54
Ca O	9.80	2.23	2.82	2.54	3.95	5.62	3.49	3.46	3.21	2.14	5.39	3.25	5.88	2.52
Na_2O	1.80	3.88	4.01	3.79	3.95	3.13	3.26	3.73	2.78	2.50	2.36	2.47	2.49	3.76
K_2O	1.45	2.68	2.58	2.87	1.05	1.41	4.43	2.17	1.25	1.60	1.86	1.70	1.90	2.83
H_2O	3.50	1.95	2.60	2.16	-	2.58	1.24	2.39	2.50	3.53	3.40	4.09	1.17	2.92
CO_2	6.60	-	0.09	0.06	-	2.83	-	3.04	0.88	1.01	-	-	-	-
TiO_2	0.17	0.25	0.60	0.48	-	0.46	0.34	0.62	0.62	0.87	0.91	1.03	0.75	0.74
P_2O_5	0.18	0.15	0.22	0.17	0.12	0.08	-	-	0.19	0.27	0.30	0.27	0.23	0.05
MnO	-	-	0.08	0.11	0.27	0.11	-	-	0.12	0.16	0.09	0.09	0.28	0.16
BaO	-	0.04	0.07	0.08	-	-	-	-	-	-	-	-	-	-
ZrO_2	-	0.05	-	-	-	-	-	-	0.07	-	-	-	-	-
S	-	-	0.01	0.02	-	0.05	-	-	0.15	0.42	-	-	-	-
C	-	-	-	-	-	0.07	-	-	-	0.05	-	-	-	-
Cl_2	-	-	-	-	-	-	-	-	-	-	0.03	0.03	0.04	-
SO_3	-	0.15	-	-	-	-	-	-	-	-	0.09	0.05	tr.	-
Etc.	-	-	-	-	-	-	1.92	-	0.07	-	-	-	-	-
TOTAL	99.88	99.93	100.01	99.90	100.00	99.84	99.70	99.92	99.75	100.29	99.99	99.99	99.95	99.91

1. Greywa che, Newmain's, Dumfries-shire. Anal. W.H.Herdsman. Kennedy and Read, Q.J.G.S. vol.92 1936.
2. Franciscan sandstone, California. Talliaferro, Bull. Am. Ass. Pet. Geol. 1943 vol.27.
3. Greywache, W. Eweburn, S.E. Mount Ida, Naseby Survey District, New Zealand. Willia mson, Bull.39 N.Z. Surv. 1939.
4. Greywache, S.E. Mount Ida, Naseby Survey District, New Zealand. Williamson, Bull. 39 N.Z. Survey 1939.
5. Altered Franciscan Sandstone, Calculated free of CO_2 and H_2O. Talliaferro, Bull. Am. Ass. Pet. Geol. 1943 vol.27.
6. Greywache (Eocene), Washington. Anal. B.Bruun. Pettijohn, Sedimentary Rocks 1949.
7. Greywache, Knife Lake Slate, Jordon Lake, Minnesota. Anal. W.S.Ya rwood. A.F.Grout Jour. Geol. 1933 vol. 41.
8. Greywache, Average of 5,(Archean). after Todd. Pettijohn, Bull. Am. Geol. Soc. 1943 vol. 54.
9. Greywache slate, Knife Lake Slate, Knife Lake, Minnesota. Anal. A.F.Grout. A.F.Grout Jour. Geol. 1933 vol.41.
10. Greywache (archean), Manitou Lake, Ontario. Ana l. B.Bruun. Pettijohn, Sedimentary Rocks, 1949.
11. Greywache (miocene), Papua. Calcula ted free of $CaCO_3$. A.B.Edwards, Proc. Roy. Soc. Victoria, 1947. vol.60 new series.
12. Greywache mudstone,(miocene), Papua. Calculated free of $CaCO_3$. A.B.Edwards, Proc. Roy. Soc. Victoria, 1947. vol.60 new series.
13. Greywache(miocene), Papua. Calculated free of $CaCO_3$. A.B.Edwards, Proc. Roy. Soc. Victoria, 1947. vol.60 new series.
14. Greywache,(silurian), Pirn Quarry, Peebles-shire. Anal. W.H.Herdsman. E.K.Wa lton, Proc. Roy. Soc. Edin. 1955 vol.65.

TABLE 3. ANALYSES OF GREYWACHES.

disturbance in the form of slump structures. Although the depth of water was not great, deposition was at least below the level of wave action since such features as ripple marking and current bedding are normally not found. Carbonate rocks are not generally abundant probably on account of the rapid accumulation of detritus together with the muddy conditions that would occur in an area where unsorted material was deposited. Organic remains seldom occur either, again due to the rapid deposition. These then are the general features associated with the greywacke facies of the margin of a geosyncline.

The general characterstics of marginal geosynclinal sediments outlined above are reproduced in the Castlebar Dalradian series, which in spite of its not being possible to correlate the six groups into a stratigraphical succession all show the following features ;-

1. Variation in rock types.
2. Evidence of poor sorting of original sediment, especially in the pebbly grits.
3. General abundance of albite feldspar.

Recent work (Sutton and Watson 1955) in Banffshire points to the conclusion that much of the Upper Dalradian was laid down in comparatively deep water on an unstable sea-bottom. These conclusions are derived from a study of graded beds, slump structures and other features which have been compared with those of the British Palaeozoic the Oligocene of the Northern Appennines and the Flysch of the Alps.

While the graded beds, and occasional slump features found N.W. of Castlebar are by no means as good as those of Banffshire, the conditions of their formation were similar. An uplifted landmass lying probably to the north, from the evidence of the blue opalescent quartz

pebbles, was being rapidly eroded and re-deposited in comparatively deep water. Fluctuations in the height of the landmass are indicated by the variations in lithology observed.

The almost ubiquitous presence of albite implies that deposition from the landmass was rapid and that little time was available for weathering and decomposition of the original source rocks. Walton's study of the Silurian greywackes and that of Greensmith in the carboniferous of the Sheffield district show that finely divided alkali feldspar make up a large proportion of greywacke sediments. This is the type of original material envisaged by Cunningham Craig, Bailey and Harker, as giving rise to albite bearing schists as a result of regional metamorphism.

The evidence from this area of Ireland further emphasiges this view. It is a study of a succession of sediments as a whole that will give pointers to their origin rather than one rock type as has been done by some workers. In this connection trace element studies have considerable application and importance.

E. TECTONICS OF THE CASTLEBAR DALRADIAN ROCKS.

In view of the fact that each of the groups show different features of structure they will be dealt with individually before discussing the structure of the area as a whole. (Map No. 4)

1. Glenisland group.

The whole of this succession shows an easterly dip varying from 30° to 80° and with a N.-S. strike in the north which tends to swing round towards the east in the south.

There is a general pausity of minor structures, but where present they are poor lineations in the Lough Cashel schists and the micaceous beds above the quartzites, which plunge steadily S.W. at between 10° and 20°.

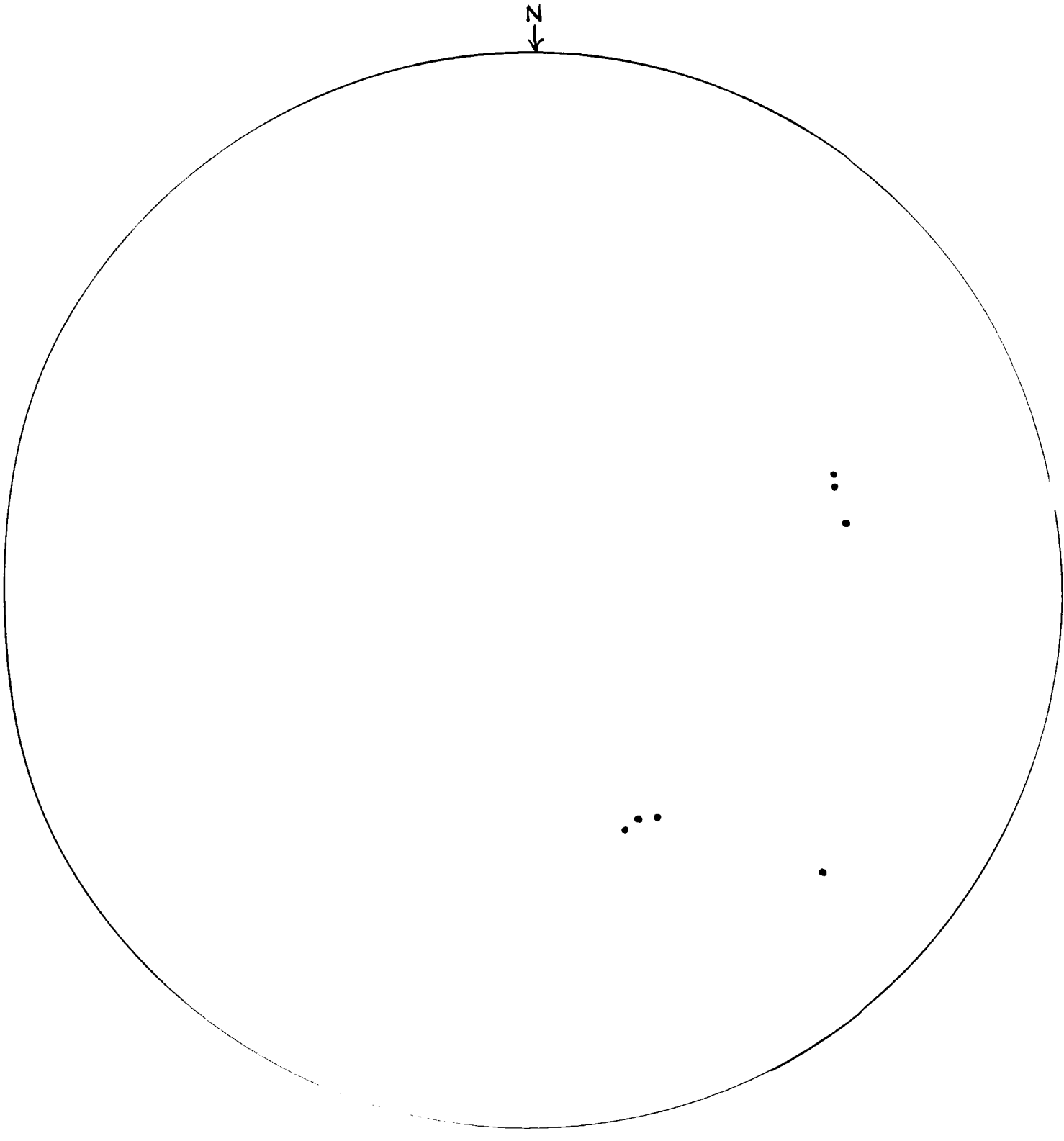
Two N.W. - S.E. faults between which pebbly grits occur immediately to the east of the epidiorite are probably comparatively minor dislocations. The general absence of exposures, however, makes further observation unwise. Although evidence of way up is only certain in the Brockagh grits, the whole sequence is regarded as the right way up, despite the occurrence of one isolated exposure of apparently inverted graded bedding (G.R. 106577). If this fault bounded strip of pebbly grit is regarded as inverted on this evidence, then the structure becomes unnecessarily complicated.

2. Raheenbarr Group.

This sequence strikes N.N.E. - S.S.W. and dips consistently eastwards at angles between 30° and 50°. Bedding as revealed by variations in the lithology of the pebbly grits and pelitic bands in the albite schists is homo planar with schistosity. The attitude of schistosity seen in the metasediments is also present in the epidiorites both in the west part of the region

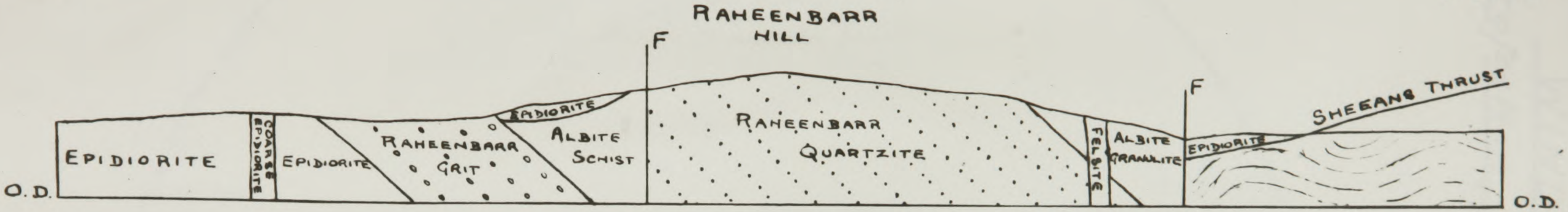
RAHEENBARR GROUP

Projection of Minor Structures.



W.S.W.
168540

E.N.E.
315585



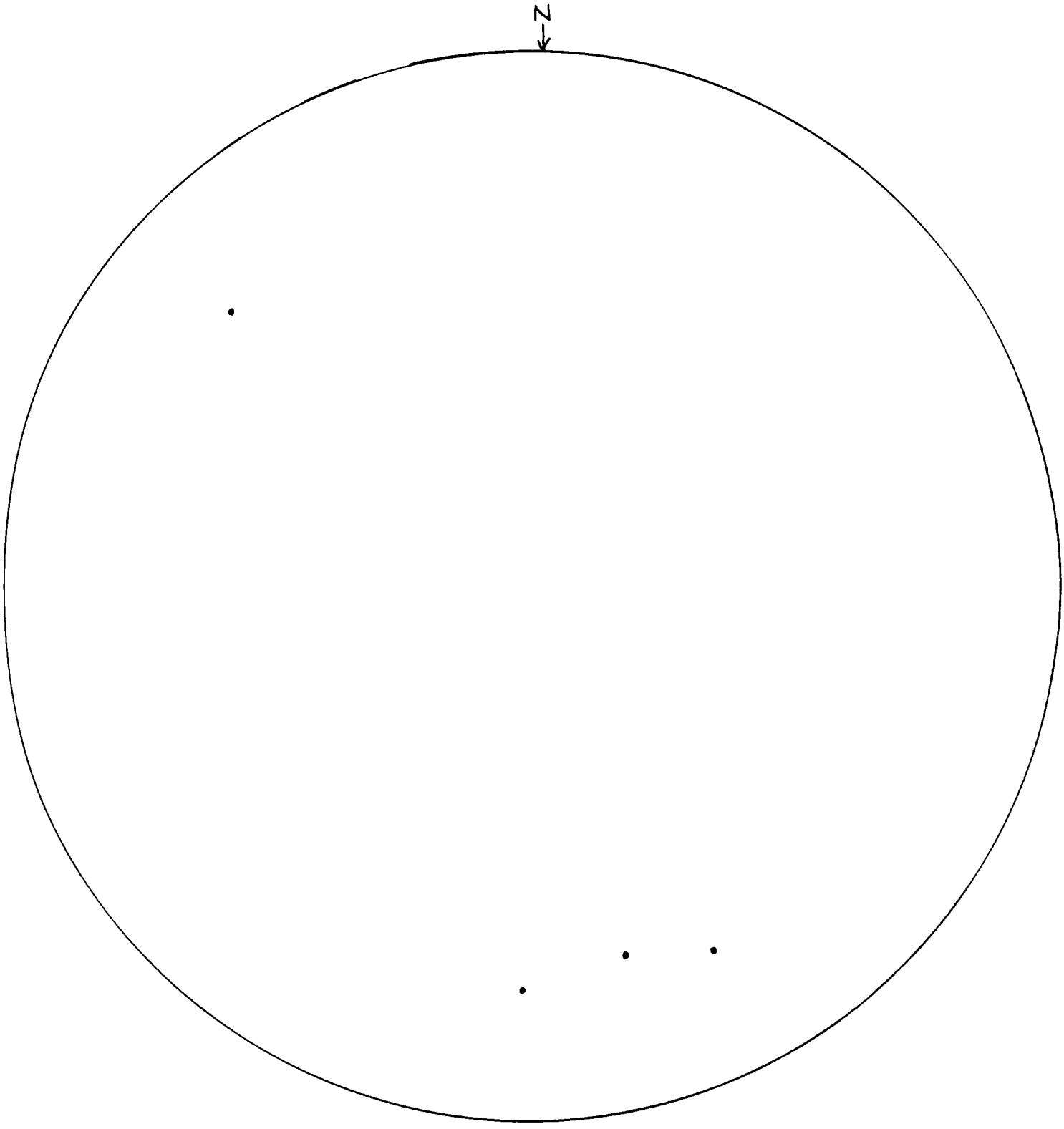
SCALE: 6" TO 1 MILE

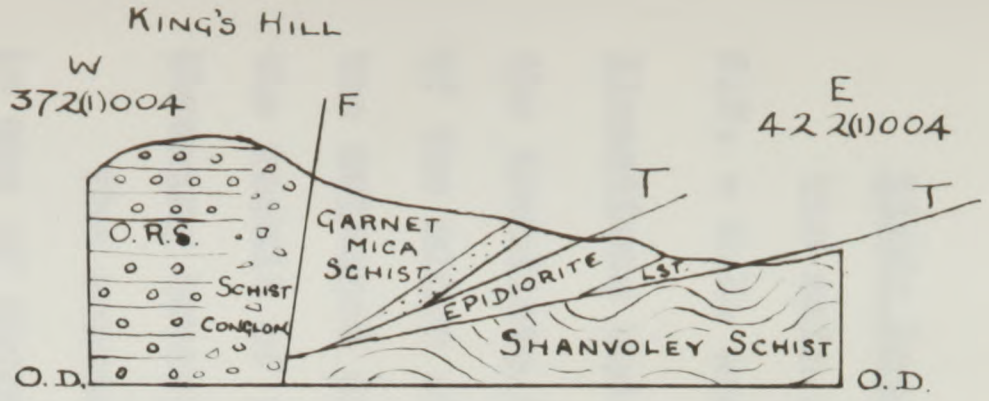
SECTION THROUGH RAHEENBARR GROUP.

SECTION 2

WINDY GAP GROUP

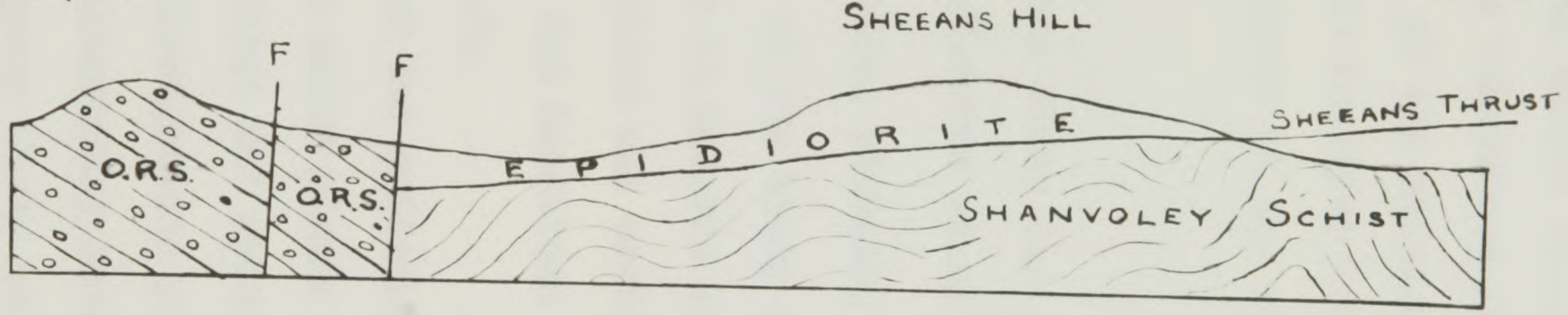
Projection of Minor Structures.





N.W.
533943

S.E.
424887



SCALE: 6" TO 1 MILE.

SECTIONS THROUGH THE WINDY GAP THRUST SHEET.

SECTION 3

and in the small dyke like mass immediately west of the top of Raheenbarr hill, and is shown up by the parallel alignment of albite porphyroblasts and chlorite flakes.

Fold mullions are found in the quartzites of Raheenbarr (Fig. 36) bounded by micaceous surfaces and plunge 40° S.S.E. In this same locality minor folds axes in micaceous quartz schist bands plunge 40° N. of E.

To the east of the Raheenbarr fault minor fold axes in the micaceous parts of the epidiorite plunge 25° S.W.

These discrepancies in direction are discussed under the general structure of the whole area.

Windy Gap.

The main mass of the Windy Gap group strikes N.W. - S.E. and dips S.W.wards at up to 50°, with lineations and minor folds, plunging S.E. at 25°. In the immediate vicinity of the Windy Gap fault the plunge of the minor structures is towards the N.W., and from the evidence of brecciation and contortion is obviously the result of post Old Red Sandstone movements down throwing towards the N.W.

The contact between the epidiorite and the limestone is one of shearing with shear planes dipping S.W. in the epidiorite within the first 20' above the junction, while minor folds and corrugations plunge 60° in the same direction in the underlying limestone.

Thus within this group there are three main structural directions indicated by minor folds. Those associated with the epidiorite-limestone contact are clearly in an 'a' direction, while the status of those developed in the garnet mica schist and at right angles to them is uncertain.

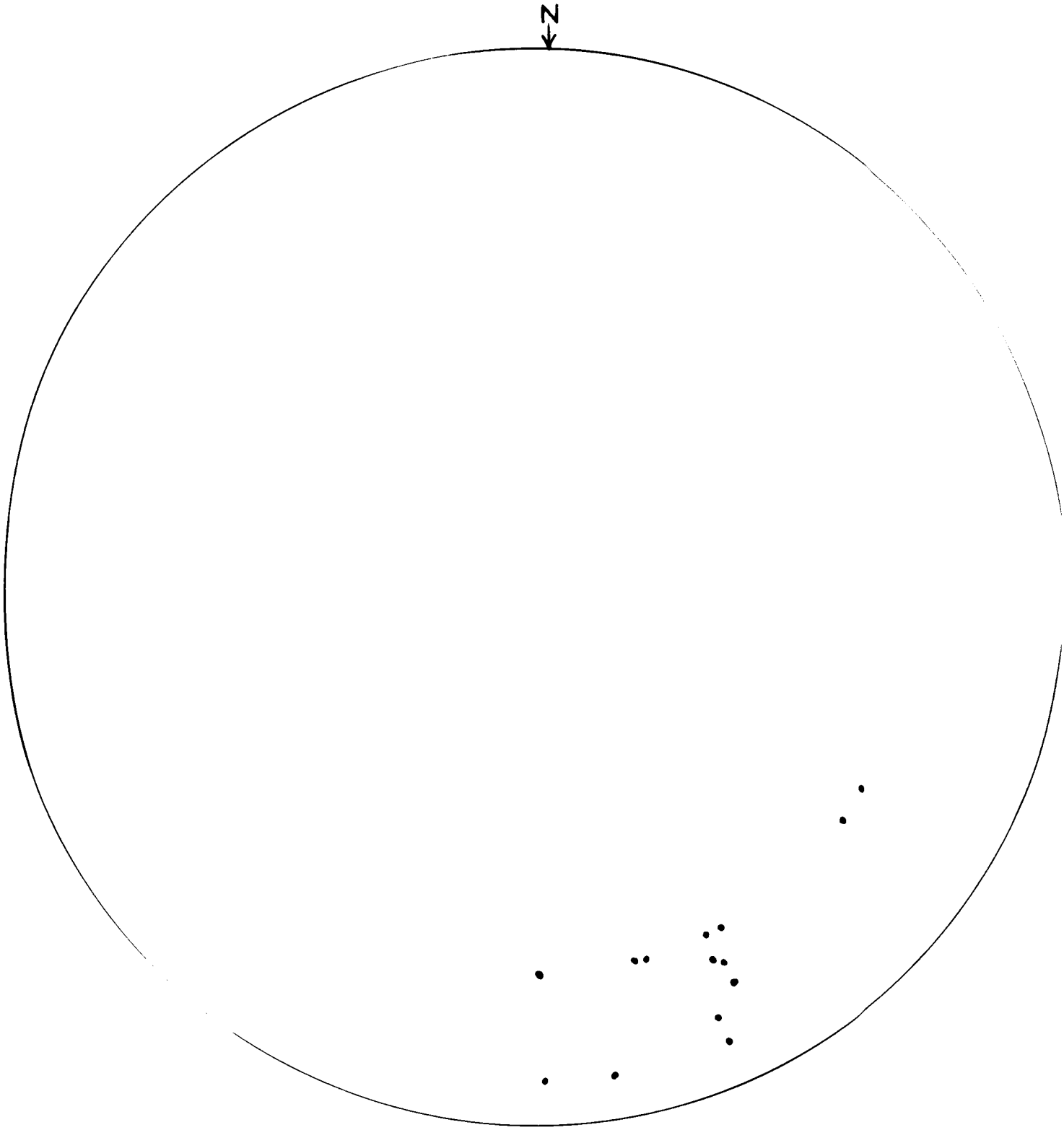
Derryharriff Group.

The absence of distinct mappable horizons renders



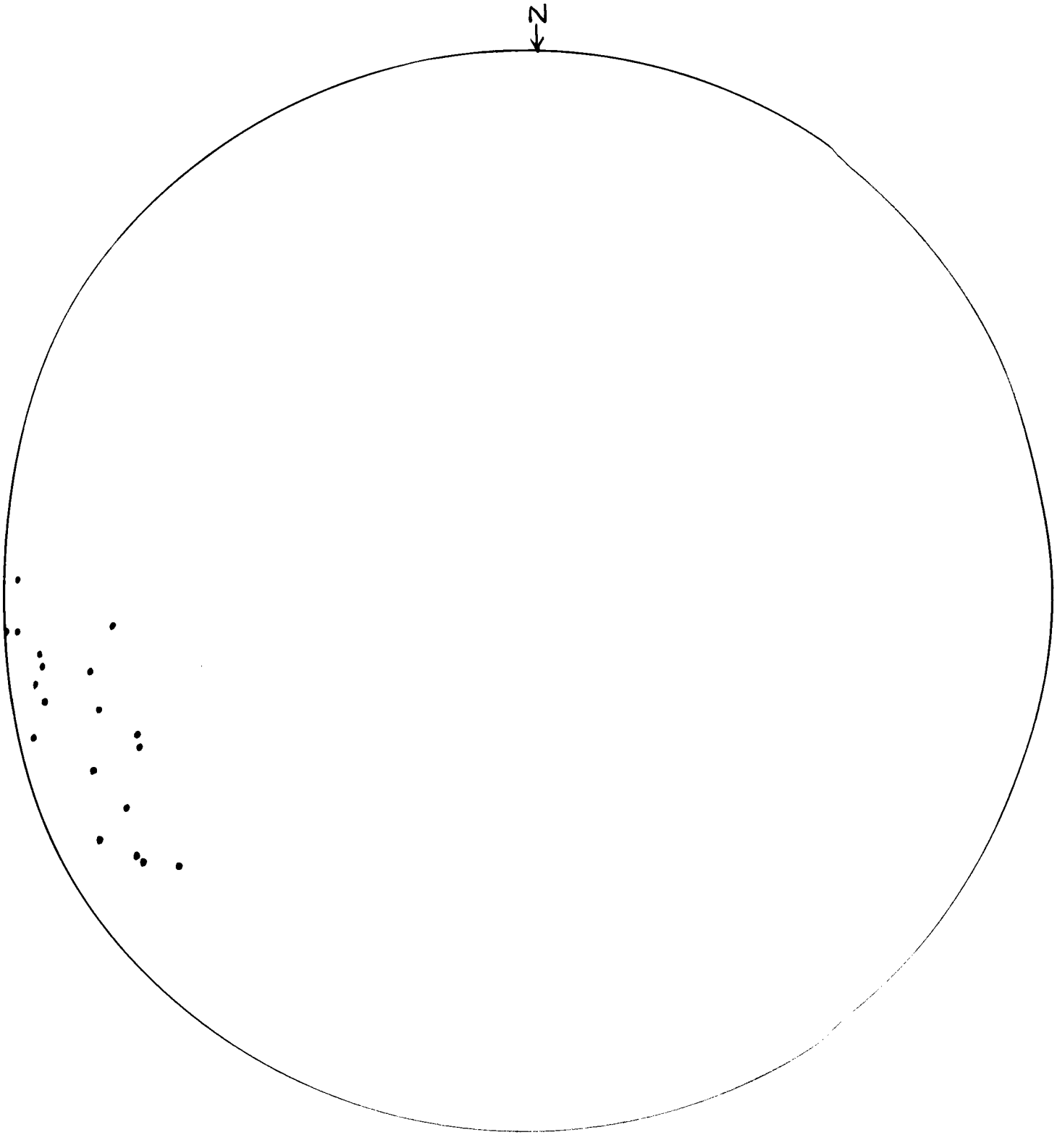
Fig. 36. Fold mullion structures in Raheenbarr quartzite.
South slope Raheenbarr Hill.
G.R. 249557.

DERRYHARRIFF GROUP
Projection of Minor Structures.



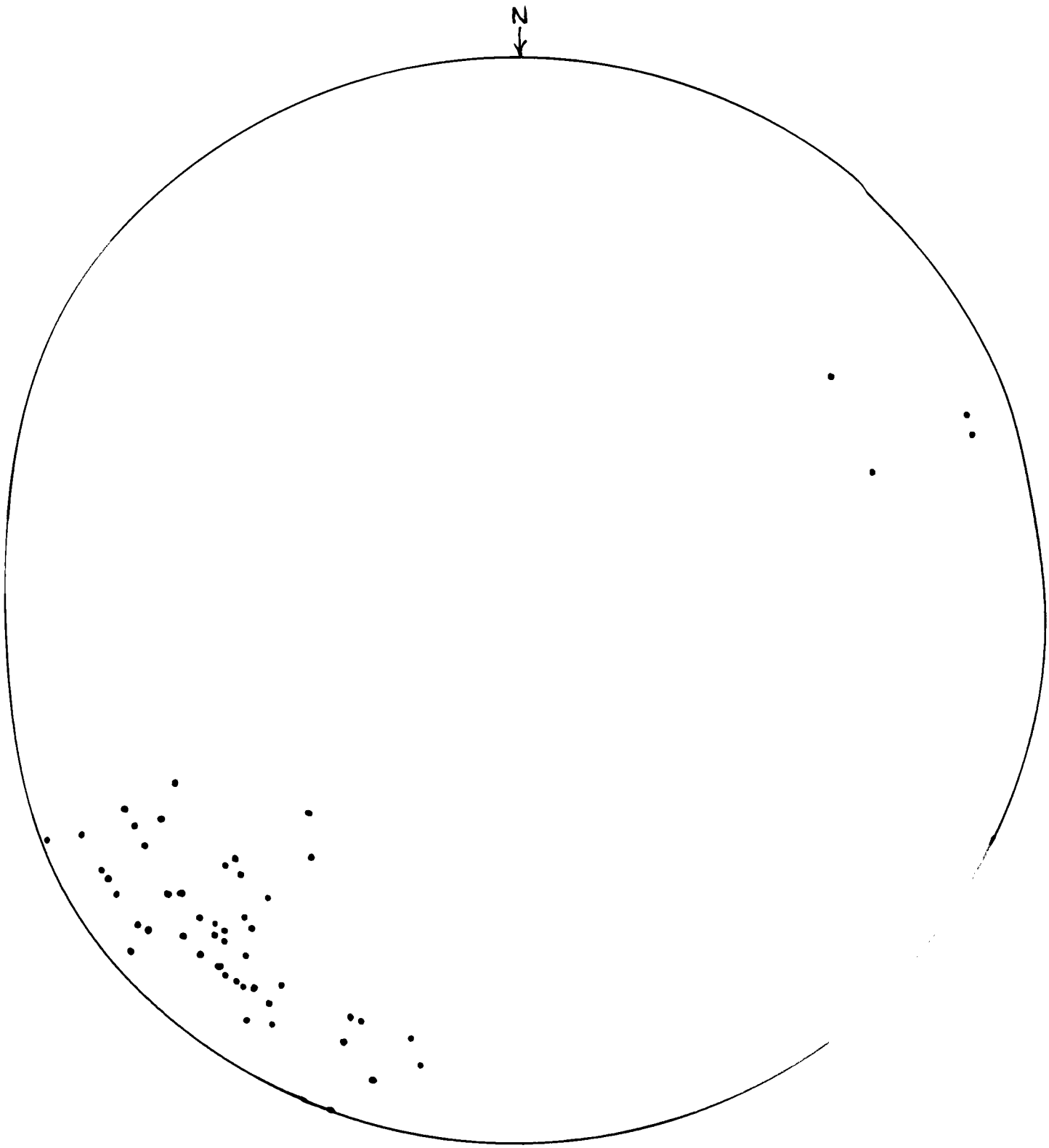
COMMAUNS GROUP.

Projection of Minor Structures.



SHANVOLEY GROUP.

Projection of Minor Structures.



it difficult to decide with certainty the general structure. However, the plotting of the axes of small scale folds (i.e. those with an amplitude of up to 300 yards) makes it possible to obtain a picture of the general trend. These small scale folds are open in character but normally have high dips (40° - 50°). They show that the general strike of folding is N.W. - S.E., except in the vicinity of the Raheenbarr area the folding swings round to N.E. - S.W.

The development of minor folds and lineation reflect the structure exhibited by small scale folds including the change in direction east of Raheenbarr.

At this point it may be pointed out that the general pattern of folding and lineation exhibited by the Glenisland, Raheenbarr, Windy Gap and Derryharriff groups is similar, i.e. it is predominently N.W. - S.E., see diagram of minor fold axes.

Commauns and Shanvoley Group.

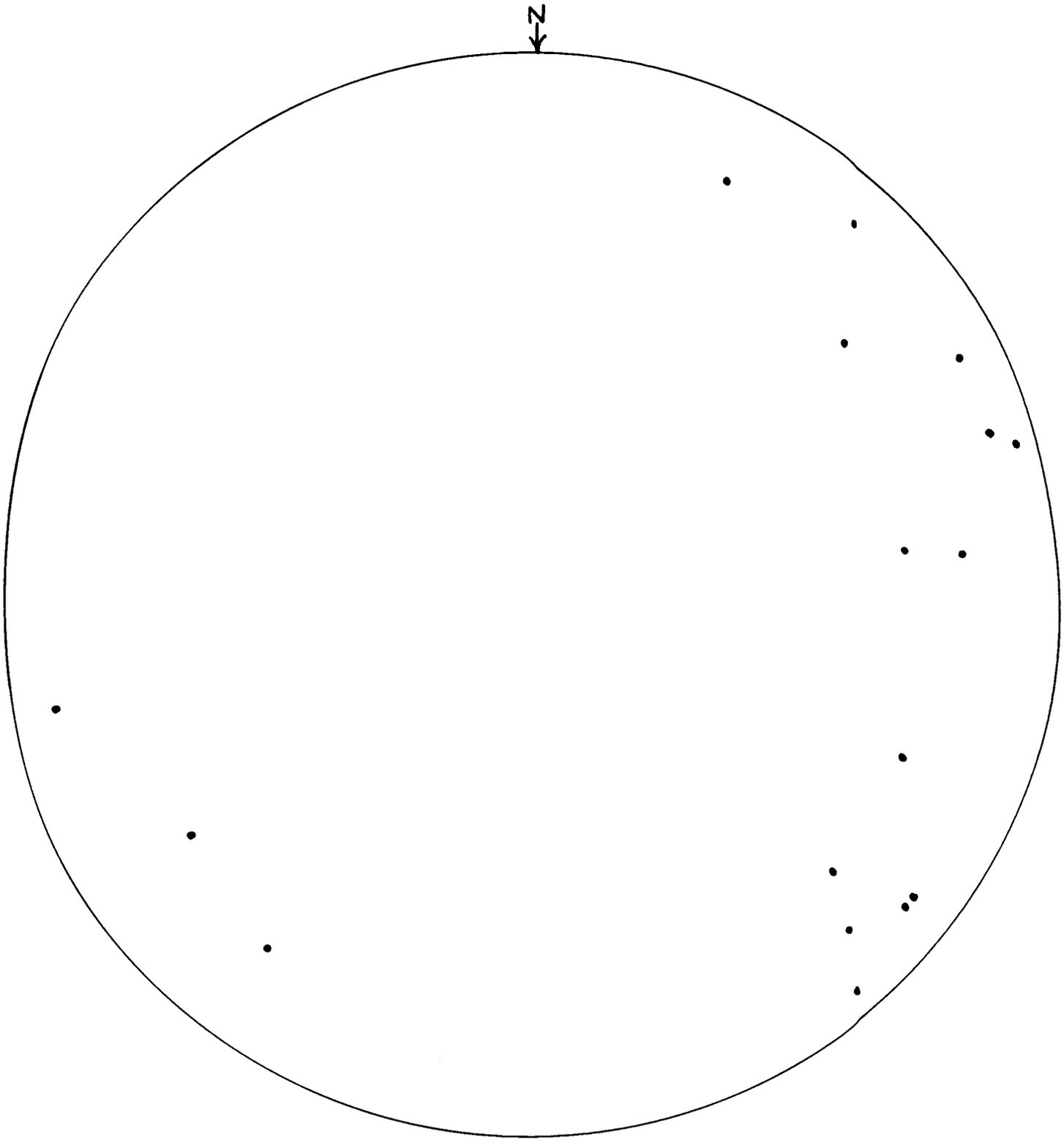
As in the Derryharriff group use has been made of small scale folds to obtain some idea of the structure presented by this group.

Minor fold axes together with lineation and quartz rodding in the more quartzose part of the succession all show a S.W. plunge at angles between 5° and 30°, while the small scale fold axes although trending in the same direction are irregular in their course.

In the Commauns region there is overfolding of the small scale folds towards the N.W., while in the Shanvoley district they can repeatedly be observed overfolded to the S.E.

The general form of the structures together with the constancy of the lithology suggests that a comparatively thin sequence is exposed in this area.

ARDVARNE GROUP
Projection of Minor Structures.



The main part of the Shanvoley area has not been mapped in detail. The reconnaisances that have been made however indicate that the structure is much more complicated than that outlined and in addition is probably highly faulted. In the north a sequence of micaceous quartzites are interbedded with the quartzo-feldspathic schists of the main part of the sequences. These show well developed minor folds plunging towards N.E. (see Fig. 21A &B).

Shearing which increases in intensity north and eastwards has been accompanied by movement in a N.E. - S.W. direction, as is indicated by the frequent occurrence of slickensiding on the sheared surfaces.

Ardvarne Group.

Small scale folds in the Ardvarne grits show a N.E.-S.W. trend with a variety of directions of minor folds axes and lineation. In the S.W. part it can be shown that the folding producing this trend is later than folding which produced the minor folds. Here the minor fold axes plunge in opposite directions on either side of the folds.

Towards the Conloon fault the fold axes swing slightly northwards into the fault line.

Elongation of quartz pebbles in the coarser parts of the series are normally parallel to the small scale fold axes and are probably associated with them.

Joints.

Joints are common throughout the whole of the Castlebar Dalradian series, and are best developed in the more quartzose horizons. They are of comparatively late development, being constant in their direction in all groups. There are two main sets one trending N.E. - S.W. the other N.W. - S.E.

IV. THE CONLOON FAULT ZONE.

The line of disturbance separating the typically Dalradian sequences, chiefly of the biotite and chlorite zone of metamorphism, from the higher grade schists, granulites and the acid injection complex further east is named after the townland of Conloon on the line of the fault zone.

The low grade grits and phyllites of the Dalradian immediately west of Slievenagark Lough (G.R. 440470) lie in a fairly shallow synclinal structure striking parallel to the fault which runs approximately along the line of the drainage dyke. Half a mile northwards they strike obliquely to this line and dip steeply N.W. away from it at angles of up to 80°.

The zone will be dealt with from south to north. There is little topographical evidence of disturbance in the area of the Carboniferous overstep. A third of a mile N.E. of Black Lough (G.R. 380399) a band of a hard, compact, brecciated rock may be traced approximately 20 yards in a N.E. - S.W. direction, but its relationship to the normal grits is not known. It is much cracked and haematite stained with a quartz infilling of cracks and joints showing up on the weathered surface. The thin section (Fig. 29) shows an intensely crushed and brecciated quartzose rock with lines of movement marked by narrow belts of very fine quartz. It probably represents a crush rock which has been recemented. Although it is suggested that the narrow belts represent lines of movement there are two features which make their nature problematical.

1. they possess a definite structure : either very fine grained with dark dust and a clear white margin, or very fine grained dark interior and a coarser wide clear margin, or wholly grains of clear quartz up to .75 mm. in diameter.

2. they may be seen to intersect each other and thus have a definite age relationship.

As the main fault is approached from the east the folded axes of the minor folded pelitic and semi-pelitic beds dip more steeply into the fault plane, indicating an effective downthrow direction to the west.

Beds which are essentially Ox Mountain complex in character, that is to say, garnetiferous, feldspathic, and highly micaceous, form a V shaped fault wedge 200 yards wide at the junction of the Windy Gap and Tawnykinaff roads (G.R. 425450), and disappear 700 yards to the north. They are in a highly contorted and crumpled state but even so indicate a general tendency to dip into the main fault plane. In thin section these rocks from near the fault plane show crushing. Angular fragments of quartz up to 2mm. in diameter, are set in a very fine grained matrix of quartz and mica. Further away the degree of intensity diminishes and the original garnet mica schist is recognisable.

Minor fault structures parallel to the main one follow the line of boggy hollows separating exposures of essentially differing rock type. Immediately to the west of Slievenagark Lough such faults separate a hornblende, feldspar gneiss, a sheared garnet, feldspar, chlorite schist, and a sheared quartz, muscovite granulite. Further north granitic veins in the granulite also display partial shearing and crushing. Other features associated with the fault zone are the shattering of the hornblende feldspar gneiss which in places cuts the granitic, gneiss and a general narrowing of the zone towards the sharp bend in the Clydagh river at the ford (G.R. 476584).

Along this part of the fracture line small isolated patches of serpentine occur, protruding from the bog cover. They consist entirely of a very fine grained fibrous

chlorite and are frequently associated with large patches of carbonate weathering to a rusty orange which in itself crushed and shows the development of curved glide lamellae. No trace of original minerals or textures are found in the serpentine. It would however appear to have been present earlier than the main part of the movement along the fault plane.

North of the ford on the Clydagh river the fault zone cuts through the southern end of the Farbreiga ridge and runs in a straight line along its eastern edge towards Pontoon, making a prominant fault scarp, in places rising to 200 feet from the gently undulating, ice worn table of the Ox Mountain granite gneisses. The zone itself is marked by a line of bog of varying width from 50 to 100 yards. Crushing of the granite gneiss is frequently intense and produces a green crush rock in which small fragments of quartz and feldspar may be recognised. (specimen M61).

As the ground rises towards the hills immediately west of Pontoon, the fault zone becomes prominent (as a topographical feature) although no further information has been obtained as to its nature.

The general twisting of the beds towards the plane of the fault indicates a sinistral movement, as well as the vertical displacement already indicated. Its character would thus appear to conform to that of the wrench faults of the Scottish Highlands (Anderson 1946 and Kennedy 1947).

V. OX MOUNTAIN SUCCESSION.

The Ox Mountain succession has only been investigated in so far as it was necessary to show its relationship to the Dalradian sequences to the west of the Conloon fault. The area mapped has therefore been arbitarily defined as that between the Conloon fault and the Castlebar-Pontoon road. It has not been mapped in detail nor has any investigation been carried out of the many problems that the succession presents.

The northern part of the area consists of a coarse epidotic granite gneiss which shows a transitional boundary into a succession of pelitic and psammitic beds within the garnet and sillimanite zones of metamorphism forming the southern flank and giving a diapiric form to the complex. In this region meta-sediments are only found on the southern flank, as the northern flank is lost beneath Lough Conn. Further north-east however towards Foxford the diapiric form is marked, with metasediments dipping away from the granite.

A. Paragneisses.

Psammitic and Pelitic beds.

The stratigraphical sequence of the Ox Mountain succession is as follows :-

Semi-pelite with feldspathic bands.

Garnet pelite.

Semi-pelite with psammitic bands.

Biotite pelite.

Flaggy quartzite.

Semi pelite with psammitic bands.

Field Occurrence.

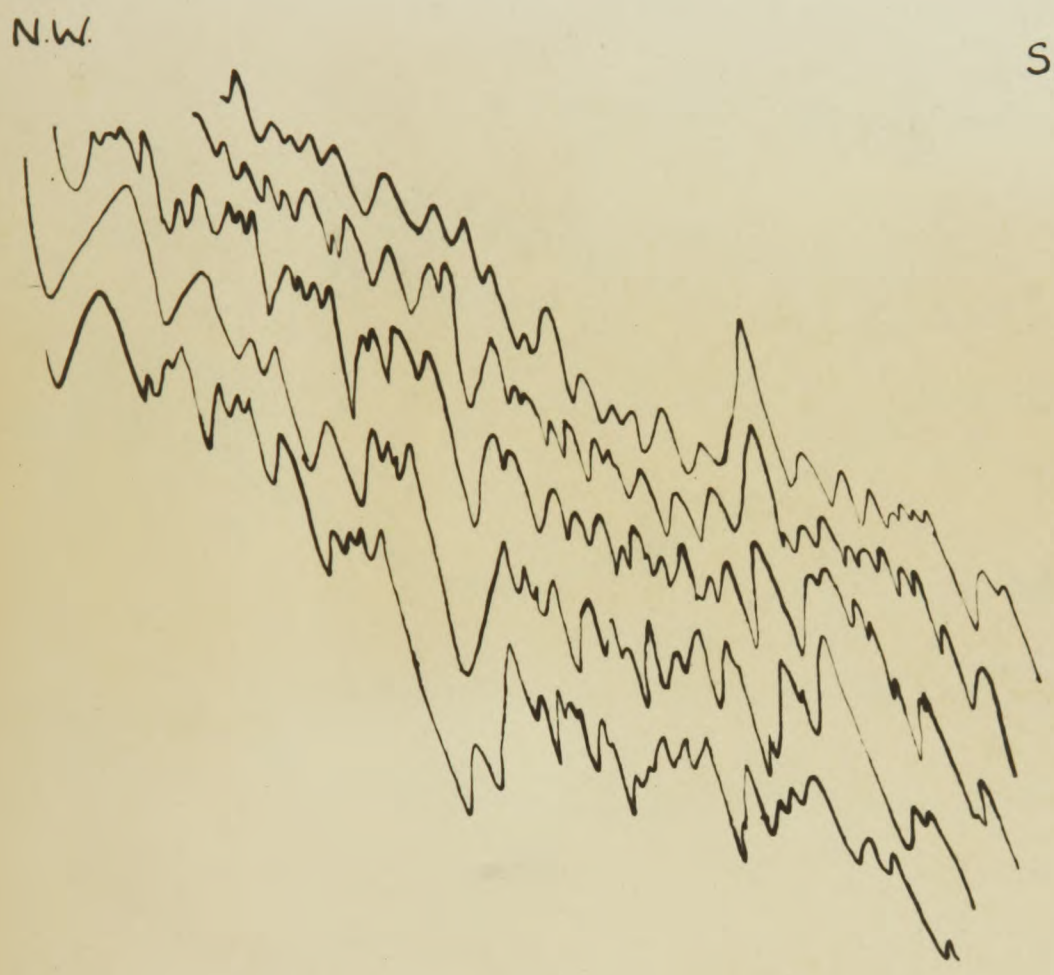
This sequence on the south east side of the main granite gneiss of the Ox Mountains is comparatively well exposed in flat glaciated areas of up to approximately a ½ mile square separated by bog. It provides a striking contrast to the more hilly region of the Castlebar Dalradian series to the west. Further east however, beyond Foxford the main part of the Ox Mountains rise to over 1500'. This tract approximately 5 miles wide running north to south rarely rises above the 200' contour, and marks the line taken by one of the northward moving glaciers (Charlesworth 1928).

The sequence is largely composed of semi-pelitic schists with minor psammitic or feldspathic bands which make individual parts of the sequence distinctive. These bands may vary in thickness from one inch to ten feet. Interbedded with the semi-pelitic schists are garnet or biotite bearing pelitic beds, and flaggy quartzites both of which form distinct mapping horizons. While distinct belts can be mapped, at their boundaries they tend to merge so that their position can only be regarded as approximate. The placing of these lines on the map is further complicated by the highly crumpled state of the pelitic and semi pelitic beds, which makes any estimation of thicknesses impossible. The more competent and uncrumpled psammitic beds show high dips towards the south east, while in the Clydagh river section they are frequently vertical or sometimes dipping steeply to the north west. In the crumpled pelitic and semi pelitic beds quartz layers with laminae composed of muscovite, feldspar with tourmaline, show the crumpling to consist of very tight folds with an amplitude up to three of four times the wavelength. This shows up particularly well on the

weathered surface where the quartz is seen to be thickened in crests and troughs of folds. The limbs of the folds are normally near vertical or steeply dipping to the south east, giving the appearance of a vertical schistosity on the flat glaciated surfaces. The axes of the folds show a consistant plunge to the south west of between 15° and 20° which steepen towards the line of the Conloon fault. The predominant south east dip seen in the psammitic beds may be distinguished by the longer limbs on south east side of the folds (Fig 37).

There is a concentration of feldspathic bands in the semi-pelite forming the uppermost part of the series, which contain large irregular feldspar grains up to 5 mm. in diameter. There is fairly abundant quartz within these bands, but it is scattered throughout the rock together with muscovite, and does not normally form individual layers as in the more typical crumpled beds. They are also associated with lenticular structures having tectonic boundaries. In some cases a sinistral sense of movement is indicated by the general schistosity being smeared into the N.E. - S.W. plane of movement. Their shape (Fig. 38) suggests that they are essentially tensional structures produced under conditions of some plasticity. Jointing is also common in a general north-south direction and may occasionally show small scale displacement of thin quartz veins on either side. The tensional structures are affected by the jointing which is regarded as being one of the last episodes in the structural history.

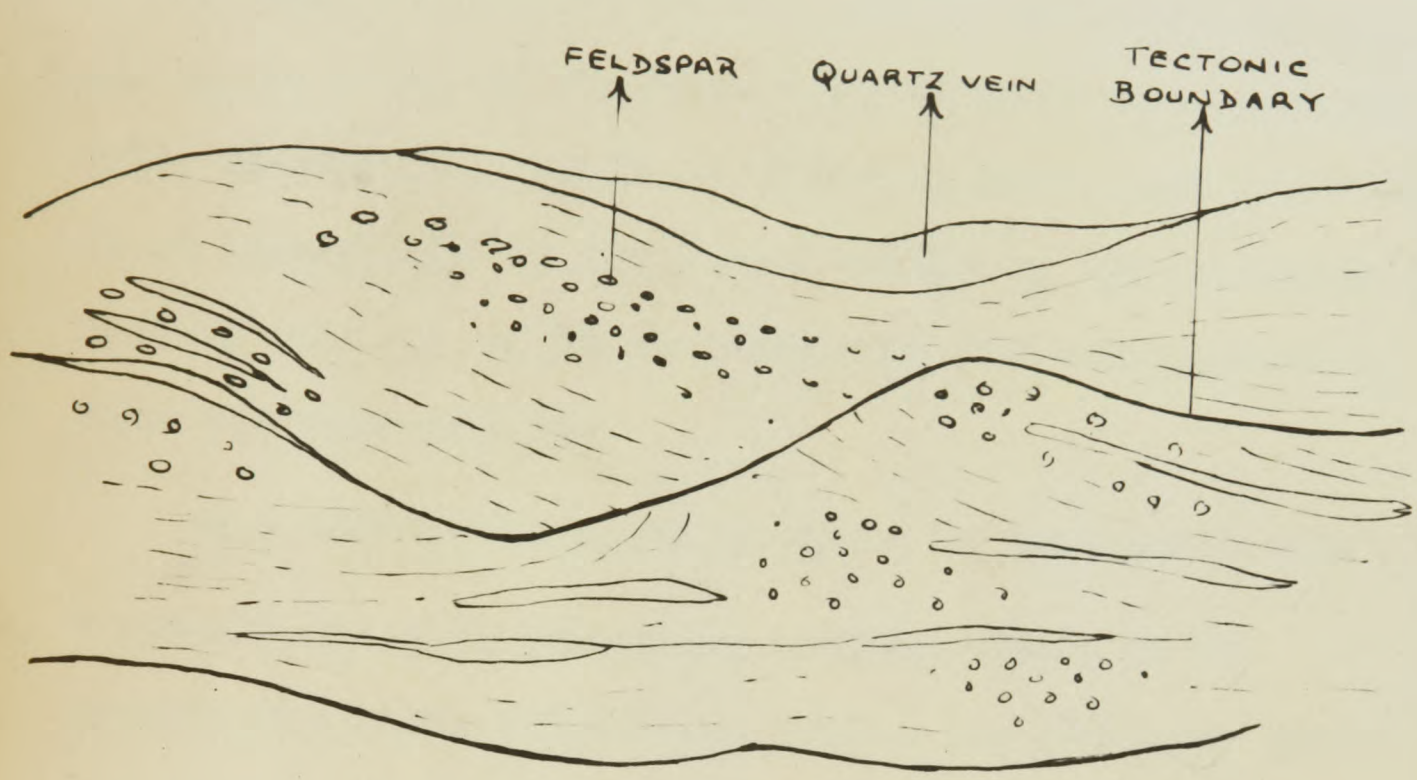
The psammitic bands are normally granulitic and weather to a light grey or brown colour and are thus easily distinguishable from the darker pelitic and semi-



MICRO-FOLDING IN GARNET PELITE (NATURAL SIZE)

LINES OF FOLD SHOWN UP BY QUARTZ RICH LAMINAE.

Fig. 37.



← 12" →.

'FLOW' STRUCTURES IN FELDSPATHIC PELITE.

Fig. 38.

pelitic beds. Thin laminae composed of biotite are common.

There is a band of flaggy quartzite approximately 50' in thickness well exposed in the Clydagh river section down stream from Conloon bridge (G.R. 498595) where it is dipping 45° N.W. It may be picked up further north-east along the strike (G.R. 560656) where it is lying vertical.

A belt of garnet bearing pelite in which the garnets are up to 1 cm. in diameter lies between two semi-pelitic belts immediately south of Slievenagark Lough (G.R. 440480). It is recognised in the field solely by the presence of visible garnet, as it is otherwise indistinguishable from the semi-pelite.

The semi-pelites and pelites in particular are traversed by thin irregular quartz veins, or by pegmatitic veins containing quartz and feldspar with occasional muscovite.

Petrography.

Psammitic beds.

These rocks are mainly coarse grained and in thin section show typically a granoblastic structure. Interlocking granular grains of quartz and feldspar show sutured margins which are more prominent in quartz together with strain shadows. The dominant feldspar is oligoclase which frequently shows multiple twinning (max. sym. ext. $L = 8^{\circ}$). Orthoclase normally is subsidiary to oligoclase and is invariably sericitized. The tendency towards flagginess is caused by the roughly parallel alignment of muscovite and biotite. Muscovite is always more prominent and in some cases may be the only mica present. This is the case in the flaggy quartzites (Specimen 1110)

where an interlocking network of granular sutured quartz with a small amount of oligoclase contains abundant small flakes of muscovite lying parallel to each other. (Fig. 39).

Microcline feldspar has not been observed in any of the psammitic rocks. The ratio of oligoclase to orthoclase is rarely less than two to one and normally is about five to one. There is noticeable increase in the percentage of orthoclase northwards towards the main granite mass. This however is probably due simply to stratigraphical variations in chemical composition.

Semi-pelites.

This group has been set up because it contains a group of rock types that do not conveniently fit into either the granulitic rocks of the psammites or the more micaceous pelites. Quartz forms approximately 50% with the remainder consisting of orthoclase and oligoclase feldspar muscovite, biotite, sporadic garnets, and iron ore.

In specimen M164 from G.R. 433429, the dominant feldspar is orthoclase with a small amount of oligoclase. These two and quartz are present in roughly equal proportions. Muscovite and biotite show up the general schistosity and tend to be located in definite bands. The biotite is pleochroic pale straw to olive green/brown. Scattered small fresh garnets are also present.

The wide expanse of semi-pelite with psammitic bands containing the thick granite gneiss veins and hornblende orthogneiss contains several bands which indicate a calcareous composition. In the field they are not sufficiently distinctive to be recognised as such. In one case M367 from G.R. 490505, from an isolated exposure



Fig. 39. Photomicrograph of flaggy quartzite. Ox Mountain series. Specimen 1110.

surrounded by bog, numerous sillimanite needles are present in oligoclase which form an interlocking network with biotite and a small amount of quartz. The pleochroism of the biotite differs from that already described in being pale brown to dark brown/black. Clinozoisite is of frequent occurrence and is associated with abundant sphene, which is either lozenge shaped or anhedral, and is pleochroic in shades of pale brown. (see Fig. 40).

Pelites.

The main pelitic belt consists of highly micaceous, garnetiferous and quartzose rocks. In the main they are coarse grained with occasionally finer grained bands. Red garnets are invariably present, showing rounded or subhedral outline. They are for the most part fresh and uncracked although hexagonal pseudomorphs of chlorite after garnet may be found. e.g. M171 from G.R. 430440.

Oligoclase is the dominant feldspar (R.I. = or R.I. > Canada Balsam) occasionally showing development of multiple twins giving a maximum symmetrical extinction angle of 6°. The grains which are 3 - 4 mm. in diameter are rounded or rectangular in outline and show sieve structure with included quartz. Orthoclase may also be present but is always in small quantity. In the more highly garnetiferous bands both types of feldspar may be absent, e.g. M368 from G.R. 525487, in which case the schist is entirely composed of quartz, muscovite, biotite and garnet.

Quartz forms thin bands often only one grain wide separated by micaceous laminae, or fine grained more or less equigranular grains in association with feldspar and mica. It invariably shows strain shadows.

Muscovite and biotite are abundant showing up the



Fig. 40. Sillimanite needles in oligoclase feldspar. Semi-pelite, Ox Mountain series.
Isolated bog exposure ½ mile S.S.W. Lough Naspleenagh. G.R. 490505.

minor folds characteristic of the semi-pelitic and pelitic beds. The longer flakes tend to be bent indicating that the minor folding is largely post-metamorphic. Biotite which is usually fresh shows distinctive pleochroism from pale straw to dark olive green/brown or black.

Accessory minerals are zoned tourmaline (dark olive green) often with a secondary development enclosing small inclusions of quartz, rounded to subhedral apatite, ilmenite altering to leucoxene, and pyrite which westwards towards the Conloon fault tends to be replaced by haematite.

Calc-silicate bands which are usually fine grained contain abundant pistacite in euhedral grains. In one such specimen M169 from 200 yards S.E. of Slievenagark Lough (G.R. 445455), short thin sillimanite needles are present in orthoclase.

B. Orthogneisses.

The igneous rocks of the Ox Mountain series are of two types. Firstly, the central core of the series is made up of coarse granite gneiss with which are associated dyke like veins that cut the meta-sediments parallel to the strike. Secondly, elongated lenses of hornblende orthogneiss also cut the meta-sediments and may or may not be associated with the granite gneiss.

Granite gneiss.

Field Occurrence.

The main belt of granite gneiss is at least four miles in width at the S.W. end of the Ox Mountain series and is shown on the one inch Geological Survey Sheets to extent North-east for approximately sixteen miles.

Throughout this area it is remarkably constant in its appearance. There are two main types : firstly, a coarse

grained pink granite gneiss which contains abundant pink and white feldspar with small amounts of mica; and secondly, a medium grained grey variety in which only white feldspar is present together with abundant dark mica. The former occurs over the main part of the region while the latter is found as irregular areas immediately south of Pontoon. (G.R. 785(1)140). Also in the Pontoon area beside the road (G.R. 818(1)070), pegmatite veins one to two feet across traverse the grey gneiss in a N.E. - S.W. direction, and consist almost entirely of feldspar with small amounts of quartz.

The granite shows a distinct vertical or highly dipping foliation parallel to the strike of the meta-sediments and the N.E. - S.W. line of the Ox Mountains.

In two places features of possible sedimentary origin are found. In a bluff 200 yards west of the Pontoon-Castlebar road (G.R. 767(1)024) a band 12 inches thick consisting of siliceous and micaceous bands is traceable the entire length of the 150 yard exposure. (Fig. 4 1). At some stage horizontal movement has taken place as indicated by slickensiding occurring between some surfaces of the siliceous and micaceous bands. There is no evidence of chilling or of absorption of the material into the main mass of the granite. The strike of the schistosity is parallel to the foliation of granite and they both also dip steeply N.W. Irregular blocks of medium to fine grained granulite, one to two feet across sometimes occur included in the coarse granite gneiss. (G.R. 563698). They show sharp boundaries and similar features to the other example. In addition the whole exposure is traversed by very coarse veins of pegmatite 2 - 12 inches across composed of euhedral feldspar crystals 2 inches long, quartz and mica.

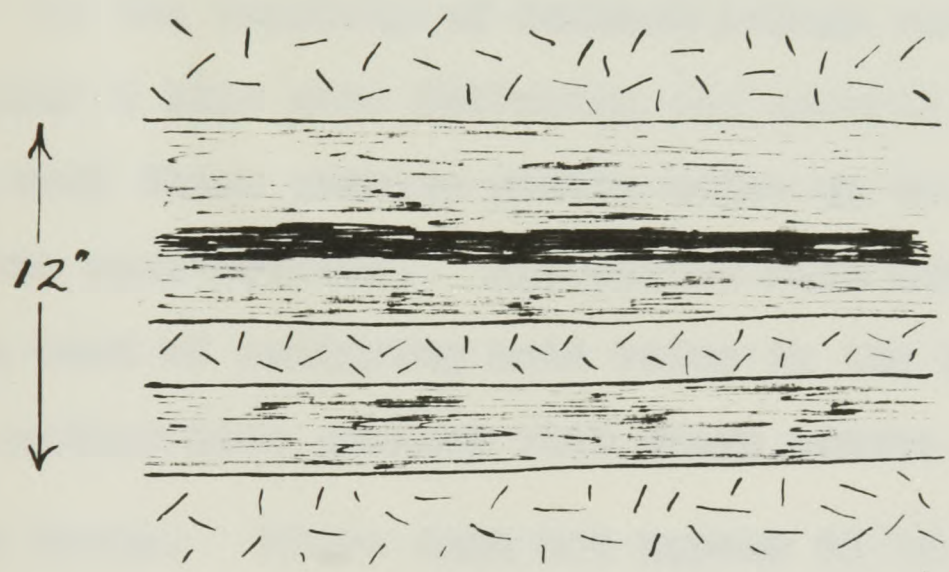


FIG. 41.? SEDIMENTARY GHOST STRUCTURE IN GRANITE GNEISS — 2 MILES SOUTH OF PONTOON.

G.R. 767(1)024.

The southern margin of the granite gneiss is a transitional one from a typical granite gneiss to a typical semi-pelitic schist, with lit par lit injection of granitic material between highly micaceous sedimentary material. Fine grained veins of granitic material traverse the whole transitional zone and in addition form a distinct belt parallel to the transitional gneiss, tending to be slightly transegressive to the general strike direction. Coarse pegmatite veins are also common in this zone but are irregular in development and transgressive to everything. The contacts are always sharp.

In the vicinity of Conloon Bridge and in a belt roughly a mile wide following the general strike coarse and very thick granite gneiss veins up to 100 yards occur in the semi-pelites. Associated with most of them, there is a band of ramifying acid veins in the schists. They are either fine grained with sharp coarse margins or vice versa. There does not appear to be any definite age relationship between them. In some cases one may be shown to be earlier, in others the other. This zone of injection dies out 100 yards south of the thick veins.

In several localities, particularly towards the southern margin of the main granite mass belts of an extra coarse variety occur about 20 yards wide. They do not show sharp margins and are distinguishable on account of the development of feldspar phenocrysts roughly subhedral and up to 5 cm. in length. The other constituents are on the whole no larger than in the normal rock.

Petrography.

Granite gneiss.

Coarse variety.

Pink Granite gneiss.

In hand specimen the pink granite gneiss shows a marked

foliation due to the orientation of micas and the slight elongation exhibited by both feldspar and quartz.

Thin sections reveals the rock as inequigranular with large rounded orthoclase grains up to 1cm. long and sometimes larger, and smaller plagioclase and quartz in a finer grained and partially crushed groundmass. Their margins are sutured and granulated with strain shadows commonly present. This feature is present throughout the granite gneisses whether occurring in the main mass or in the large veins, and is more highly developed in quartz than in feldspar. It may often be sufficiently advanced to be described as mortar structure.

Orthoclase is about four times as abundant as oligoclase. Small quantities of microcline are also present and frequently exhibit a myrmekitic intergrowths along their junction with oligoclase (M 371,100 yards north of the Clydagh river, G.R. 568645). Oligoclase commonly exhibits multiple twinning giving maximum extinction angles which vary from 4° - 8°.

Muscovite and biotite although emphasizing the foliation are not abundant. Biotite normally is pleochroic light brown to dark muddy brown. The flakes are always short and frequently broken.

A distinctive feature of the granite gneisses is the presence of pistacite in the form of roughly euhedral or subhedral grains. In the coarser rocks they may be 2 mm. long, while in the fine grained acid veins they are normally hexagonal in outline and approximately 0.1 mm. in diameter. It is colourless or very pale brown and faintly pleochroic. The centres almost invariably show a euhedral core of allanite, (Fig.42A & 42B) which is in optical continuity with the surrounding pistacite. Radiating cracks are developed in pistacite around the core. The fact that the cores are sometimes fragmental



Fig. 42A. Crossed nicols x 5.
Granite gneiss showing quartz, orthoclase, oligoclase, pistacite and allanite.
Specimen M380. ½ mile west of Ross West. G.R. 582728.

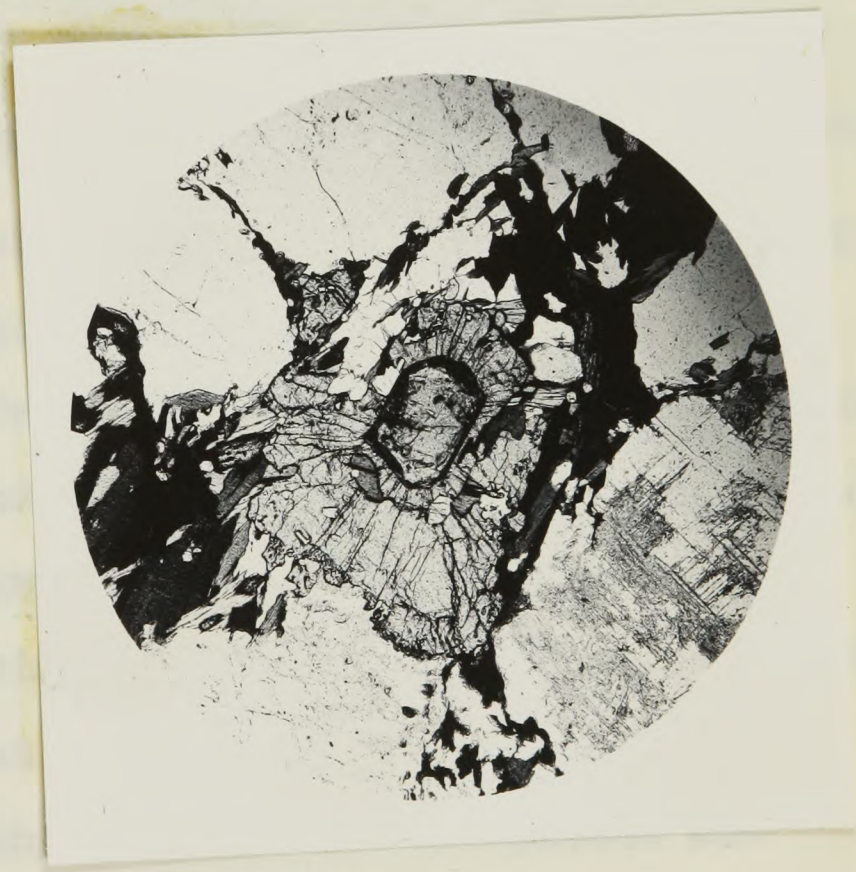


Fig. 42B. Ordinary light x 5.
Allanite core to pistacite in granite gneiss.
Specimen M380. ½ mile west of Ross West. G.R. 582728.

suggests that pistacite has grown as a secondary development on grains which had already been broken. Optically the allanite is plecchroic light straw to yellowish brown and gives an extinction angle X ^ C of 35°.

Apatite is abundant as an accessory and sphene is common as lozenge shaped grains.

Grey variety.

The grey granite gneisses possess a more distinct foliation than the pink because of the greater development of dark mica and the fact that the larger grains of feldspar and quartz tend to be more elongate.

In thin section oligoclase is the dominant feldspar, e.g. Specimen M6 from the roadside ¼ mile N. of Ross West (G.R. 694815). This rock shows large grains of oligoclase (maximum symmetrical extinction L 9½° and R.I. > R.I. Canada Balsam indicating an approximate composition of An_{27}) with a few grains of orthoclase and microcline. Serecitization is common. Myrmekitic intergrowths of quartz in plagioclase are common along margins with microcline and in some cases orthoclase.

Quartz, apart from a few large grains occurs mainly as small blebs around feldspar as a granulated sheath. Biotite forms abundant large flakes exhibiting small amount of decomposition to Penninite chlorite. Optically it is similar to that in the pink variety.

Epidote enclosing allanite cores, apatite and sphene are also present.

Fine grained veins.

The veins show a poor foliation on account of their being composed of a nearly equigranular assemblage similar to that of the coarse granite gneisses. Under the

microscope a faint preferred orientation of biotite flakes is seen. Orthoclase is frequently in an advanced state of serecitization.

Specimen M365 from 200 yards south of Conloon bridge (G.R. 498582) shows the junction between the fine grained middle and the coarser margin of a vein. The junction is fairly sharp and represents the boundary between two similar rock types, but with the one showing the development of zoned phenocrysts of oligoclase. These possess rounded outlines with the sutured and granulated margins of the feldspars of the normal coarse gneiss. Some phenocrysts are orthoclase, with the development of myrmekitic intergrowths of quartz common between it and oligoclase. The fine grained groundmass shows rounded oligoclase, crushed quartz and with biotite flakes more commonly broken than bent. Allanite although frequently enclosed by pistacite does occur without it. Dark brown pleochroic sphene is the most abundant accessory and often envelopes irregular grains of ilmenite.

Transitional gneiss.

M376 from ½ mile north of Lough Anaffrin (G.R. 570695) is typical of the migmatized semi politic schist from the border of the main granite mass. In hand specimen it is a banded rock with alternate quartzo-feldspathic and micaceous layers with a definite granitic aspect.

The thin section shows the quartzo-feldspathic layers to consist of roughly equal amounts of quartzo and feldspar. Microcline is dominant over oligoclase which has myrmekitic intergrowths. The micaceous layers are composed mainly of biotite (pleochroic pale straw to muddy brown) in association with lathes of hornblende

pleochroic X = straw

Z = dark green

epidote and allanite.

Hornblende orthogneiss.

Field Occurrence.

Coarsely crystalline hornblendic orthogneisses form a thick tongue intruded into semi pelitic beds with psammitic bands in the region of Clydagh bridge (G.R. 602552). The tongue which is ½ mile wide at this point tapers southwestwards terminating 100 yards south of Lough Naspleenagh (G.R. 520550). Further thick veins occur roughly parallel to the strike of the country rocks on either side of Lough Naspleenagh, and also in the vicinity of the Conloon fault south of Conloon bridge.

The orthogneiss shows sharp boundaries with the schists and on the south side of the main tongue is associated with pink granite gneiss. The relationship between them is not certain. In some cases granite contains included xenoliths of hornblende rock whilst in others hornblende rocks interfingers into the granite.

There is considerable variation of composition not only in the main tongue, but also in the isolated veins. This varies from a rock composed entirely of hornblende which may be subhedral and up to 5 cms. long and shows a rude schistosity parallel to the general N.E. - S.W. strike, to a leucocratic type consisting of plagioclase feldspar and hornblende. The passage from one type to the other is gradational and nowhere have sharp boundaries been observed.

Ramifying veins of fine grained hornblende gneiss, between one and three inches across, run through much of

the country rock in the immediate neighbourhood of the contacts and are particularly well displayed beside the roadside ¼ mile N.W. of Clydagh bridge (G.R. 583566). The veins weather more easily than the quartzose schists, which stand up as ridges between them.

The intrusive nature of these hornblendic rocks is further demonstrated by the inclusion of xenoliths of semi-pelitic material in exposures on the east side of the Pontoon-Castlebar road immediately on the north side of the Clydagh bridge. At this spot also pegmatitic veins occur showing large feldspars, hornblende gneiss up to one inch long and abundant books of dark mica.

Petrography.

Hornblende orthogneiss.

The dominant rock type of the hornblende orthogneiss is coarse, green in colour with a very rough preferred orientation of the component hornblende crystals. Thin sections shows interlocking tabulae hornblende, pleochroic X = light green, Y = pale straw, Z = dark green, in close association with ragged flakes of biotite which it often encloses. Irregular areas of quartz together with a few large highly sericitized feldspars, in which traces of multiple twinning are recognisable make up the remainder of the rock. Specimen M366 from G.R. 495548 200 yards west of Lough Naspleenagh is typical of this type. The breakdown of the feldspar is complete in some instances in the main orthogneiss tongue with hornblende breaking down to chlorite and with biotite decomposing to penninite chlorite, the thin needles of rutile lying parallel to the cleavages.

The more leucocratic varieties, e.g. specimen M375 from 100 yards west of river Clydagh at G.R. 583563,

contain abundant plagioclase feldspar of labradorite composition (R.I. > R.I. Canada Balsam, maximum symmetrical extinction L = 31°). The twin lamellae may be bent. As in the hornblende rich type, hornblende is in close association with biotite. Irregular areas of iron ore are also present.

VI. OLD RED SANDSTONE.

Unaltered and unfossiliferous grey-red sandstones and conglomerates which are regarded as being of old Red Sandstone age (Bishopp 1950) lie with apparant angular unconformity on the irregular topography of the underlying Dalradian. Nowhere are the two series seen with an unfaulted relationship, and only in the stream section a mile south of Windy Gap at G.R. 366040 is an actual faulted junction observed.

The nature of the junctions will be discussed in the section dealing with the structures of the region as a whole. Sandstones and conglomerates frequently rise sharply from the generally more undulating topography of the Dalradian. Immediately to the west of the area the O.R.S. forms the N.E. - S.W. range of the Croaghmoyle hills rising to 1400'.

Character of the succession.

The succession consists of a very thick series of alternating conglomerates - often boulder beds with rounded fragments of quartzite, or white vein quartz 12 inches in diameter - and coarse grey-red sandstones. The conglomeratic bands show a considerable variation in pebble type, including, white quartzite, pebbly grit, felsite, red jasper, red sandstone and white vein quartz. A variety of schist types are also present but usually in a poor state of preservation.

In places the conglomerate may form only thin bands with comparatively few pebbles in a coarse sandstone as on the slopes S.W. of Windy Gap or south of Derryharriff, while in others great thicknesses of coarse conglomerate with little sandy material predominate, as on the sharply

rising southward facing slopes at Derrynadivva or the western scarp of Kings Hill. (Figs. 43A & 43B.)

Bedding is shown up well by the variations in grain size (Fig.44A & 44B), but there is a general absence of false bedding structures and other features which might give some indication of the depositional history. The rounded nature of the pebbles however, indicates a water lain deposit and from a consideration of their grain size, were derived from a high land mass undergoing active erosion situated not far away (c.f. Jones 1966). In this connection it is noteworthy that fragments of the underlying rock types are absent - in fact for the most part the pebble assemblage is alien.

On the eastern side of Kings hill, along the line of the Windy Gap fault there is developed a band at least 125 feet wide and probably more, which is distinct from the normal Old Red Sandstone succession. It consists largely of angular fragments of schist, similar to that of Windy Gap and Shanvoley, commonly 2 feet across. They show some variation in size and are unsorted. The accumulation shows no evidence of bedding nor is it obviously a fault breccia. The angular fragments suggest possibly a scree formation developed at a time when the Dalradian stood at a higher level to the east. Its position along the fault junction and the absence of local material in the main conglomerates also suggest that the Windy Gap fault may have been active in O.R.S. times with a fault scarp along the junction. (Fig. 45).

Interbedded with the more conglomeratic beds in the vertical cliffs at the north end of Durren hill (1310') are green flaggy micaceous sandstones. A similar green sandstone but poor in mica forms part of a fault breccia along the line of the Lough Boy fault approximately 100 yards



Fig. 43A. King's Hill from S.W. showing fault scarp with Shanvoley schist to east.



Fig. 43B. Old Red Sandstone conglomerate W. side King's Hill.



Fig. 44A. Coarse sandstone bands O.R.S.
S.W. Windy Gap.



Fig. 44B. Pebbly sandstone O.R.S. Windy Gap.



Fig. 45. Fossil schist scree E. side King's Hill.

below the lough's outlet. The breccia contains blocks of red conglomerate and angular schist fragments, and is placed between the epidiorites of Raheenbarr to the east and the mica schists and epidiorites of Glenisland to the west.

Structure.

The structures exhibited by the Old Red Sandstone are of open synclinal and anticlinal folds, frequently with steep limbs, having a general N.E. - S.W. alignment. These are split up by the major faults affecting the region as a whole and are discussed later. They do however, divide up the O.R.S. in predominantly conglomeratic and predominantly sandy blocks.

VII. CARBONIFEROUS LIMESTONE.

Carboniferous limestone forms the southern margin of the Ox Mountain complex from Co. Sligo, down into this region, and southwestwards to the coast where it overstepe onto the Old Red Sandstone.

The succession is best seen in the stream section running along the line of the junction with the metamorphic rocks, and in the bluffs that lie 50 yards back from the south side of the stream in the townland of New Antrim. The actual junction is not seen but may be placed to within a few feet.

Succession in this area.

current bedded sandy crinoidal limestones, with chert bands, and conglomerate bands.	50 + feet.
calcareous and micaceous sandstone.	20 feet.
white quartzite with a few pebbles of white and pink quartz.	5 feet.
quartz conglomerate.	base not seen.

The white basal quartz conglomerate contains rounded pebbles of white vein quartz, pink vein quartz, white and grey quartzite, red jasper, red sandstone, and sporadic schist fragments, which are commonest in the lowest part and rapidly become fewer upwards. The pebbles show considerable uniformity of size and above the immediate base are rarely more than 0.5 cm. in diameter. The matrix consists of a coarse white sand with a siliceous cement.

Upwards the sequence becomes fine grained and passes into a white calcareous and micaceous sandstone, becoming more calcareous towards the normal massive grey-white limestone typical of the country to the southeast.

Abundant quartz grains on the weathered surface show it to be essentially a sandy limestone with current bedding. In a disused quarry beside the Castlebar - Newport road at the southwestern end of Lough Mallard, (G.R. 167222), distinctly flaggy bands occur together with nodular bands of black chert. This exposure together with others showing current bedding indicate that the sandy material has been derived from the north west.

A quarry by the side of Lough Akeel, 2 miles north east of Castlebar, (G.R. 456545) contains a sequence of thin quartzites at the base which pass upwards into calcareous sandstones gradually merging into crinoidal limestones. Fossils are not common, but a species of spirifer and a modioloid have been found. Professor T.N. George in a personal communication says "there is not much doubt of the beds being Low Visean (Upper Caninia or Lower part of Seminula Zone). The spirifer is a type common at that horizon and the modioloid is a member of a recurrent group of lamellibranchs running through much of the Visean in that part of Ireland". It may thus be correlated approximately with the Ballyshannon limestone of the Sligo area (Oswald 1955).

The basal beds of the carboniferous indicate that the junction in this region is a depositional one. Some workers, notably Bailey and Holtedahl (1938) show it as a tectonic boundary by extending the Highland Boundary fault along the south side of the Ox Mountains to the southern shore of Clew Bay, immediately west of the present area.

VIII. POST-CARBONIFEROUS IGNEOUS ROCKS.

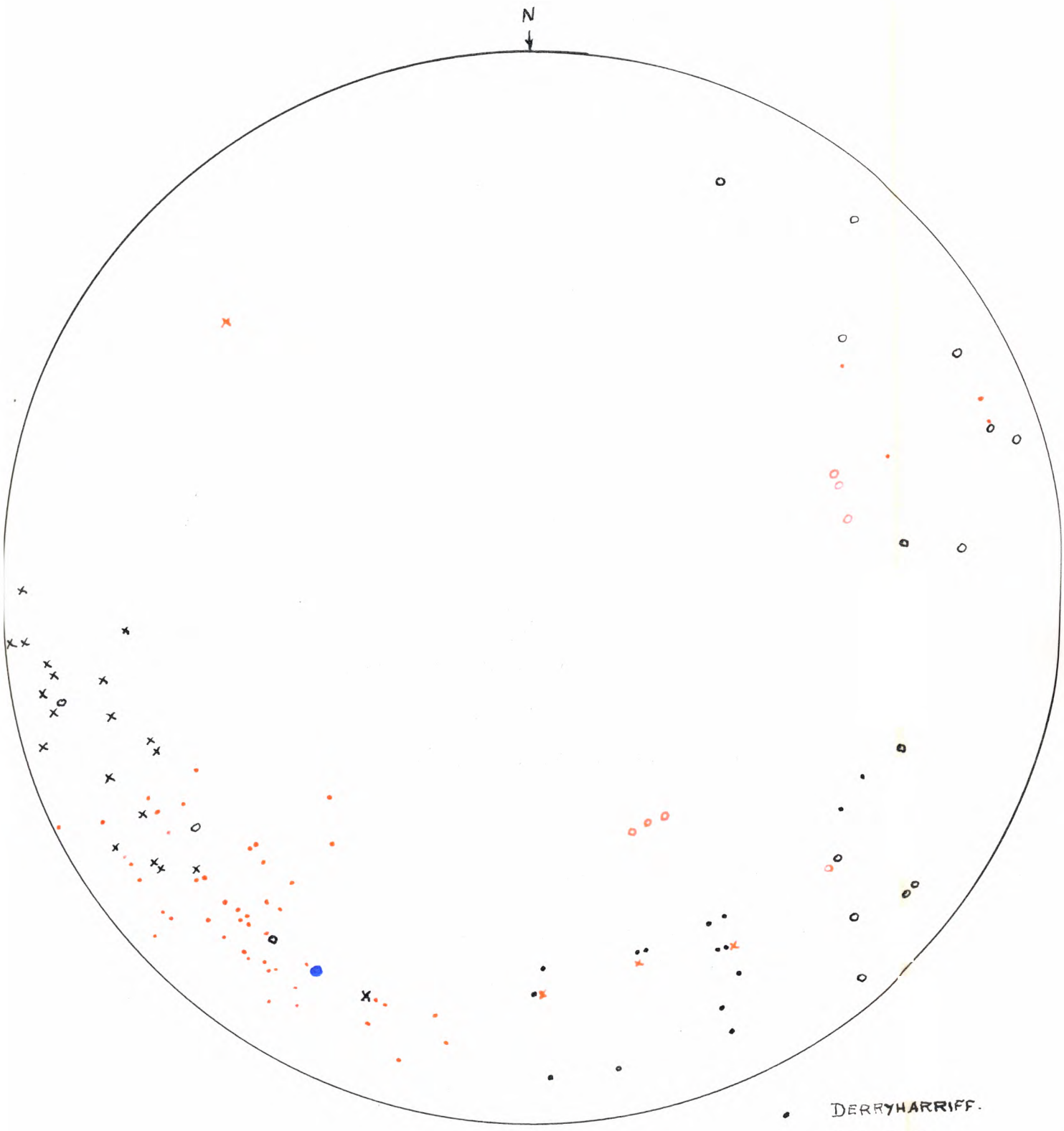
Post carboniferous dolerite intrusions are common in the carboniferous limestone flanking the Ox Mountains. They form elongated lenses parallel to the strike and are invariably poorly exposed and rotten, but form narrow ridges rising from the more of less flat limestone country. One such lens occurs westwards from Lough Mallard. Fresh material from the north side of the lough at G.R. 270310 shows it to be medium grained. In thin section (specimen M252) labradorite feldspar (maximum symmetrical extinction $L = 29^{\circ}$) is in an ophitic relationship with clinopyroxene. Olivine is much cracked and beginning to decompose. Scattered irregular grains of iron ore are also present.

(Fig. 46).



Fig. 46. Augite and Labradorite feldspar showing ophitic relationship. Olivine Dolerite.
North side Lough Mallard. G.R. 270310

CASTLEBAR DALRADIAN SERIES.
Projection of Minor Structures.



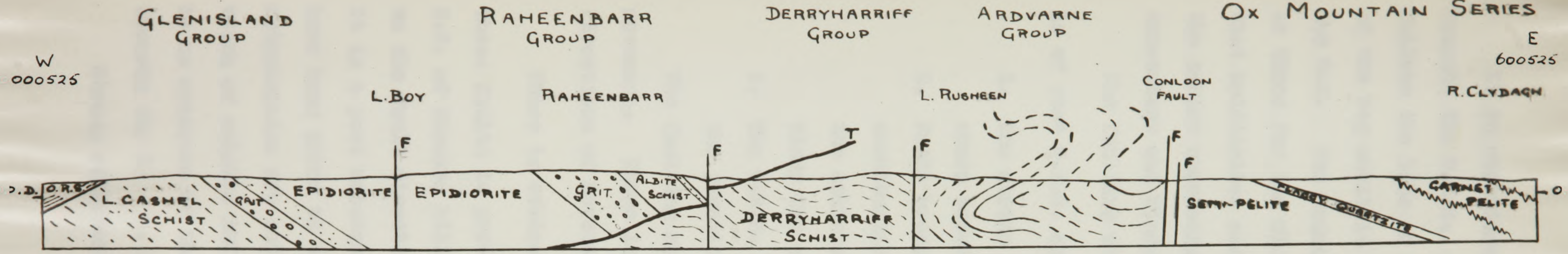
IX. GENERAL STRUCTURE AND METAMORPHISM.

The area is divided by a fault system that can be shown to be post O.R.S. in age. This has resulted in the production of fault blocks whose variation in metamorphic grade and tectonic style make it difficult to arrive at any definite conclusions on the original metamorphism and folding that the schists originally underwent.

The earliest post - metamorphic movement that the area has undergone is shearing in a N.E. - S.W. direction increasing in intensity in the N. and E. towards the Conloon fault zone. How far this is associated with it is uncertain, but at any rate the distinct contrast between the tectonic style on either side of the Conloon fault coupled with the marked difference in grade of metamorphism as well as lithology show that the pattern of the Ox Mountains was formed well before movements along the fault.

The Windy Gap thrust mass was brought to its present position by later movements acting in a N.W. - S.E. direction. This thrust mass is separated from the Shanvoley schists by the Sheeans thrust. Evidence for this is based on the difference in lithology and their tectonic styles. Further, shearing of the type present in the Shanvoley schists is absent in the Windy Gap group. The thrust mass rises sharply from its base (see Figs. 12 and 13.), which may be traced round the E. and S. sides of the Sheeans hill to the W. where it is cut off by a N. - S. fault separating it from the old Red Sandstone. A small part of it comes in on the west side of the stream which has eroded through the thrust plane.

The thrust plane has an undulating surface dipping between 5° and 15° towards the N.W.



SCALE : 2" TO 1 MILE

EAST-WEST SECTION OF AREA NORTH WEST OF CASTLEBAR, CO. MAYO, EIRE.

SECTION 4

It is considered that the thrust plane emerges from beneath the O.R.S. N.E. of Raheenbarr hill and follows the line of a small change in slope at the edge of the bog until it disappears again under the O.R.S. to the S.E. The reasons for placing it here are similar to those for the Windy Gap region together with the fact that epidiorites are not elsewhere found associated with the schist successions except in the Glenisland, Raheenbarr and Windy Gap groups.

The faulting which has produced the fault blocks is of post O.R.S. age because

1. The strike of the O.R.S. frequently shows a sharp termination at the schist boundaries.
2. Fault breccias in the O.R.S. occur in the continuation of the fault lines as proved in the schists e.g. S.W. of Raheenbarr, S. of Windy Gap and S.W. of Lough Boy.
3. The O.R.S. frequently dips steeply towards the junction.

The faulting appears to be essentially a tear movement. There is however, no evidence of the relative directions of movement on either side.

There is evidence that some of the movement along these faults is pre-O.R.S. In the stream section S.E. of Sheeans hill shattering of black schists parallel to the fault direction has been infilled by calcite. It is a post metamorphic effect because feldspars which have been shown to be developed late in the period of metamorphism are cut across by calcite stringers. Also veins of calcite infill tension cracks in quartz. There is no evidence of this calcite flowage, which increases towards the N. - S. fault line, in the O.R.S.

Strong evidence of considerable down throw to the

N.W. is exhibited by the Windy Gap fault which continues S.W.wards along a vertical scarp on the N.W. side of Burren hill in the O.R.S. This is further emphasized by the turning of the direction of minor fold axes in the Windy Gap schists.

The absence of faulting in the carboniferous limestone indicates that these movements were pre-carboniferous in age and that no movement in this area has taken place since.

REFERENCES

1. Anderson J.G.C. 'The Geology of the Highland border : Stonehaven to Arran.' Trans.Roy.Soc.Edin.1946 vol.61 Pt.II pp.479-515.
2. Anderson J.G.C. 'The occurrence of Moinian Rocks in Ireland.' Q.J.G.S.1947 vol.103 pp.171-191.
3. Bailey E.B. 'The metamorphism of the S.W.Highlands.' Geol.Mag.1923 vol.60 pp.317-331.
4. Bailey E.B. & Holtedahl O. 'Regionale Geologie der Erde' Bd.2, Palaeozoische Tafeln und Gebirge Abt.III Leipzig,1938.
5. Bailey E.B. & McCallein W.J. 'Metamorphic rocks of N.E. Antrim'. Trans.Roy.Soc.Edin.1934 vol. 58 Pt.I pp.163-177.
6. Barrow G. 'Chloritoid schists from Kincardineshire.' Q.J.G.S.1898 vol.54 pp.149-155.
7. Bastin E.S. 'Chemical composition as a criterion in identifying metamorphosed sediments.' Jour.Geol.1909 vol.17.
8. Bishopp D.W. 'Some Upper and Lower Limits of the Devonian System in Ireland, with proposed corrections to maps.' Proc.Roy.Irish Acad. 1950 vol.53 Sect.B No3 pp.25-32.
9. Charlesworth J.K. 'Glacial geology of North Mayo and West Sligo.' Proc. Roy. Irish Acad. 1928 vol.38 Sect.B No.6 pp.100-115.
10. Clough C.T. & others. 'The Geology of Cowal.' Mem. Geol. Surv. Scot. 1897.
11. Cunningham Craig E.H. 'Metamorphism in the Loch Lomond area.' Q.J.G.S. 1904 vol.60 pp.10
12. Daly R.A. 'Igneous Rocks and the depths of the Earth.' McGraw Hill 1933.

13. Edwards A.B. 'Petrology of the Miocene Sediments of the Aure Trough, Papua.' Proc. Roy. Soc. Vict. 1947 vol.60 (new series) pp.123-148.

14. Geikie A. Annual report of the Geol. Surv. & Museum of Pract. Geol. Appendix E 1893 p270.

15. Goldschmidt V.M. 'Geologisch-Petrographische studien im Hochgebirge des sudlichen norwegens.' Die injectionsmetamorphoseim Stavanger-gebiete 1920 Videns Skr. Mat.-Naturv. Klasse No.10.

16. Greensmith J.T. 'A study of some Carboniferous sediments with particular reference to the mode and environment of sedimentation.' 1955. Unpublished Ph.D. thesis deposited in the University of Sheffield.

17. Grout F.F. 'Origin of the igneous rocks of Minnesota.' Jour. Geol. 1933 vol. 41 pp196-218.

18. Gumbel C.W. von. 'Die Palaeolithischen Eruptivgesteine des Fichelgebirge.' 1874. Munich.

19. Harker A. 'Tertiary igneous Rocks of Skye.' Mem. Geol. Surv. Scot. 1904.

20. Harker A. 'Metamorphism.' 1952. Methuen.

21. Hartley J.J. 'The Dalradian rocks of the Sperrin Mountains and adjacent areas in Northern Ireland.' Proc. Roy. Irish Acad. 1938 vol. 44 Sect. B No.8. pp.141-171.

22. Hill J.B. & others. 'The Geology of Mid Argyll.' Mem. Geol. Surv. Scot. 1905.

23. Holmes A. 'Petrographic Methods and Calculations.' 1921 Murby.

24. Jones O.T. 'Evolution of a Geosyncline.' Pres. Add. Q.J.G.S. 1938 vol. 94 pp.lx-cx.

25. Jones O.T. 'The Geological Evolution of Wales and the adjacent regions.' 10th. Wm. Smith Lecture 1954. Q.J.G.S. 1955 vol. 111 pp323-351.

26. Kennedy W.Q. 'The Great Glen Fault.' Q.J.G.S. 1946 vol. 102 pp. 41-76.

27. Kennedy W.Q. & Read H.H. 'The differentiated dyke of Newmain's, Dumfries-shire and its contact and contamination phenomena.' Q.J.G.S. 1936 vol. 92 pp.116-145.

28. Kilroe J.R. 'Silurian and Metamorphic rocks of Mayo and North Galway.' Proc. Roy. Irish Acad. 1907 vol. 26 Sect. B. No. 10 pp. 129-160.

29. Kinaghan G.H. 'Geology of Ireland.' 1878.

30. McCallein W.J. 'The Metamorphic rocks of Kintyre.' Trans. Roy. Soc. Edin. 1929 vol. 56 Pt.II pp. 409-436.

31. MacCulloch J. 'Memoirs to H.M. Treasury respecting a Geological Survey of Scotland.' 1836. Arrowsmith, London.

32. M'Henry A. 'Report on the Ox Mountains and their probable continuation from Galway into Donegal, Tyrone, and Londonderry.' Proc. Roy. Irish Acad. 1903 vol. 24 Sect. B No.4 pp. 371-378.

33. McLintock W.F.P. 'Zeolites and associated minerals from Tertiary lavas around Ben More, Mull.' Trans.Roy. Soc. Edin. 1915 vol.51. pp.1-33.

34. Oswald,D.H. 'The Carboniferous rocks between the Ox Mountains and Donegal Bay.' 1955 Q.J.G.S. vol.111 pp167-186.

35. Pettijohn F.J. 'Sedimentary Rocks.' Harper Bros 1949.

36. Phillips F.C. 'Metamorphism in the Upper Devonian of North Cornwall.' Geol. Mag. 1928 vol. 65 pp. 550-556.

37. Phillips F.C. 'Some mineralogical changes induced by progressive metamorphism in the Green Bed group of the Scottish Dalradian.' Min. Mag. 1930 vol. 22 pp. 239-256.

38. Reynolds D.L. 'The Albite schists of Antrim and their relationship to Caledonian orogeny.' Proc. Roy. Irish Acad. 1942 vol. 48 Sect. B No.3 pp. 43-66.

39. Shrock R.R. 'Sequence in Layered Rocks.' 1948 McGraw Hill.

40. Sutton J. & Watson J. 'Varying trends in the metamorphism of Dolerites.' Geol. Mag. 1951 vol.88 pp.25-55.

41. Sutton J. & Watson J. 'Deposition of the Upper Dalradian Rocks of the Banffshire coast.' P.G.A. 1955 vol.66 pp.101-133.

42. Symes R.G. 'Explanatory Memoir to accompany Sheet 75 of the maps of the Geological Survey of Ireland illustrating a portion of Mayo.' Mem. Geol. Surv. Ireland. 1872.

43. Taylor S.R. 'The origin of some New Zealand metamorphic rocks as shown by their major and trace element composition.' Geochim. et Cosmochim. Acta 1955 vol.8 pp.182-197.

44. Teall J.J.H. in 'Geology of Cowal.' Mem. Geol. Survey Scot. 1897.

45. Teall J.J.H. in 'The Geological structure of the N.W. Highlands of Scotland.' Mem. Geol. Survey Scot. 1907.

46. Tilley C.E. 'The petrology of the metamorphosed rocks of the Start Area, South Devon.' Q.J.G.S. 1923 vol.79 pp.172-204.

47. Tilley C.E. 'Some aspects of magmatic evolution.' Pres. Add. 1949 Q.J.G.S. 1950 vol.106 pp.37-61.

48. Trendall A.F. 'The origin of Albite Gneisses.' unpublished Ph.D. thesis deposited in the University of Liverpool. 1953.

49. Tsuboi S. 'Dispersion method of plagioclase identification.' Min, Mag. 1923 vol.20 pp.108-122.

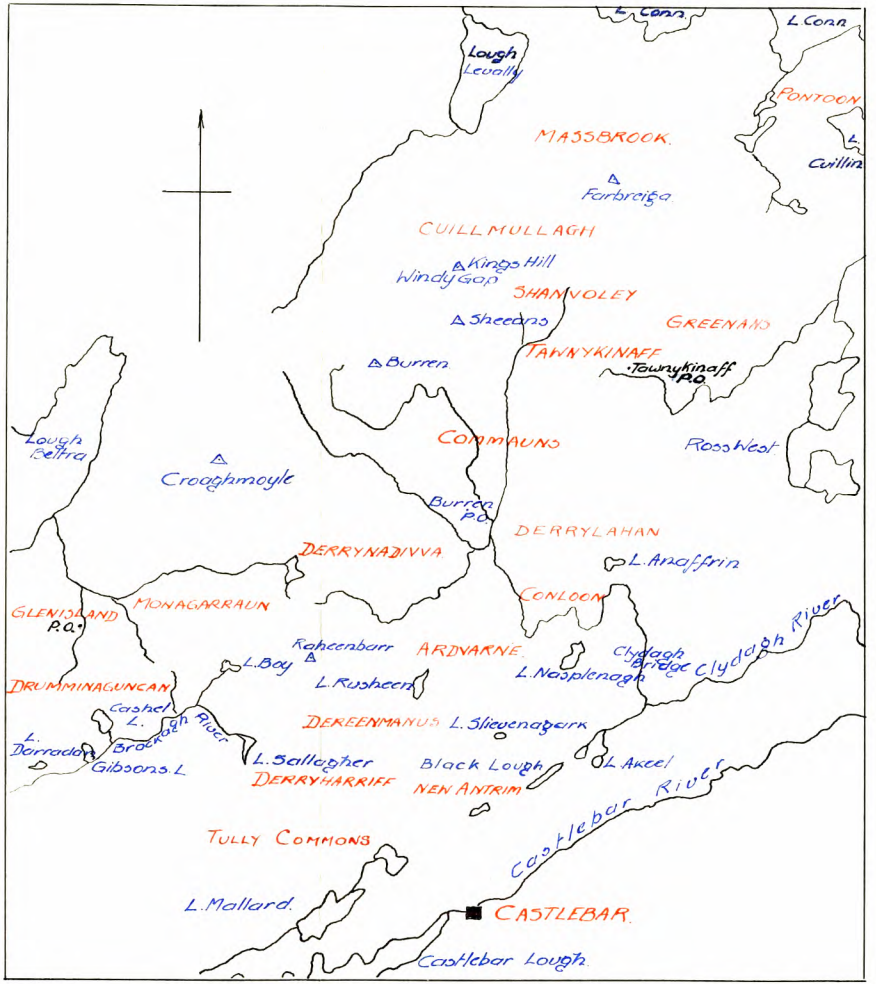
50. Turner F.J. & Verhoogen J. 'Igneous and metamorphic Petrology.' 1951 McGraw Hill.

51. Walton E.K. 'Silurian Greywaches in Peebles-shire.' Proc. Roy.Soc. Edin. 1955 vol.65 Pt.III pp.327-357.

52. Williamson J.H. Geology of the Naseby Survey District, New Zealand.' Bull.39 New Zealand Geol. Surv. 1939.

53. Winchell A.N. & Winchell H. 'Elements of Optical Mineralogy.' Part II 1951 John Wiley.

54. Wiseman J.D.H. 'The Central and S.W. Highlands Epidiorites.' Q.J.G.S. 1934 vol.90 pp.355-417.

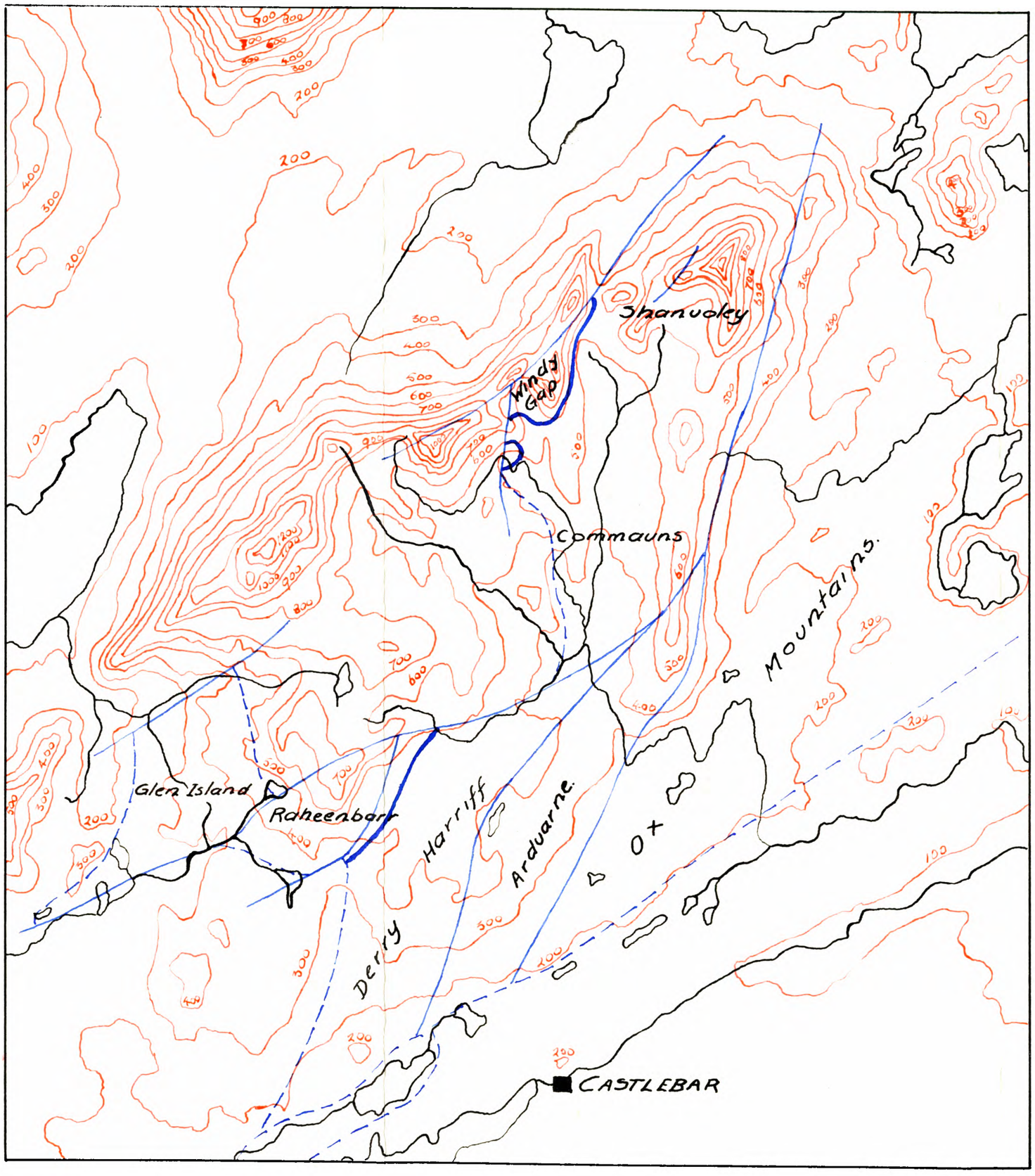


Townlands. CONLOON

Rivers Loughs & Hills. Raheenbarr

Scale:- 1" to 1 mile

MAP No 1 Locality Map of the Area N.W of CASTLEBAR.
Co. Mayo. EIRE.



—500— Contours.

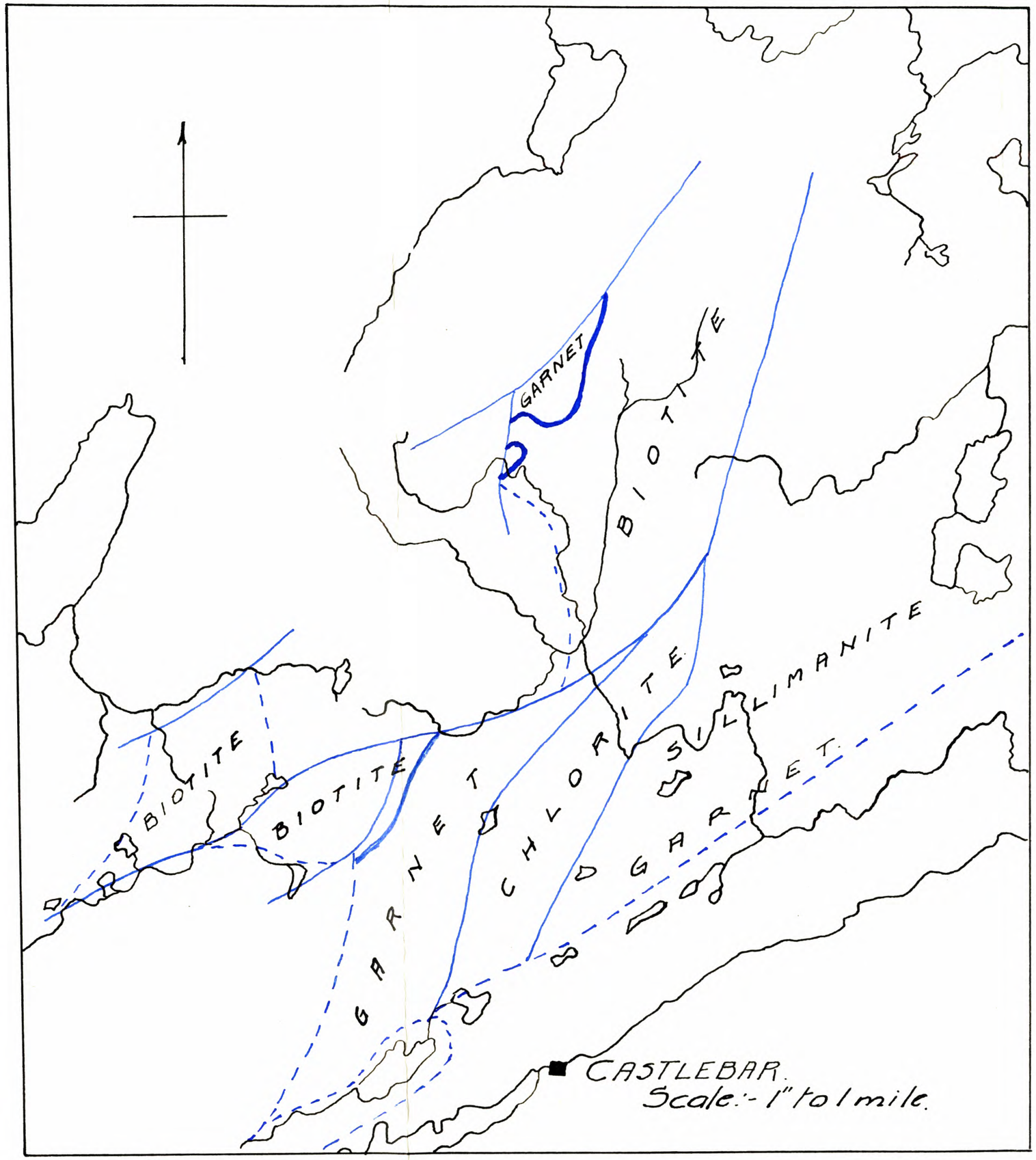
Thrusts.

Faults.

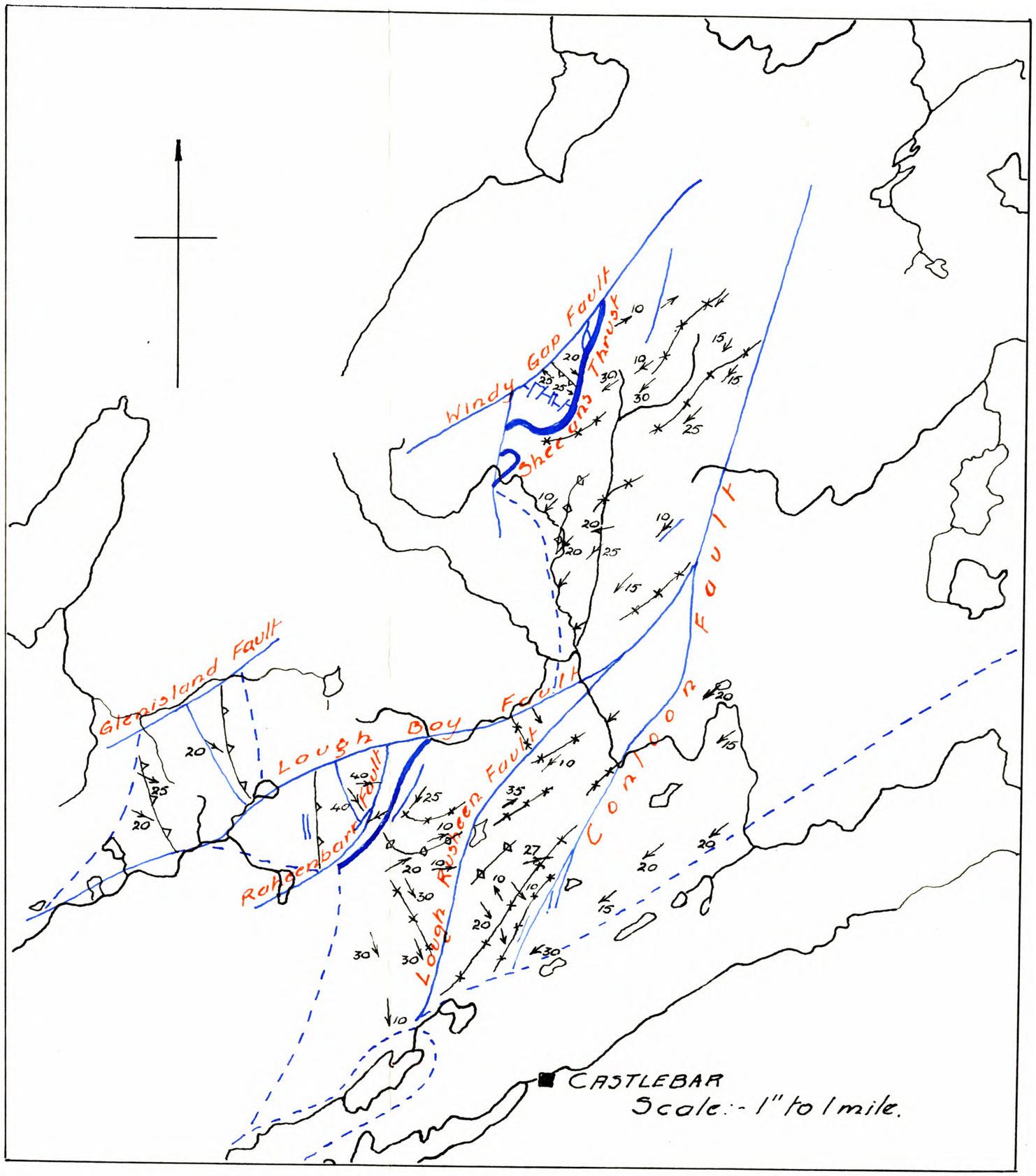
- - - - - Stratigraphical Boundaries.

Scale :- 1" to 1 mile.

MAP N°2 Topographical Map of the Area N.W. of CASTLEBAR.
Co. Mayo. EIRE.



MAP Nº 3 Metamorphic Map of the Area N.W. of CASTLEBAR
Co Mayo EIRE.



LEGEND

- Plunge of minor folds.
- Lineation [arrow head at point of observation]
- Anticlinal Trends.
- Synclinal Trends.
- Trend Line of Fold Limb [arrow head indicates direction of dip]
- Thrusts.
- Faults
- Stratigraphical Boundaries.

MAP N° 4 Structural Map of the Area N.W of CASTLEBAR
Co Mayo. EIRE.