THE GEOLOGY OF PORTNOO DISTRICT OF CO. DONEGAL

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ABSTRACT

A thick series of Dalradian sediments, beginning with the Portnoo Limestone and continuing with the Rosbeg Pelitic-Semipelitic Schists, together with associated dolerite sills, has been subjected to movements, directed from south to north, and concurrently metamorphosed. Pelitic rocks reached assemblages characterised by garnet and biotite. An appinitic type of metadolerite of great interest is probably in part of limestone parentage.

Subsequently, the country-rocks suffered regional retrogression marked by the breakdown of garnet and biotite into chlorite and sericite, the growth of new chlorite, and a reduction in grain-size - by this process of phyllonitisation the country-rocks have been made to appear to be of low grade.

Later, a varied series of lamprophyres and felsites, divisible into age-groups on their mutual relationships, was intruded. Certain of these intrusions are crammed with fragments of different country-rocks and the mechanism of their emplacement is an attractive problem.

A remarkable development of explosion-breccias with a granophyric matrix and associated with mobilised country-rocks is described from four localities within the Rosbeg Group. Minor granitic bodies provide excellent examples of contamination, but the major and latest intrusion-event was the emplacement of the Ardara pluton, consisting of interior granodioritic and exterior tonalitic portions, both rich in xenoliths. The emplacement of this pluton was responsible for a great curvature in the regional strike. A wide aureole is developed and, locally, mixed rocks between granite and metadolerites are formed. Following the emplacement, the contact-rocks underwent hydrothermal alteration with the transformation of garnet to chlorite and of staurolite and andalusite to shimmer-aggregate. As a final stage of the consolidation, a perfect radial, cross, longitudinal, ring and marginal joint-system was produced in granitic and contact rocks alike.

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I. INTRODUCTION AND GENERAL PHYSICAL FEATURES.

The area which forms the subject of the present study covers about 18 sq. miles, included in parts of the 6 inch Irish Ordnance Survey sheets 64 and 73 and lying within latitudes 54 degrees 46 - 51 and longitude 8 degrees 25 - 35. It occupies the Portnoo - Rosbeg districts within the old baronial division known as the Boylagh, which lies in extreme north-west of County Donegal in the Republic of Ireland. The general shape of the area investigated is triangular, and comprises the Dunmore and Dawros Head peninsulas in the north and west and the Carrilagh peninsula in the south. On the North, it is bounded by Gweebarra Bay and the Atlantic Ocean, and on the east by the Narin-Ardara Rd., in the south by the Owenea river and its estuary and in the west the Atlantic again washes the shores of the region. The geology of the area is represented on the 1 inch Geological Survey maps no. 15 and 23, published in 1890.

Though the physical features of western Ireland have been dealt with in much detail in the Geological Survey Memoirs of 1888 & 1891, these memoirs forming indeed the basis for geographical study even at the present day - the portion which the writer has investigated has not received

much attention. Hence it is proposed to give a short account of the physical features, drainage, communications and related topics before the detailed geological study is set forth (~~see fig. 1~~).

Communications :- The village of Portnoo and the surrounding district are reached by a good tarmac road from Glenties and Ardara, which are situated 11 miles S.E. and 7 miles South respectively. Narin, Portnoo and Rosbeg, the favourite sea resorts for summer holiday makers, are connected with the important towns of Dungloe in the north and Donegal and Sligo in the South by regular motor transport.

People :- The arable area is small and the cultivation is confined to places around the lakes, gullies, and drumlins in the southern part or in thin strips near the coast. The major part of the local permanent inhabitants form the peasantry. The people are hospitable, honest, lethargic but hard-working - an Indian never felt himself to be in a foreign land. As in other European countries, the tendency of Irish youngsters to migrate to America or Canada is age old, and much discussed both in public and press. It will be a tragedy if the unsophisticated Catholic youth are not persuaded to remain at home and concentrate their energies on the development of their own motherland.

Climate :- For most of the year, the region is wet and has a mild climate. During the months of October to April, the westerly winds are very severe, making the branches of the very few trees lean towards the East and South-East, so that they appear to bow down. In some years the snow fall is heavy during the winter and the author experienced a heavy snowfall even on the 26th. May, 1951. The short summer months of May to August are pleasant and inviting and provide the best time for a field worker to carry out geological investigations.

Physical Features :- The northern part of the area is studded with hills, and stands in bold contrast to the southern part which is made up of areas of Sand-dunes and low lying bog, terminating southwards in a wavy and undulating shore-line. All along the rocky coast of the north and the sandy beach of the south-west are innumerable islands.

Hills :- Dunmore 430 ft., Cashel 350 ft., and Narin 362 ft., hills stand like fortress walls built on the northern coast of the area. On the top of Dunmore the Observation Tower erected during the last war forms an important landmark, looking like a sentinal and attracting the attention of all visitors to this part of Ireland. In the central region Lefrin 337 ft., and Meendooish 335 ft.

hills, separated by the Portnoo-Rosbeg Road gap, are conspicuous. In the Dawros peninsula, the northern portion is much higher than the southern and Spy Hill 135 ft. makes an important feature. The low-lying tracts in the south and the areas in between the hills are in general covered with a thin layer of peat and occasionally by bogs. The topography with its valleys, gullies, hills, rivers and even its coast line is mainly dependent on the fracture system of the rocks. The north-south trend of the narrow elevated plateau between Narin-Sheshkinmore lough is the consequence of harder resistance to weathering of the hornfelsed semi-pelites striking against the low-lying granites. The Summy, and Sheshkinmore loughs are probably due to the differential weathering of these two types of rocks, while the other lakes are probably controlled by joints and slips or by granitic intrusive bosses and later modified by the Pleistocene glaciation.

Rivers :- There are a good many small rivers and streams flowing generally in an E-W and NE-SW directions ~~(Fig. 2)~~ and connecting some of the lakes. The most important river is the Owenea which, like the Abberchrin-Bellangoal rivers, flows in the East to West direction. Of the minor rivers, special mention may be made of R. Birroge which takes a general NE-SW and N-S direction and flows

into the Sheshkinmore loughs and thence through the sand-dunes to the estuary of the Owenea. Another small southwardly flowing stream originates from the southern tip of Lough Doon, and, after flowing in a sinuous course up to Terrylagh, takes a sharp bend and then flows into the Kiltooris Lough and thence into the sea near Rosbeg. Like many of the other features of the area, the directions of the rivers are controlled by structural elements, especially jointing.

Lakes :- Of the dozen or more lakes, the two largest are the Kiltooris and Sheshkinmore Loughs. The smaller lakes Pound, Birroge, Doon with the Kiltooris Lough are famous for fishing. In most of these lakes are a number of small islands which enhance the scenic beauty. On such an island in the Doon Lough stands the ancient fort of "Bawn" with twelve-feet thick circular walls. Such beautiful spots with their natural scenery and ancient history and culture, combined with their sporting facilities, attract many visitors.

The waters of the rivers mostly run to waste, but at some places, where it is potable, the local inhabitants draw it for consumption. At Portnoo and Narin villages, the water from the Pound Lough is piped for drinking purposes. It is interesting to record that

the surplus water of the Pound Lough is utilized by the Rector of the Narin-Portnoo Church to generate electricity for use in the Swan Mount (Rectory). It will not therefore be out of place to mention that the waters from the lakes Still and Con, Birroge, Pound and Doon situated one above the other could be harnessed by short open-cut channels, connecting each of them and thus help in the development of Hydro-electric power.

Present Study :- The present study is based on field-work carried out for twenty-seven weeks. Mapping was done on topographic Sheets No. 64 & 73 on the scale 6" to one mile. In order to obtain a fuller idea of the intricate geology of the northern parts, comprising the Portnoo-Dunmore Coastal strip, mapping was carried out on an enlarged scale of 24" to one mile. About a thousand specimens of the various rocks types were collected and about 375 sections were prepared for microscopic study.

The present work is part of a large-scale plan to investigate the Dalradian rocks of Donegal and their granitic associates. Fig. 1 shows the area of the present investigation, together with those of other workers engaged on this composite plan of study, from Imperial College and Queen Mary College, University of

London, and the University of Liverpool and the University of Leeds.

The rocks met with in the area are a series of highly metamorphosed limestones, pelitic schists with associated basic sills of metadolerites. These are cut by a host of lamprophyric and felsitic dykes and sheets, later by granitic dykes, bosses and plutons followed by a few aplites and pegmatites. The granitic rocks form the Ardara complex and other minor hybrid associates at Narin-Portnoo, Dirty Rock-Sand Hole and Roanish Islands.

Mapping :- Outcrops of rocks in the area studied are fairly prominent and were mapped as accurately as possible. Those on the Coast line are so bare and fresh that an Indian geologist could but feast his eyes on so many beautiful geological features exhibited in so brilliant a fashion.

An effort has been made to study the several rock-types, both in the field and the laboratory, so as to unravel their inter-relationship and the geological history of the region. The observations made in the field and the results of the subsequent examination carried out in the laboratory form the basis of the present Thesis.

II. SUMMARY OF PREVIOUS LITERATURE.

The three broad rock-groups of the writer's area are the metamorphic country-rocks, the granite and the lamprophyre dykes. Almost nothing relevant to the last topic has appeared in earlier investigations, so that this summary of previous literature deals only with the country-rocks and the granites.

Between the years 1860-71 this western region of Co. Donegal was studied by several geologists, and in the report of E.Hull, (1881) the then director of the Irish Geological Survey, a good account is provided of the so-called Laurentian sediments and their associated granitic rocks. Later, in his memoir (1891), Hull summarised the work of Haughton (1862), Scott (1861-63), Blake (1862), Green (1871) and Kilroe (1890).

Metamorphosed Sedimentary Rocks :-

The establishment of a succession in the metamorphosed sediments is rather difficult, particularly when there is not even a trace of fossil remains in the rocks. The attempts of Harkness (1860, p.60) Blake (1861, p.p.294-9) and Callaway (1885, p.p.230-8) to correlate these ancient schistose formations appear to be very preliminary. However, the succession given on page 18 of the 1891 memoir

forms a basis of all later study. The order worked out by Kilroe and given on page 46 of the memoir (1891) is not applicable to the same suite of rocks in the area investigated. There is no need to detail these successions here.

Harkness (1860, p.80) and, later quoted in the 1881 memoir (P609) ~~(609)~~ regarded the metamorphic rocks of N. Ireland, as "Irish representatives of the Grampian strata" i.e. "the lower Silurian beds of Scotland" (Hull, p.609).

On the basis of lithology, Hunt (1863, p.59) considers them to be identical with the Laurentian rocks of Canada but he appears to suggest also that parts of the Donegal rocks might be correlated with the altered Palaeozoic strata of America. Hull (1881, p.609) considered the ancient rocks of Donegal to be "Laurentian gneisses, granites, and lower Silurian sediments with an unconformity in between" but later he revised his opinion, as is clear from the foot-note given on page 18 of the memoir (1891). Kinahan (1881, p.610) thought the metamorphic rocks to be "more probably Huronian than Laurentian". Geikie, (Mem.1891, p.2) describes them as, "Vastly younger than the Archean, but much older than the Silurian". Cole in 1900 (p.23-4) grouped them with the Dalradian rocks of Scotland. Recently Anderson (1948) divided them into two

stages and assigned a Moine age to the lower quartzites and schists and Dalradian to the upper members of the series. It has not been possible for the later workers to determine accurately the age of these rocks, and the author is also beset with the same difficulties. Further investigations by Iyengar (1949), Gindy (1950), Pitcher (1950), McCall and Cheesman (1951) in the eastern, northern and southern portions of the general area under investigation have amassed considerable detail on the geology of N.W. Donegal which will make possible the final correlation of the local successions, and those even further afield.

Granites :-

The granitic and gneissose rocks of Donegal have attracted the attention of a large number of geologists for more than 120 years. Diverse opinions have been advanced by these previous workers with regard to the origin of the rocks, and particularly to that of the main Donegal granites.

M.Adam (1834, p,p.133,135-6) considered the metamorphosed sediments referred to above to be a series of "Eurites passing into gneiss..... and also into well defined mica slates." The twisting and contortions of the mica-schists at the contacts with the granites led Griffith(1852) to believe that these features were due to the intrusion of the granitic bodies.

Scott in 1861 was of the opinion that the formation of the Donegal Granites was due to metasomatism of the pre-existing sediments, his reasons for this view being :-

1. There are different varieties of granite, varying both in their mineralogical and chemical compositions. In fact, some types cannot be called granites at all as they are low in silica content but rich in lime, magnesia and alumina (pp. 287-9).
2. "..... at actual contacts between granite and limestone, the former is orthose" which is neither rich in intermediate or basic plagioclase felspars, indicating a low temperature insufficient for any chemical reaction. If it were to happen, "..... ... the granite becomes oligoclase bearing and all traces of limestone disappear". (pp.289-90).
3. "It presents no appearance of being of purely igneous origin .....; the evidence seems to point out a metamorphic origin for it, ... it is thoroughly gneissose in its character and lies in thin beds corresponding to the bedding of the stratified rocks of the country". (p.290).

4. "Strongest evidence ....., far within limit of the granite at ....., we find isolated patches of metamorphic rocks not lying on the granite, but, in it and run in directions corresponding to (that of strata) outside the granite area, the direction (bearing) of which is nearly parallel to that of the main axis of the granite" (p.290).
5. The rich association of oligoclase and quartz in the same type of granite, which "would be hardly possible if the rock were supposed to have been in a state of simple fusion". (p.291).
6. "..... quartz and felspars were introduced in a wet way, not in a state of simple fusion" is another evidence that the intrusion did not take place at high temperatures. Further the similarity in the physical characters of quartz, both from the main granite and the veins intruding the same, lend support to this view.

Blake, a mining engineer, at the same time (1861) affirmed that the granites were the products of metamorphism, the points in support of his view being :-

1. The changes in the different bands of country schists to gneisses, granites and porphyries are so gradual and uniform that it is "hard to

tell when the one ends or the other commences". Further, "ordinary slates (were noticed) to become highly siliceous in character at places, and sometimes presented the appearance of a regular porphyry, but without any alteration in its structure or bearing and without any upheaval, faults or other visible causes for such alteration".(P.289).

2. "..... Complete regularity of contact between granitic layers", the repeated occurrence of similar rock facies led him to conclude that the country rocks were vertical otherwise" no less than three separate(anticlinal) axes are essential to explain this repetition (p.299).
3. "No (tectonic) disturbances which by many are supposed to be caused by the eruptive action of granites etc., forming lodes, cross-courses, faults etc."; while on the other hand he observes "a district abounding in granites, slates, etc., but representing scarcely a trace of lodes, and wanting in those very conditions which are supposed to be the result of eruptive action, and presenting to all appearance a regularity quite inconsistent with this idea (p.299).

4. Continuation of long limestone bands from the country rocks into the granites (p.296).

Haughton (1862, pt.III) also advocated a metamorphic origin on the following grounds :-

1. "It possesses a stratified structure in beds which are nearly vertical ....., appears to be intimately interstratified with the aqueous rocks on its boundaries. Still, well within the granite border, stratified rocks occur with the same bearing as those outside". (pp.403-4 & 406-7).
2. "..... at many places, the metamorphic slates are penetrated by coarse veins of granite, in some, the granitic material seems, as if formed in the bosom of the rock without any connection with a vein or dyke or granite" (p.407).
3. On the basis of more than a dozen chemical analyses of the granites he pointed that "those granites differ from each other much more in chemical composition than the granites of Leinster....., a difference to be expected from the more decidedly eruptive character of the Leinster granites, which nowhere simulate the stratified character so remarkable in those of Donegal" (p.410).

4. "The rocks analysed are hardly to be considered all as true granites, some gneiss-like, but in the mode of their occurrence they do not differ from the granites and it is almost impossible to say exactly when the granite begins and the gneiss ends". (p.410).

5. "The granites of Donegal vary much in texture and appearance as might be expected from their gneissic character. It occasionally passes into a granitic syenite, composed of hornblende, oligoclase and little quartz and sphene ..... "(p.415).

Later in 1863 (p.269) and 1870 (pp.232-235) he compared the Donegal granites with the metamorphic granites of Scandinavia, Finland and Scotland and found them to possess the same mineralogical and chemical composition.

In 1863 Scott on the basis of Macfarlane's paper on the Laurentian gneisses of Canada and Norway took the view that his (Macfarlane's) descriptions were also applicable to the Donegal granites with respect to the conformability of the gneissose granites with the parallelism of the schists and the granitic bodies cutting through the country rocks.

In a joint paper Scott, Haughton and Griffith (1863) state that "The occurrence of non-granitic rocks in the granite is not strictly confined to the district where the

structure of the rock (granite) is most decidedly gneissose".

Harte (1865, p.144) observed the presence of lenticular bodies of gneissose granite in massive crystalline granite.

Westropp (1867) also considered the Donegal granites to be metamorphic in origin and very rich in basic felspars.

Kinahan (1869, pp.7-9 & 15-16, Memoir) classified the Galway granites into (I) Earlier metamorphic (a) porphyritic (b) foliated porphyritic granite (II) A later igneous type, and also observed the same phenomena as noticed by Haughton in Donegal. This view postulated a later granitic intrusion through intense metamorphism and foreshadowed the modern idea of rheomorphism.

An interesting controversy on the origin of these granites arose between Green and Forbes, when the former favoured a metamorphic origin (1878). Forbes (1870,pp.450, & 1871, pp.12-15) was definitely against all the ideas of a metamorphic origin, and considered that no arguments have been given by any of the previous workers to explain the concordant and discordant relationships of the granites with the country rocks. But Green again (1871, pp.553-61) states "that a metamorphic rock may be at places intrusive

has been explained so often that I am almost ashamed to mention it".

Hull's views (1881) on the metamorphic origin of these rocks, referred to by Calloway (1885) are opposed by the latter for the following reasons :-

1. The fissility of the sediments was the result of subsequent pressure and the granitic magma penetrated through these foliation planes. The toughness of the intercalated basic schists having resisted the flow, and the granitic juices probably permeated through the joint-planes (p.224).
2. The granite "is not grading into the sediments; inclusions of schist about a man's hand (size) occur in it, but their margins are quite sharp ..... Impossible to be remains of unmelted series ..... on the other hand they are quite similar to inclusions in intrusive diorites (epidiorites) from the same area". (p.229).
3. The variation in lithological, mineralogical, and chemical composition of the granites i.e. the occurrence of a highly siliceous granite along with mica-and hornblende-schists

and a plagioclase-rich biotite-granite adjacent to the quartzites does not permit the possibility of fusion of the country rocks in situ, particularly when these rocks are entirely different in their character both physical and chemical (p.229).

4. The lateral pressure, which came into play after consolidation of the magma might have been responsible for the gneissic structure of the granitic rocks (p.239).
5. The complete silicification of the inter-bedded and the associated limestones of the country rocks.

On the basis of the above facts Callaway (1887,p.524) described the Galway granites (studied previously by Kinahan 1869) and postulated that "at least some of the schists had been formed out of igneous rocks (by shear)". According to him there was nothing to prove that the foliation of these igneous rocks was due to regional (metamorphism) pressure.

The Irish Geological Survey Memoir (1891) gives the official view that these rocks are intrusive in nature. But Kinahan (p.32) in a separate note in the same volume maintains the metamorphic origin of these granites. Kilroe (footnote p.18) however was of the opinion that the granitic

intrusion took place in between separate diastrophic movements, and foliation in the granite was due to post-granitic metamorphism varying in intensity from place to place. At certain localities he also observed inclusions of a highly foliated micaceous granite in a comparatively massive granite (p.72) and thus recognised the occurrence of granites in granite in Donegal.

Cole in several of his papers (1902,1906, 1913, 1915, and 1916) maintained that these granites belonged to a composite type --- what in modern petrology is termed Migmatite. His conclusions were based on field evidence, which he considered to be far more important than any or both of the chemical and petrological studies in the laboratory (1902, pp.204,209-210). He feels that the authors of the memoir (op.cit). have given undue importance to late shearing. On the basis that a single magma would be unlikely to give rise to different types of rocks he discredited the theory of differentiation of a parent basic magma saying, "..... such separation, in a single cauldron down below, remains in the vast majority of cases, a pure assumption. It has been fashionable, ... to suggest a common origin for all igneous rocks of a district, without regard for the countless chances offered for the admixture of any igneous mass with earlier masses ...."(1905,pp.117-8).

Following Daly (1906, p.17) he describes these granites as the products of assimilation and "intimate injection and partial absorption of granitic material along bedding and foliation planes as well as shear lines etc." (1906 A,pp.3 & 16). Further, he regarded the relict sediments as the remnants of stopes of an arching dome of anticlinal roof. The granitic juices have flowed along the foliation planes and upwards into the cavities produced by the dissolution of the engulfed country rocks, thus making a lit-par-lit injection. (1906A, p.11 & 1914 p.311). Foliation in granites he thought to be present to some extent due both to the igneous and sedimentary characters. "The gneisses thus retain to a considerable degree the structures both of an igneous and stratified material". (1902, p.204, 1900. p.466).

Andrew in his paper on the contact relation of the Donegal granites (1928, p.212-15) also observed the marked foliation in these rocks and its parallelism with the granitic margin. He laid more emphasis on this gneissose structure than on the shears, and considered that the biotite gneisses at the contacts were the products of a partial assimilation and lit-par-lit injection of the original argillaceous sediments.

Results so far available from the Donegal Research

Team of the Imperial College indicate that there are a large number of Donegal granites. Some are migmatitic and formed by replacement of the country rocks, others occur as intrusive plutons. (Pitcher, 1952, Gindy 1952). It is one of the chief aims of the Research Team to dissect the Donegal granite into its various components both in place and time. The present thesis is a contribution to the fulfilment of this aim.

III. SUMMARY OF GEOLOGICAL HISTORY OF THE PORTNOO DISTRICT.

The purpose of this summary of the geological history of the solid rocks of the area is to make it easier for the reader to follow the great amount of geological and petrological detail set out in the subsequent parts of the Thesis. In broadest outline, this history is one of sedimentation, basic sill intrusion, orogeny and metamorphism, intermediate dyke intrusion, and finally emplacement of granites.

The geological history starts with the deposition of a thick series of sediments, which, when subsequently metamorphosed provide the Dalradian Rocks. These sediments began with a thick calcareous member -- the Portnoo Limestone -- which is succeeded by pelitic and semi-pelitic rocks -- the Rosbeg Pelitic-semi-pelitic schists. The original sediments were deposited in shallow water and many primary sedimentation-characters are preserved. These include current and graded bedding which have provided great help in the determination of the sedimentary succession.

Soon after the deposition of the sediments there were intruded considerable bodies of basic material which,

on metamorphism, provide the metadolerites. These were originally pyroxene-labradorite dolerites with typical ophitic texture, and occurred mostly as sills, some of which are slightly transgressive. Chilled edges are rarely preserved, and thermal effects on the country rocks are not conspicuous.

Next followed orogenic deformation. Sediments and associated sills were subjected to severe folding and thrusting from the south. The less resistant sediments became plastic and were compressed into small scale isoclinal and recumbent folds. This was accompanied by sliding of the resistant rocks, such as the dolerites, over the folded limestone, pelites and semipelites, the impression of a marked lineation parallel to the dip of the sediments and the development of cleavage and schistosity both parallel to the bedding. Differential slip on the bedding planes gave rise to a puckering parallel to the strike of the beds; likewise, broken pieces of the resistant dolerites assumed an alignment in the same strike direction. Lastly, there was the development of strike joints now trending predominantly in the directions 280 - 310 degrees.

Probably in close connection with the deformation, a regional metamorphism was impressed upon the sedimentary and igneous rocks. The sediments were converted into

metamorphic rocks which,in the pelitic facies are characterised by garnet and biotite. The dolerites formed in general the more rigid parts of the structure, the smaller bodies were metamorphosed to hornblende-schists; the larger have interiors of non-foliated amphibolite, consisting of green hornblende, plagioclase, epidote and garnet with relict minerals and textures. Special features of the metamorphism include the production of large garnets at contact zones of metadolerites and pelitic and semipelitic schists. An appinitic type of metadolerite of considerable interest may probably be of limestone parentage.

The next event in the geological history was the impression of a regional retrogressive metamorphism, recorded in the regional country rocks by the breakdown of garnet and biotite, the production of chlorite, generally porphyroblastic, and a possible reduction of grain size. By this process of phyllonitisation, the country rocks have been made to appear to be of a low metamorphic grade.

The next important episode in the general history of the area was the intrusion of a varied series of dyke rocks grouped loosely under the name lamprophyres and felsites. Except for two occurrences, these dykes are

later than the main regional orogeny and metamorphism; these two exceptions are sheared rocks and, though cutting across the regional structures, are themselves markedly deformed. The main portion of the lamprophyre series is a group of grey and pink lamprophyres and felsites. Many of these dykes occupy the joint fractures. Most of the dykes of this group have a steep attitude, but some few are sill-like. Their edges are sharp and no reaction at their contacts is seen. A few of these dykes carry xenoliths of the country rocks, these xenoliths being almost unaffected by their immersion in the lamprophyre material. Hornblende is a ubiquitous component of this group. Certain greenish grey lamprophyres include members which are seen to cut dykes of the group just mentioned. These greenish grey lamprophyres are petrographically similar to the main suite, though usually richer in hornblende. They most likely form a set of dykes later than the main group rather than representing fractions of the main magma which were emplaced slightly later in the same region of the crust.

Later intrusions of this phase are pink felsites, occurring as dykes and running in general parallel to the lamprophyres. The felsite dykes are few in number and are seen in some examples to cut members of the main

lamprophyre suite. The felsites in some developments are so crammed with xenoliths, that there results a kind of "conglomerate" with blocks of limestone, pelites or epidiorites "cemented" by a thin matrix of igneous material. The mechanism of emplacement of such xenolithic sills and dykes is a subject of great interest.

By this time probably all the movements had ended and even the cross-joints had developed, running in a N-S or 180 - 210 degrees direction. These joints traverse all the lamprophyric and felsitic dyke rocks already mentioned. The production of these joints was followed by the emplacement, often along them, of a suite of green xenolithic and spherulitic dykes and sheets. Occasionally this suite is transgressive across the bedding and is found to cut the earlier lamprophyres and felsites. Their shapes are very irregular and they are often filled with angular and oriented xenoliths of a variety of country rocks and metadolerites, the matrix to these xenoliths is very fine grained and composed of hornblende and chlorite. A peculiar feature of this suite is the occurrence within them of "pockets" of hornblendic granitic material - these may be cognate inclusions.

The last and final phase of the dyke episode was represented by the intrusion of porphyritic felsites, few in number, along the cross joints in the Rosbeg pelitic and semipelitic group. These dykes are much thicker than any of the lamprophyric dykes. Their general course is 210 - 220 degrees. The rock making them is a pinkish brown porphyry, with 1 cm. long felspar phenocrysts in a medium to fine grained matrix. The contacts are generally sharp but occasionally detached fragments of the metamorphosed country rocks are present in the dyke rock. At one locality, a porphyritic felsite of this group is seen to cut a green xenolithic lamprophyre of the type mentioned in the preceding paragraph.

A remarkable development of explosion breccias is seen at four localities within the Rosbeg group of metamorphic rocks. The largest occurrence amounts to some 20 acres or so and the bodies are irregular in form, approximating to sills, necks and dykes. Around the larger developments, mobilised country rocks are found to occur. The explosion breccia itself is a very heterogenous rock composed of fragments of country rocks and of lamprophyres in a scanty felsitic or granophyric matrix. The dating of these explosion breccias is not exact; their formation is certainly later than some of the lamprophyres

but whether they are to be considered as an end phase of the lamprophyric activity or as an early expression of granitic activity is not yet decided.

The next episode in the geological history appears to be the intrusion of minor granitic bosses and dykes. These intrusions have produced a local contact effect on their country rocks, the metadolerites especially being considerably transformed. By these processes there results a group of contaminated rocks, such as at Dirty Rock and Sand Hole, which are variable in composition and texture. These vary from pure tonalite to pure metadolerite with countless intermediate types. At the contact with limestone, garnet-diopside skarns are developed whilst pelitic and semipelitic rocks are hornfelsed and also impregnated with quartz along their foliations and shear planes.

The last major episode of this long intrusion history was the emplacement of the Ardara granodiorite pluton which enters into the eastern portion of the area investigated. This pluton has a fine grained and slightly lineated interior granodiorite portion surrounded by a coarser tonalite which is lineated. Xenoliths are everywhere abundant and are orientated parallel to the arcuate margin of the pluton in the sector investigated, there

being about a third of the complete dome. The emplacement of the plutons is held to be responsible for the curvature of the regional strike and also for the production of a crinkling across the bedding and schistosity. This crinkling is tangential to the margin of the pluton and dies out away from it.

The sediments at the contact have been converted into massive hornfelses. At the immediate contact with the pluton, the hornfelses show a lineation standing vertical or plunging at 80 degrees, and they contain sillimanite, staurolite, garnet, andalusite and cordierite. Rocks with sillimanite and garnet form a narrow zone at the contact with the pluton, this zone being followed outwards by one with staurolite which in turn is succeeded by a zone with andalusite and cordierite, this last being the widest zone of all.

The granitic rocks at their contact with metadolerites show well developed assimilation of basic material. The massive metadolerite is seen to grade into diorite, quartz-diorite and eventually into granodiorite, as well displayed in the Summy-Sheshkinmore Lough areas. Sporadically, coarse pink felspar phenocrysts are developed in metadolerite at a number of localities.

Following the emplacement of the Ardara pluton, the hornfelses have undergone hydrothermal alteration, recorded by the transformation of garnet to chlorite, staurolite and andalusite to sericitic shimmer-aggregate, brown hornblende to green hornblende etc.,

At the concluding stages of the consolidation of the granitic mass, a perfect radial, cross, longitudinal, ring and marginal joint system was produced, both in the granitic rocks and the hornfelses. A few aplites and coarse pegmatites are found intruded along these joints. In the contaminated zone of mixture of granitic rocks and metadolerite, veins of epidote can be traced from the massive granite into the coarse grained dioritic rocks, being then lost in the matrix of the latter.

Movement along prominent and radial ring joints is recorded by well developed slickensides which appear to indicate accommodation of the interior of the pluton. Movement along radial joints affects also the country rocks.

A few Tertiary dolerite dykes mark an episode not connected with the events so far summarised. Their general trend is about E:W.

The geological history is completed by the Pliestocene glaciation, which has produced the usual

erosional and depositional features of land-glaciation. With these phenomena this Thesis is not concerned.

IV. SEDIMENTARY ROCKS.

Country Rocks.-

These, in general, are highly metamorphosed calcareous and arenaceous sediments, intercalated with dark green basic igneous sills and transgressive sheets of metadolerites. Except for a few dislocations and contortions of relatively minor importance, the sediments show a continuous series beginning with a thick crystalline limestone, with some three bands of intercalated schists in it, followed by a much thicker series of Pelitic and Semipelitic schists. Towards the southern region, the latter are found to grade upwards into garnet-muscovite-biotite-schists, in which are also found thin intercalations of calc-schists. The dip, strike and other structural characters of the rocks govern the general topography and the widths of the outcrops are seen to be dependant on these features rather than their original depositional nature. In general, the marked thinning of the Pelitic schists, e.g. near Doon and Pound Loughs immediately overlying the limestone, is due to subsequent shear, caused by the intrusion of the granitic pluton. The E.-W. fault running north of Aghros Hill extending up to Doon Lough likewise seems to have contributed to the thinning of this outcrop.

Succession:-

The rocks are completely devoid of fossils and are polymetamorphosed. The classification given below is based on (a) lithology (b) Current and Graded bedding -- "Younging" (c) field relations and(d) mineral composition. The sequence of rocks is a continuous one in which transitions from the lower members to the upper ones are perfectly displayed. Thinning of the intercalated calc and other schists is a result of tectonic disturbance as has already been noted. The rocks of the area show the following succession.

YOUNGEST

Rosbeg Pelitic - Semipelitic group (with their metadoleritic sills	3. Dawros-Rosbeg banded Semipelitic Schists. 2. Aghros Hill - Eden House Semipelitic Schists. 1. Dunmore - Doon Lough Pelitic phyllites.
Portnoo-Limestone group (with their metadoleritic sills)	5. Blackish grey flaggy limestone. 4. Pelitic schists (pyritiferous) 3. Massive blue limestone. 2. Semipelitic pyritiferous schist. 1. Banded limestone.

OLDEST

Nowhere is an actual boundary between the two main groups visible, but a normal transition from the limestone to the pelitic - semipelitic schists can be observed west of the main Portnoo - Rosbeg road and in the area between the Pound and Mullyalla Loughs (about half a mile west of Pound Lough). The abrupt contact of the pelites

against limestone north of Aghros Hill is due to the late faulting referred to above. The structural elements such as dip, schistosity and cleavage of the two groups are sufficient evidence for the primary nature of their juxtaposition, even though there may be some minor disturbances.

Leaving aside the eastern (aureole) part of the metasediments, the general strike of the beds is WNW. - ESE. and the dip varies from 0 - 75 degrees; the average dip is between 25 - 30 degrees to S. & S.W. In the eastern half of the area, the metasediments show a general curved strike around the granitic pluton veering from 230 - 180 - 270 degrees or SW-S-W. and the dip is almost vertical. In the granite, xenoliths (up to 3ft. long) of sedimentary schists and metadolerites, striking parallel to the contact of the main granite and the sediments, are seen for a distance of one mile towards the centre of the pluton.

1. Portnoo Limestone group.-

This group of rocks, about 1000 feet thick, contains intercalated bands of pelitic and semipelitic pyritiferous schists of considerable thickness. The banded uppermost member is thickest and is more pelitic than the other two lower in the succession. The buff coloured limestone at the base is made up of alternating

bands of thin carbonaceous (graphitic) layers and sugary-grained crystalline limestone. These carbonaceous bands show a ribboned appearance on the weathered surface. The massive Blue limestone forming the main mass is pure and is a mosaic of calcite. It shows a bluish grey colour on the weathered surface. The grey flaggy limestone is characteristic of the top and gradually grades upwards into Pelitic schists of the Rosbeg group. This latter limestone is also fairly coarse, with elongated crystals of calcite, and is spangled with mica.

Distribution.- The rocks of this group are best exposed, almost in continuous bands, in the Narin, Portnoo and Dunmore areas. At Narin, the strike is WNW.- ESE., but just east of Narin Church the limestone is dislocated by a NNE.-SSW. fault. Limestone on the eastern side is well exposed in the fields south of the road while on the western side it crops out on the coast and forms prominent cliffs. Almost half way between Narin and Portnoo harbour, the banded limestones strike WNW.-ESE. with a vertical dip. In fact, two such bands can easily be traced with their intercalated schists and metadolerites in the low vertical cliffs and the rocky shore. Again, the crumpled and brecciated limestones exposed on both sides of the road, about one furlong west of the Church, indicate

that these rocks have been subjected to WSW.-ENE. faulting. These faults can be traced up to the foot of the Cashel Hill which is probably also affected by them. The position of the limestone and metadolerites on the sea cliffs between Portnoo harbour and Narin is due to the fact that they have been moved northwards along these faults.

The limestone again appears in the ridge just south and S.W. of the Portnoo P.O. Here the rock shows slight disturbance, registered by later gash veins, but exhibits beautiful current bedding which shows that the limestone is the "Right Way Up". The best exposures of the banded limestone are on the shore just north of the Portnoo Pier. All the characters of graded and current bedding and banding are very well developed and different bands can be traced as far as Dirty Rock. On the coast in between Dirty Rock and Sand Hole or still further west, xenoliths up to 50 yards x 20 yards of limestone are found embedded in granitic and metadoleritic matrixes.

The crumpled and brecciated bluish limestone is again met with just north of Pound Lough. On the west side of this Lough and towards Dunmore Hill, the limestone series crops out in force. Soon after crossing the Portnoo - Rosbeg road, the rocks show a low to horizontal dip, which

continues up to Dunmore Hill, while on the north and the west sides of this hill the dip is as high as 35 degrees. On the north-west flank of the Hill (near the xenolithic Felsite dyke) the rocks of this group plunge seawards and form cliffs, more than 100 ft. high. Similar high cliffs run up to Dunmore Hole, where the bluish banded limestone again forms the rocky shore.

2. Rosbeg Pelitic-Semipelitic group.-

The lithology, mineralogy and the graded nature of these sediments permit a three-fold stratigraphical division of this group of rocks (as shown below - youngest at the top):-

(iii) Dawros - Rosbeg banded biotite-muscovite-schists

(ii) Aghros Hill - Eden House Semipelitic schists

(i) Dunmore - Doon Lough Pelitic phyllites.

If the succession is continuous, the thickness of the Rosbeg group along with their intercalated meta-dolerites is about 12,000 ft. (11,800). It will be again worth mentioning that the gradation from one member is so gradual and uniform that it is almost impossible to define their boundaries in the field. The best developed schistosity and the cleavage are generally parallel to the bedding. At and towards the contact of these sedimentary

rocks with the granites, the country rocks show effects of contact metamorphism, and gradually (from west to east) pass into Andalusite, Staurolite, garnet and sillimanite assemblages.

(i) Dunmore - Doon Lough Pelitic phyllites.- Resting conformably on the Portnoo Limestone group just south of Dunmore Hill are highly micaceous grey phyllites and schists. They are characterised by a silvery grey colour, soft shining silky lustre and two sets of well developed lineations or puckerings. Towards the top they are carbonaceous, while the lower members are highly crinkled and show an abundance of white mica. Towards the south, they pass into rather darker grey flags, which are comparatively siliceous in nature and have a higher specific gravity. Towards the east near the Pound, Still and Con Loughs, the sub-group is exposed in a narrow belt and the rocks have a slightly reddish tinge. Further east, just north of the Doon Loughs, near Narin Hill, they are characterised by the development of cordierite, andalusite, garnet and sillimanite, which continue and pass east of the main Narin - Ardara road. Current or graded bedding is completely absent. To the south this sub-group passes into the Aghros Hill - Eden House Semipelitic schists.

(ii) Aghros Hill - Eden House Semipelitic Schists.-

This is a series of grey, fissile and flaggy schists of dull lustre. As in the previous sub-group, the schistosity and cleavage are parallel to the bedding. The colour varies from light to dark grey. Slightly less developed than in the previous sub-group are seen two lineations, along which (towards the east) are found to occur (on the planes of schistosity and cleavages) partially developed andalusite crystals. The rock varies from micaeous phyllitic schists to true mica-biotite schists, with well developed cleavage.

Towards the granite boundary, the size of the andalusite (shimmer) crystals increases, and crystals up to 4 - 5 inches in length and $\frac{1}{2}$ to $\frac{3}{4}$ inch across are seen just west of Summy Lough. Many large cross-shaped twinned crystals of Staurolite are also found to occur just south of the same Lough.

Near Eden House in a quarry by the road side, the rock is exceedingly fine grained and evidently phyllonitic. Though apparently it shows a laminated structure of fine to finer grain, graded bedding could not be established under the microscope.

The rocks of this series are best exposed on the West coast line, and in the area between the Aghros Hill

to Kiltooris Lough - Terrylagh regions. Disconnected exposures are found north of Eden House to the Dawros Bay Hotel (about half a mile north of Rosbeg P.O.) in the west and in the swampy region between Meendooish Hill and the Summy Lough.

(iii) Dawros - Rosbeg banded Semipelitic schists.- Overlying the rocks of the sub-group just described is a thick series of grey to dark grey (with pinkish hue) banded fissile schists. The light or dark coloured bands vary from 2 inches to 2 feet in thickness. When traced along the strike, a particular band becomes thinned or thickened even over very small distances. In the same way, dark grey graphitic pelitic bands change to light silvery grey lustrous bands or into comparatively semi-pelitic types. Sometimes the rocks of this sub-group can be classified in the field, as certain bands are characterised by small holes, or spots on the weathered surface. These are caused by the weathering out of the garnet crystals or chloritic spots (after garnet), the chorite being one of the constant and regional minerals. In this sub-group are probably two or three thin bands of a calcareous nature, in which calcite is one of the chief constituents. The garnets in this type of rock are often recognisably rolled. These rocks of the sub-group are typically muscovite-biotite-chlori e-schists.

These rocks are best developed in the whole of Dawros, Rosbeg, Kiltooris and Carrickalagh regions. In fact, this is the most widespread group of all the rock types.

(b) Correlation.- As has been shown in the previous paragraphs the sequence of rocks in this area is a continuous one. The authors of the Survey Memoir (Mem. 1891, pp.30-31) considered that these rocks were the well developed western continuation of the Lough Gartan group. The Memoir reads; "Not only the limestone thus attains an important degree of development, but the schists of the Lough Gartan group appear in much greater variety in this portion of the district than elsewhere". The work of the Imperial College Research Team has shown that the rocks of the Portnoo Limestone group are comparable to the "Main Limestone Group" of Read, Pitcher and Iyengar, which Dr. A. Gindy has classified as Group V in the area north of Gweebarra Bay. The Rosbeg Pelitic and Semipelitic group of rocks, though not exactly similar to the Cleegort Pelitic group (Read, Pitcher and Iyengar) can be taken as the Western continuation of this and can be correlated with "Group VI" of the Lettermackaward area (Gindy, 1951).

(c) Features of Sediments before Regional Metamorphism.

As has been summarised in the previous pages, the area had been subjected to several movements, and the impressions of these are clearly visible on the rocks. Even though many of the primary structural features of these rocks have thus been obliterated, Current bedding and Graded bedding in general have proved to be very valuable criteria in the determination of the Order of Superposition. Further, their present mineralogical composition and textural relationship reveal in many cases their original sedimentary features prior to the first and most effective regional event in the metamorphic history.

Features of sediments.- The rocks of the limestone group show a ribboned appearance towards the bottom with intercalations of (i) Thin pebbly siliceous bands ranging in thickness from a few millimeters to about two to three centimeters; (ii) dark graphitic bands at lower horizons; (iii) Hard, rigid, and comparatively fine grained siliceous bands, few in number; (iv) Pyritiferous Semipelitic (at lower levels) to Pelitic schist near the top. The massive limestone exposures at the roadside near the Portnoo P.O., and the banded limestone north of Dunmore Hill show well developed current bedding (Figs 3A.,B.&C..). The siliceous bands reveal later drag-folding and sygmoidal fracture

cleavage as developed later.

(i) Intercalations.- Of these the first to be considered are the thin siliceous bands. These are distinctly varved and exhibit drag-folding. On closer examination, in a particular band itself one could notice fine and coarse grained quartz particles set in a calcareous matrix (Fig.....). It is interesting to record here that a lateral textural gradation occurring over very short distances could be deciphered in the same band.

(ii) Dark graphitic bands.- The maximum thickness of these bands is not more than 6 inches to 8 inches. They are dark, and occasionally shining, lineated, fractured and knotted. They alternate with 1 - 2 ft. thick bands of limestone, in which the portion immediately below the graphitic band is finer grained, and poorer in silica than the material further down in the same band.

(iii) Hard siliceous bands.- These are few in number and never more than 5 ft. in thickness. They are light greenish grey to bluish and typically glassy in texture. Sometimes their dark blue to blackish shade causes them to be mistaken for an igneous rock in the field. But the occurrence of elongated streaks and blebs of shining metallic ores in thin parallel laminae mark out their bedding planes.

(iv) Pyritiferous Semipelitic-Pelitic bands.- Such bands are three in number. They are highly metamorphosed, lineated, rodded and schistose in character. The one best exposed just at the foot of Portnoo Pier is more siliceous than that exposed in a quarry west of Pound Lough, which is micaceous and is a true pelitic schist.

(v) "Igneous looking" carbonaceous bands.- In the two major groups (Portnoo Limestone and Rosbeg Groups) there are three very peculiar "igneous-looking" sheet-like bodies with one of their edges showing a "chilled" appearance of half to one and a half inch in width. Typical exposures of these are on the coast just north of Dunmore Hill and half way between Crocakun and Scoltnaweehoge, (on the north coast line of the Dawros Peninsula). Their sharp and glassy-looking margins grade into a fine grained to oolitic material set in a limonitic matrix. The rock is graphite black on the weathered surface. It does not yield easily to the hammer, and a fresh piece is difficult to obtain.

Two such bands (6 - 8 inches and 2 ft.) on the coast north of Dunmore and another 1½ ft. thick on the north coast of Dawros Peninsula are the best exposed in the area. These are about 150 yards long and have the same dip and strike, schistosity and lineations etc., as the associated major rock-types. North of Dunmore the

(drag-folded) limestone is overturned. It has a dip of 65° - 70° to the south or south-west. The thicker graphitic band near the limestone gradually diminishes in thickness (never less than 1½ ft.) and forms a lenticular sheet sometimes coming against the limestone itself. The band on the coast of Dawros is uniform in thickness, lies parallel to the banded schist and seems to be traversed by a grey lamprophyre (Fig .13....) (observed on the western side of the cavern of the small peninsula).

Under the microscope, the rock of these bands shows a schistose structure with small "augen" of dark grey colour embedded in a carbonaceous schistose matrix. In some of the augen, broken and crushed quartz, muscovite and a few feebly lamellar twinned plagioclase crystals of grey colour can be made out. Associated with these are calcite, apatite, chlorite, pyrite, limonite and some prismatic clinozoisite. Some of the grey rounded spots appear to show a mild sector twinning (under ordinary low power) so that cordierite may be suspected. The rock is more than 60% graphitic or carbonaceous, and graphite actually coats the planes of schistosity.

It may be worth while to discuss the possible nature of these carbonaceous bands since opinion on this subject of the Donegal Research Team is divided.

On the basis of the field and laboratory studies three possible explanations can be put forward by the writer with regard to their origin, though it is difficult to decide which, if any, is correct.

1. Intrusion as igneous sills or dykes.
2. (Volcanic lava flows) or Pyroclastic deposits.
3. Carbonaceous sediments similar to the dark graphitic bands.

1. Outside the writer's area, at Carrickfad, better developed similar lenticular bodies are reported by some of the observers to have chilled margins on both their sides, and are accordingly thought to be earlier igneous dykes or sheet intrusions. As regards their lenticular shape, it has already been stated that pelitic or semi-pelitic schists of the limestone group are also found to occur as lenses due to the comparative resistant nature to deformation of the limestone when the pelites or semipelites became plastic. Regarding the chilled margins, the writer would like to mention, that though he himself has only briefly studied the above mentioned occurrences at Carrickfad, he does not recall having observed their marked chilled margins on both their sides. Further, it is interesting to record here that until the final stage of this work, the writer was inclined towards their igneous origin but the field relations in the area dealt with here,

the presence of only one "chilled" edge reinforced by later microscopic study, have convinced him that the bands are sedimentary in origin.

2. As regards the second mode of origin, (volcanic lava flow or Pyroclastic deposit), the bands show a well developed schistosity both in the "chilled margin" (under the microscope) and in the body of the rock. If the rock is volcanic, and if the primary flow structures are supposed to have been destroyed due to later movements and subsequent metamorphism, then the same argument can be supposed to destroy the "chilled margin" as well. Secondly, there does not seem to be any change at the contact with the limestone and there is no mutual contact zone between the two.

If they are of pyroclastic origin, the volcanic dust, ash, and lapilli and bombs, thrown up into the air, are partly in a hot molten state, but before they fall and are deposited, they become cool and hardened. These (pyroclastic) deposits have some characteristic angular fragments embedded in a fine grained matrix; the rocks under discussion are completely devoid of such structures. Further, recent and present day pyroclastic deposits do not show so high a percentage of free carbon, this being on the other hand a common constituent of sedimentary rocks.

3. According to Rankama and Sahama (1950, p.533), graphite "is however, a common constituent of metamorphic rocks, and it is formed from carbonaceous material of the sediments during metamorphism". Further, (p.534) "the content of carbon in igneous rocks is relatively low --------" and finally, "It is evident that the amount of carbon contained in igneous rocks is comparatively smaller than that present in sediments and sedimentary rocks".

From the above factors and with support of the field observations, these carbonaceous "igneous looking" bands may possibly be the thicker representatives of the graphitic bands (already described above) present in the limestone group. It may also be pointed out here that the schists of the Rosbeg Group also have bands rich in carbon. Even with all these facts, the author would like to leave the origin of these bands rather an open question.

(d) Conditions of deposition.- Considering the nature of the different rock types associated with the banded limestone, their current bedding and textural gradation of the fine siliceous bands, the deposition must have originally started under shallow water or deltaic conditions with alternate torrential and calm climates. The composition of the massive limestone and

the pelitic schists at the top, reveal that the basin of deposition had become deeper, in which the clayey matter was laid down probably in a slowly sinking trough. This sinking does not appear to have lasted long. The Graded bedding of the pelites or semipelites supports the suggestion of a shallow transgression or slow regression. The chloritic semipelites, with thin garnet (chlorite)-rich calc-schists (represented by calc-biotite-chlorite-schists) must have been deposited as impure marls.

V. DOLERITES.

A. Introduction.- A casual glance at the geological map of the area attracts attention towards the rock type shown in black. These are the bodies of epidiorites and amphibolites representing basic sheets intruded into the sediments before the folding and regional metamorphism. In their occurrence, physical characters and mineralogical composition, they are similar to the basic rocks found to occur throughout the County of Donegal and are probably the Irish representatives of the epidiorites of the Scottish Highlands.

(i) Occurrence.- The best developments are those forming the Narin-Cashel hills with their offshoots running towards Dunmore Hill; other good outcrops are found along the coast from Dirty Rock to Dunmore Head. The continuous cliffs along the coast between Portnoo harbour and the N.E. corner of the area are possibly the northern extensions of the Narin Sheet.

A swarm of lenses, well exposed north of Aghros Hill, thicken towards the west coast and are seen to thin by the side of the unmetalled road, west of Pound Lough. About a hundred feet higher than the above are irregular lenticular bodies culminating in Aghros Point. These may be parts of a

sill or different sills exposed as thin lenses extending towards the west of Lough Birroge. Another group of such lenses tends to follow the sedimentary horizons on the N.W. side of Lough Doon.

In the centre of the area lies the most important and largest sheet, about 40 - 50 ft. thick. It is best exposed north-east of Kiltooris Lough and forms the top of Lefrin Hill. It has an irregular outline. On the north side, it is partly dislocated by a fault running WNW. - ESE.

In the Dawros, Rosbeg and Carrickalagh areas, exposures of metadolerites are numerous, but none of these is comparable either in shape and size with any of those occurring in the Kiltooris-Narin region.

Between Summy-Sheshkinmore Loughs area, and the Renny Points, older dolerites are well developed around the circular margin of the Ardara Granite Pluton, and provide material for the production of a variety of contaminated rocks.

These early dolerites thus occur as dark green to greenish black sills, sheets or lenses and lie interbedded with the sediments, in which some individual bodies can be followed for long distances in the same stratigraphic horizon. They rarely cut across the sedimentary bedding. Occasionally their form is irregular but in general they lie parallel to the sediments. In a general way, these

intrusives are especially developed in the Portnoo Limestone and in the semipelitic portion of the Rosbeg group.

The larger sills and the other lenticular bodies show a schistose character at their original chilled margins. The central portions of the bigger sheets are massive. Occasionally they show a well developed columnar structure as on the western portion of Aghros Hill near Sand Hole and Pollmurry south of Kiltooris school. The Cashel-Narin sill and the Kiltooris sheet are traversed by well marked shear-planes in which the pink felspars are drawn out into thin streaks.

The weathered surfaces of many of these sills show at both their contact planes brecciated and angular xenoliths of sedimentary rocks embedded in a compact dull green matrix. Some of these xenoliths are folded, presumably due to softening and movement on their incorporation in the magma (Fig .11..D...). On broken surfaces it is hardly possible to differentiate the main rock from the xenoliths. The best examples of these are seen on the road side two furlongs south of Lefrin Hill and on the coast at Carrickalagh and Illanglass. At Dirty Rock, an epidiorite sill is seen to contain sharply folded "anticlinal" pieces of limestone without any marked change at the contacts; (Fig. Pl.5.....) this is best interpreted as a result of the intrusion of the

metadolerite. The folding at the contacts of metadolerite and limestone is probably due to later deformation.

So far we have dealt with what may be called normal metadolerites. There remains, however, to be noted an <u>appinitic</u> group which possesses features of great interest. These rocks differ from the normal type in being much coarser in grain and richly studded with black prismatic crystals of hornblende; they are dull green in colour. They are never seen to cut or pass through the other dark green varieties. Such appinitic types are developed in two main areas. First, they form a band of small lenses in the semipelitic rocks stretching from Rosbeg Pier for 1½ miles to Pollmurry, S. of Kiltooris School. The second occurrence is more important and is made up of three large sheets found between the Sheskinmore and Kiltooris Loughs. The country rocks immediately associated with the appinitic types include calcareous varieties, and rocks of a similar kind are abundant as xenoliths within the appinites, as for example near Rosbeg P.O. Nodules of tremolite-actinolite are also common in these rocks. Both contact rocks and the appinitic rocks are garnetiferous. As will be discussed in detail later, these appinitic rocks are possibly the result of an interaction be ween basic rock and calcareous country rocks possibly activated by subsequent

granitic intrusions.

(ii) Composition.- Normal rocks of this group were fine to medium grained dolerites with good ophitic texture, this being almost intact in the central portion of the sills. At the contacts, the rock is now a hornblende-schist, these schistose portions representing the marginal chilled edges which have taken up the movements so that the central portions have preserved the original ophitic texture.

The common minerals now met with in these rocks include plagioclase felspars, hornblende, garnet, chlorite, apatite, epidote, biotite, sphene and iron oxides. The complete and detailed petrography of the different rock-types is given in a subsequent section. Their original composition must have been that of a basic dolerite. The appinitic variety, as already noted, may be of a composite nature deriving material from both the dolerite and the country-rocks,

B. Contact metamorphism due to the dolerites.- The intrusion of the dolerites has produced local metamorphic effects on the country rocks, the effect depending in detail on the nature of the sediment and the size of the intrusive body. The intrusions are mostly comparatively thin and lenticular bodies of fine grain, presenting as it were chilled margins throughout. The contact effect due to these

thinner sills is consequently not very marked. Thus, as has been pointed out already no large scale well-marked metamorphism of the sediments seems to have taken place, the only significant effects being found to occur at certain localised contacts. For example, the limestones of the Portnoo group, except for very local effects, are almost unmodified. However, on the rocky beach N. of Dunmore the limestones at the contact show well developed pink garnets, the distribution of which seem to give a sort of graded bedding (Fig ?f.....). Another exposure of limestone at the contact of metadolerite, just at the northern head of the Pound Lough, shows a greenish cherty-looking banded limestone with alternating bands of up to three or four inches in thickness. Unfortunately, the exposures are bad and this peculiar rock cannot be followed laterally for more than a few yards. The boundaries of the different bands are sharp, and the bands themselves never appear to be transgressive- they can be taken as bedding. These banded portions, however, do not show the typical drag-folded character of the limestone; they must have acted as hard rigid bodies during the later movements. As these bands are of very local nature and are not well exposed, the writer does not wish to deal with them in detail and leaves the question of their formation open. The limestones of other regions are almost unaffected.

The pelites and semipelites at their contacts with these dolerite sills have a baked and indurated appearance. The contact rocks are finely textured micaceous flags which pass, away from the contact, into crystalline biotite-muscovite-schist of regional development. Sometimes the contact rocks are bleached and the high percentage of silica in between the foliae of the sedimentary rocks by the side or at the contact of the sills may probably be attributed to the exudation of silica as a result of these intrusions.

In a quarry near Eden House semipelitic rocks develop cordierite near a metadolerite intrusion to which the production of this mineral can be related.

The occurrence of andalusite-schists - about two furlongs E. of Dunmore Hill near the houses, at the head of Dunmore Hole and near Scoltnaweehoge on the north coast of Dawros peninsula - near the epidorite sills and well away from the exposed granite contact raises questions of great interest which are discussed on a later page. It appears rather unlikely to the writer that the production of such schistose rocks is to be related to the intrusion of the dolerite bodies.

C. Petrography of the contact metamorphosed rocks.-

As has already been mentioned, the sedimentary rocks are polymetamorphosed. Though later intrusions have

played a great part in shaping their present nature, mineralogy and petrography, at certain localities it is apparent that only dolerites have affected them. An account illustrating such occurrences follows :-

(1). The garnetiferous rock mentioned on a previous page as occurring at the contact of limestone and a thick metadolerite on the beach north of Dunmore Hill is well away from the granite. At the contact of the metadolerites and limestones a sharp margin is visible. On the limestone side, pink garnets up to 3/4 cm. dia. are present, the number and size of which become less and less away from the contact. On the weathered surface this garnetiferous limestone shows a pitted appearance, while the contact rock or the metadolerite is massive. The metadolerite at the contact is fine grained and blackish green. The metadolerite about 4 - 5 inches away from the visible contact does not show any appreciable change.

Under the microscope the contact rock (No.1/75 Slide & Sp.) shows a fine-grained, equigranular and poikiloblastic texture. The two main mineral constituents are almost equal in amount and consist of brown-green hornblende, altering to deep green lath shaped crystals of actinolite and saussuritised plagioclase, together with a small amount of rounded to subrounded grains of quartz. The other important Fe-Mg minerals are lenticular to subangular

grains of leucoxene, and wedge-shaped to irregular grains of sphene with some limonite. A few subhedral crystals of pink garnet and small grains of epidote and probably colourless diopside (extinction angle 30 - 35 degrees) are also present.

The limestone near the contact (Sp. No. 1/76) has a buff to grey colour, is massive and saccharoidal in texture, and shows subhedral crystals of pink garnet up to 1/2 cm. in diameter. On the polished surface, it shows thin (5 mm. to 1 cm) irregular bands of white to light bluish grey colour. Under the microscope, angular to subangular equigranular calcite, clinozoisite, zoisite, pink garnet (possibly grossular), scanty plagioclase, quartz and some colourless pyroxene can be seen.

From the nature of the distribution of the individual mineral constituents in the different parts of the slice, the irregular banding observed in the hand specimen is confirmed. In the hand specimen this is a garnetiferous marble, yet in thin section uncombined quartz and felspar are present. It is likely that these two minerals must have recrystallised from the original siliceous or clayey material.

From the above stated facts it is clear that the main features of this contact metamorphism in the meta-dolerites and limestone are the result of mutual exchange

of Ca, Ti, Fe, Mg, etc., viz. (1) addition of Ca is responsible for the later formation of zoisite and clinozoisite from the original plagioclase and pyroxene in the dolerite margin; (2) production of actinolite and actinolitic hornblende and replacement of pyroxene in the metadolerites; (3) production of grossular. In the limestone the changes include the addition of Ti, Fe and Mg and thus the formation of garnet, zoisite, clinozoisite, sphene and pyroxene has taken place. A similar type of epidiorite- limestone contact from Aberdeenshire is described by Hutchinson (1932, pp.537-561), who writes : ".... the main feature .... is the enrichment in lime of the marginal part of the original doleritic intrusion .... the formation under later metamorphism, of zoisite from the plagioclase and augite, while .... actinolite took the place of pyroxene".

(2) Greenish cherty looking banded rock on the north-east corner of Pound Lough (also previously mentioned on p. 36) is found to occur in small exposures just at the north foot of the Cashel Hill. The rock is exposed in an outcrop of some 30 yards by 5 yards. For the most part it is crumpled and brecciated. The crushed fragments are cemented in a quartzose and calcitic matrix but the individual fragments show the banded and cherty nature. Hence it is considered

that before the brecciation and cementation of this limestone had taken place the rock had already acquired the cherty appearance. The thickness of these siliceous bands is very variable. A single band may be from a few millimeters to 2 - 5 cm. in thickness with alternating bands of saccharoidal limestone.

An average sized specimen is fine grained, compact and massive and reacts with dilute HCl only in alternate bands. It is glassy and made up of alternate greenish white and light dirty green to bluish green bands. A single band is never transgressive. Sometimes thin streaks of pyrite can be made out to be parallel with the white or green bands, and thus help to mark the bedding planes.

In thin section (Sp. No. 3/32A) the rock appears very fine grained and is composed of almost equigranular fine calcite, quartz and probably plagioclase, biotite and iron oxides associated with white and blackish dusty material. At one side of the slice a thin sharp band of mosaic calcite, clinozoisite, quartz, plagioclase, biotite and sphene forms the edge.

From the limited nature of the occurrence and from the circumstance that only one specimen is at the disposal of the writer, he does not wish to say anything with regard to the origin of these rocks, except that their production might

be associated with the intrusion of metadolerites. However, Dr. Gindy (1950 and 1952) considers such types of rocks occurring in force in the areas north of Gweebarra Bay to be a result of silicification due to the intrusion of metadolerites. He writes: "Small scale silicification of the pelites and limestones at their contacts with these intrusions is readily demonstrable in the field".

(3) Cordierite - bearing rocks from the quarry near Eden House occurring in the semipelitic schists, which are massive and do not show the usual phyllitic or schistose character, are grey in colour and show a fine maculose character. In the north-east corner of this quarry, almost from the top to nearly half its depth, a very peculiar pisolitic rock is exposed. There is not much difference in the weathered and the fresh pieces of this rock. A fresh and good specimen is difficult to obtain. The rock is very friable and looks like a grey laterite. On breaking, the different pea-sized, flesh-grey-coloured spherules or "oolites" are seen to be partly cemented in a yellowish grey matrix or are interlocked.

Under the microscope the rock (Sp. No. 5/66A) is fine grained and shows a typical maculose texture. It is made up of cordierite crystals embedded in a sericitic and limonitic matrix. The cordierite crystals are about 4 mm. in diameter

with generally oval shaped six or seven irregular sides (sometimes discernible); they exhibit a sector twinning. In each granule small quantities of plagioclase associated with strained quartz can be made out. The rims of these oval spots are yellow to dark brown in colour and composed of fine quartz and limonite. Of the other minerals, some small grains of apatite, ilmenite and hematite with dark brown flakes of biotite probably altering to chlorite form the bulk. The rock shows effects of induration and is probably a spilosite.

Overlying the rocks of the quarry mentioned above or in immediate contact with them there is found no trace of any metadolerite or lamprophyre or granitic intrusion. But only about 100 yards east and 150 yards south of this quarry, metadolerites are found exposed and the formation of cordierite-bearing hornfels might be attributed to the intrusion of these doleritic bodies. These cordierite-bearing rocks seem to have otherwise suffered a similar metamorphic history to the adjacent pelites, at or near the (metadolerite) epidiorite contacts. The occurrence of such cordierite hornfels is reported by Harris (1937) and Jeremine (1945), and McCall (1951).

VI. TECTONICS AND STRUCTURE.

Introduction.- In this part of the thesis, the tectonics and their relations are dealt with as fully as possible by a discussion of the exposures, the movements and the formation of new minerals, the data being fitted into their proper places in the tectonic history. For this end, the results obtained are based on the observations made on the different rock-types, which exhibit abundant evidence of deformation, the development of lineations due to puckerings or the impressions of closely spaced lines, or cleavages. As many as five different lineations have been observed on one and the same small outcrop, besides the planes of schistosity and bedding. In the southern part of the area the rounded or oval shaped chlorites (after garnets) are so arranged as to give a definite linear pattern. At some places, particularly in the limestones and the semipelites of the Dawros area, small quartz pencils or boudins or roddings are found to occur. These different linear structures are shown on the sketch map (Fig. 5.) and geological map (Pl,I.) in which more than 500 readings are shown by their general and mean directions. A casual glance at these maps shows that there are at least three main lineations present in the area;

These are superimposed one over the other and are probably due to different movements.

On the whole the structure of the area is simple, the rocks forming the flank of an anticline. However, they have been subjected to minor dislocations due to forces acting in a north and north-easterly direction or directions. A curvature in the eastern portions of the country-rocks lends support to the view that the granitic intrusion was also accompanied by forces acting in the same directions (mentioned above).

A. Structural elements.- The common structural elements observed in the area are strike and dip, schistosity, cleavage, dragfolds, lineations, minor folds and stretched crystals of chlorite and aligned pieces of rigid dolerites. The more massive rocks do not exhibit any major or minor structural characters, and had the rocks not been banded in nature, it would have been a difficult task to unravel their present structural position and the movements to which they have been subjected, viz. their tectonic history.

(a) The strike and dip of the bedding planes strictly conform to the well developed planes of schistosity or cleavage. In almost the whole of the area, it is difficult to separate these structural elements of the sedimentary rocks. Except for local discrepancies and disturbances

the general strike is uniformly WNW-ESE or NW-SE with low south or south-westerly dip.

The mapping of the several good exposures of the limestone reveals that its regional strike is the same, NW-SE with minor local variations due to different intrusions (see enlarged map No. Fig 10). Mention may be made particularly of the local variations between Portnoo Harbour and Sand Hole, where the different bands are seen curving round between N.-S. to E.-W. and ENE.-WSW. directions, while at Dunmore Hole the strike of a particular band is seen to swing round all the points of the compass (see enlarged Map, Fig. 4). Accordingly the dip also varies in relation to the strike but its magnitude ranges from 0 to 75 degrees to the south or south-west. However, the general dip of the limestone group is rather low (horizontal to 10 degrees in the region between north-west of Pound Lough to the dilapidated houses north of Aghros Hill), but the high value observed (west of the huge xenolithic lamprophyre) north of Dunmore Hill probably indicates that it is a part of an overturned limb of a recumbent fold. This is confirmed by the beds being "wrong way up" in this locality. (see pages 36-37).

As has already been stated (page 33) the pelitic schists overlying the limestone simply grade upwards into

semipelitic types and at no place is a true boundary or any marker horizon visible. Unlike the limestones, the schists have proved more incompetent and plastic under the orogenic or later movements and hence the rocks of this series exhibit considerable variation in their local strike and dip. Within a foot or two, one and the same lamina in a thin band is seen to be contorted into several folds (drag folds, Fig. 6A-B). Such a contorted nature, the absence of any marker horizon and the polymetamorphic effects are obstacles in the interpretation of the geological structure of the area. However, with the aid of all possible field structures, these pelites or semipelites of the Rosbeg group have been found to be lying in a comparatively simple structure. The contortions are a result of the main orogeny associated with the later movements.

In a general way the length-wise directions of the dark and light bands of these schists have been treated as the strike direction. Again, due to the same contorted nature, it is difficult to measure the true dip on a bedding plane (of a single band), but the original bedding plane and its inclination are revealed by the slightly different inclinations of the planes of schistosity or cleavage which

happen to be in a particular band. As with the limestone, for the most part the general strike is WNW - ESE to NW - SE, and the dip is between 20 to 35 degrees to the S.W.

In the area south-west and west of Dunmore Peak, the pelitic schists show a NW. - SE. strike with steep or vertical southerly dip, while at the north foot of the Aghros Hill and towards the southern slopes of Dunmore the same schists have a low dip (5 - 15 degrees). Further south, in the region between Aghros Point and west of Doon Lough, the strike is almost E.-W. and though the dip is not very low, it never exceeds more than 35 degrees. e.g. in the abandoned quarries on Aghros Hill. All around Lefrin Hill and in other areas south of it as far as the southern coast line of Rosbeg and Carrikalagh and the whole of Dawros Peninsula, the schists show a WNW to NNW.-ESE to SSE. strike. These schists have an almost constant dip of 25 to 35 degrees to the southwest. East of Meendooish Hill and south of Doon Lough, the rocks are very badly exposed, but sufficient is seen to show a swing in the strike from WNW.-ESE to E -W; to the north-east of Doon Lough, at the foot of Narfin Hill, it is ENE - WSW. In this region also the dips are very low and vary from horizontal (just west of Lough Nathreebrack,

about 3/4 mile east of Meendooish Hill and half a mile south of Lough Birroge) to 15 degrees southeast of Lough Doon. At Narin Hill and southwest of it in the partially exposed rocks, the dips are between 75 degrees west and vertical.

In the region between Narin Hill and west of Lough Sheshkinmore, that is, around the granite contact, the strike curves round and the westerly dip varies from 20 degrees to vertical. In this way the rocks of this badly exposed area, though much crushed, crumpled and partly injected with later intrusions, show a NNE to ENE - SSW to WSW strike. At the granite margin, the massive hornfelses show a 60 to 90 degrees dip to the south.

From the nature of the occurrence and shape of the different outcrops of the metadoleritic sills, (except for the Kiltoorish sheet) much reliance on their stratigraphical relationship is not advisable. The Kiltoorish sheet is uniform in its thickness and both its top and bottom are fairly well exposed. Though the shape of the outcrop is irregular, the mean of its lengthwise direction can safely be regarded as the line of the strike. This strike and the dip of the slope of this sheet are coincident with the strike and dip of the overlying and underlying sediments. Other sheets or lenses are

comparatively small and badly exposed, but most of them show both concordant and discordant relations with the host sediments.

(b) Schistosity and cleavage.- From the preceding paragraphs it is clear that the present nature and disposition of these calcareous and argillaceous rocks are a result of severe metamorphism and tectonic movements. All the primary sedimentary characters are obliterated. The deformations of a rock, in general, depend on (1) its competency to deformation (2) type of deformation and (3) the environments of deformation. These factors themselves are dependent on many other factors of which the most important are the rock-composition and the nature of its occurrence.

Amongst all the rock types of this area, the limestones with their sileceous bands were simply recrystallised as a result of the first and the most important orogenic movements, and acted as rigid bodies to the subsequent movements in general. The graphitic or clayey bands, like the other pelitic or semipelitic rocks of the Rosbeg group, developed well marked foliation or schistosity or cleavage due to these movements. These graphitic bands and the semipelites, in general, show a knotted or 'pinch

and swell' structure. The schistosity is also seen to be curving round these knots and thus it represents a flowage of the micaceous minerals which are found growing parallel to the bands. In the case of the dolerites, there was either a development of similar foliation (more developed in the chilled edges of the small intrusions) or simply of a lineation of the hornblende crystals. The sediments in contact with the metadolerites are hardened and thus developed a well-marked cleavage parallel to and in place of the schistosity. As has already been stated, the different bands of the pelitic and semipelitic schists of the Rosbeg group show a contorted and wavy pattern and their trends are readily identifiable. These bands are parallel to the planes of schistosity and thus give a definite relationship between the schistosity and the bedding (Fig. 7).

The bands have a fairly constant strike and steady dip to the south or southwest. The schistosity is sometimes imperfect and can be referred to as a cleavage; this is also seen to be parallel to the bedding plane. It can be called the bedding cleavage. Rarely, where the bedding and cleavage intersect, the line of intersection has a constant trend and this

lineation is in 'b' direction (Cloos, 1937, pp.49-78, Wilson 1946). According to Billings (1942, p.218) this is a 'mimetic' cleavage formed during the re-crystallisation of the rock. Such cleavages are commonly met with in pelitic and semipelitics of this region between Aghros Hill and Doon Lough and around the granitic contact.

The nature of bedding in metamorphic rocks and its conformability with the schistosity has attracted the attention of many a geologist for nearly a century (Judd, 1889; Milch, 1894; Daly, 1917; Grubemann, 1910; Schmidt, 1932; Harker, 1932 and 1950; Eskola, 1939; Read, 1940-48; Turner, 1941; Billings, 1942, 1945, and others). Of these the first four proposed that this coincidence of bedding is due to the "Static" or "Load" metamorphism. Read (1948. p.187) has advanced the view "we are observing the result of the utilisation of the 'S' - planes of the bedding by solutions on metamorphism, and that consequently a great deal of the crystallisation is mimetic. The privileged planes are the bedding planes". He further writes (op. cit. pp. 189) that, "I prefer to believe that exceedingly often, banding in the metamorphic rocks is bedding".

According to Turner (1947) this banding may be due to metamorphic differentiation brought about by chemical mobilisation, while Billings (1942-p. 219) suggests that it may be a result of layered segregation and terms it "Segregation banding", which is parallel to bedding. Harker (1932, pp. 203-4, 1950) concludes that the foliation of a rock is largely dependent on the pre-existing structure-stratification, (or bedding), and the nature of the deformations with which the rock is effected.

The main orogenic metamorphism in Portnoo area effected a recrystallisation of the schists such that the flaky minerals were aligned parallel to the bedding, for it is along this weak plane that shear force would be most effective during plastic deformation.

(c) Drag folds:- These small folds are due to the compressive forces of the movements to which the area has been subjected and are very commonly found in the solid limestone bands of the Portnoo Group. The thin siliceous bands (reported on an earlier page) due to their comparatively rigid nature do not show these structures, but they are well registered by the graphitic bands. In the limestone, these bands are thrown into cremulated small

folds of curious nature due to drag (Fig.2A4B,4C). The axial planes and axes of these folds or even minor crenulations are always parallel to one another. As has already been mentioned on an earlier page, it is these drag folds which reveal the structure of the limestone in particular. The larger of these drag folds often exhibit a set of closely spaced sigmoidal and other fracture cleavages (Figs.2E...). If the compression is sufficient these cleavages are displaced and the siliceous bands are broken up into moved pieces separated from each other, thus producing a flow breccia.

Generally throughout the massive limestone and sometimes in the graphitic bands boudins are found up to 3"-4" in diameter; in cross section they are rounded or oval or heart shaped quartz knots, (Fig.2C,4D). The longer diameter of these boudins is in general parallel to the axial planes of the drag folds. They are very common in the banded limestone at the back of Portnoo harbour and represent the action of the compressive forces active in these rocks. In the case of the pelites and semipelites the drag folds are not so beautifully developed. This may be due to the higher plasticity of these rocks. On the 'ab' plane when visible, as for

example in a hillock on the eastern side of the Portnoo-Rosbeg Road south of Pound Lough, these drag folds do not show a very complicated nature but on the 'ac' plane the pattern is that of isoclinal drag folds (Fig.6B...). Such drag folds are a common feature of the semipelites near the Dawros Point, west of Sheshkinmore Lough and in the Carrickalagh Peninsula.

All these minor folds show a general E - W to WNW pitch, the axial planes run in directions between 290 - 320 degrees, which is the same as the general direction of strike. Both the limbs of these folds dip towards the South or SW direction but the longer ones have a lower inclination than the shorter, This suggests that the direction of the compressive forces must have been from the South or SW.

On the NW coast of Dawros Peninsula near Crocakun, the banded schists show a corrugated surface with comparatively deep troughs (more than 3"-4" deep) and high crests. Their wave-length is between 7"-9" and the axes of these corrugations plunge at angles between 10 - 17 degrees in a direction 190 - 210 degrees (towards south). In a very localised and crumpled region, these bucklings

are again folded along as axis trending 270 - 285 degrees and thus mark the complexity of the various movements to which the area has been subjected.

Again, similar crenulations on a minor scale and with varying directions from ENE-WSW, N-S and WNW-ESE are observed in the schists between the region NE of Doon Lough and South of Terrylagh. These directions are parallel to the granite margin and hence can safely be attributed to the pushing of the granitic body. Like similar features of the metasediments, these are also found not to occur in the hornfels very close to the contact.

(d) Rodding and pencils of quartz:- These features are seldom encountered. Whenever present, they are generally parallel to the dip of the country-rocks. The best rodding is shown by the pyritiferous schist just at the base of the Portnoo Pier. It is developed due to intersecting shear planes and usually lies coincident with the general dip of the bedding. The partly banded and schistose rock shows a splintery character due to the elongated crystals of quartz and mica flakes arranged in an elongated fashion. The amount of their pitch varies between 8-12 degrees in a south or SW direction.

In the semipelitic schist, in the region South and SW of Summy Lough and SW of Lough Doo (NW of

Sheshkinmore Lough) and the Carrickalagh or in a few localities South of Lough Birroge, elongated thin spindle-shaped pencils of quartz are found. Most of these pencils are generally parallel to the rodding mentioned above, but pencils of similar shape and size are occasionally seen lying in the 'ac' plane with different amounts of pitch, and in different directions. It is difficult to conceive how these pencils could survive the different later movements. If they were formed in the crinkles of the schist due to deposition from late silica-bearing solutions, then their presence in such small numbers is a matter of difficulty.

(e) Elongated oval-shaped spots of chlorite after garnet.- In the Dawros and S. Rosbeg area, sheared calc-schists are found associated with elongated lenticular bodies of epidiorite. At the contact of the two and in the sedimentary schist, rolled garnet crystals (completely or partially altered to chlorites) are very common. Such phenomena are seen, particularly in the cliffs on the west side of the road at Portnatrawbane (South of Rosbeg Post Office), east and south of Rosbeg Post Office, Elagharania and in the coast cliffs between the places marked as (on the map-) Pollingdong and Sauncy Hole on the Southern

coast line, and near Crocakun and Illanglass on the Northern coast of the Dawros Peninsula. At several of these localities these chloritic spots are elongated becoming ellipsoidal in shape. The ratio of the elongation between the ~~two~~ three diameters of the ellipse varies between 1.79 : 1.55 : 1.33. The shorter diameter varies from a few mms. to more than one cm. In most of the cases the longer axes of these ellipses are parallel to strike of the rock and make a very well-marked lineation. This elongation is best shown at Portnatrawbane, near Rosbeg P.O., in the islands west of Rosbeg and at Sauncy Hole. Occasionally, as near Rosbeg P.O. the longer axis of the ellipse is almost at right angles to the general strike.

(f) Lineations;- The lineations recorded in the field and reduced to their general directions are (shown on the sketch map, Fig. 5.) include (a). Crinkles in the schistosity, (b). Striations on bedding or other planes, (c). Rodding and pencils of quartz, (d). Stretched or ellipsoidal chloritic spots, (e). Intersection of cleavage and bedding, (f). Mineral crystallisations.

The complex nature of these structures makes their study very perplexing. While trying to interpret their disposition and relation to major structures, it is not

possible to confine oneself to the rules of rock mechanics. The author has tried to explain the full complexities displayed by these lineations. In cases where the complete explanations are not possible, the problem has at least been indicated. In the first few paragraphs below a general account of the lineations is given, followed by a short discussion of their relations to the major structural problems of the area.

The various linear structures are shown on the sketch map No. Fig. 5.. in which more than 500 readings are reduced to their general directions. From this it is clear that the following groups of lineations are present of which only three are on a regional scale and thus form the main directions of lineations. They are :-

(i) A weak lineation represented by fine striations or very closely spaced fine crinkles of low amplitude. This is generally parallel to the strike of the country-rocks and is the most widespread (though some times obliterated) in the whole of the area. It is best developed in the pelitic, semipelitic or carbonaceous bands of the two main rock-groups. The linear structure formed by the elongated oval-shaped crystals of chlorite in the Nawros and Rosbeg areas is also

parallel to this. The pitch of this lineation is between 8 - 10 degrees but varies from horizontal to 55 degrees. At places it is more pronounced, but generally it is a faint structure. It can safely be regarded as a regional character of the rocks.

(ii) A well-marked lineation shown as striations, puckers or ribs and directed down the dip of the bedding or banding. This structure is apparently due to the intersection of bedding foliation and a type of fracture cleavage (See Fig. 7). It is best developed in the western and central portions of the pelitic or semipelitic groups and in the limestone. Near the granite contact it is hardly seen. The pitch is generally SW at 20 to 22 degrees varying from 5 to 45 degrees. The rodding observed in the schist of the limestone group also lies in the same direction. It is formed by a puckering of the early bedding plane foliations and it is definitely absent from the hornfelses (around the granite contact).

This structure is connected with the development of the New Chlorite on a regional scale. The green prismatic crystals of New Chlorite are often aligned at an angle of 30 - 60 degrees in the plane of schistosity. The development of this structure is best found in the central portion of the

semipelitic schists i.e. between Lough Birroge and Carrickalagh in the east and south east and up to the central portion of the Dawros Peninsula. These prismatic crystals of chlorite are found to occupy thin microscopic crinkles developed in the schist. In the metadolerites this lineation is also probably represented by the thin parallel streaky lines of felspar, well developed in the Kiltoorish and Narin regions. This lineation can also be regarded as a second lineation of regional importance, possibly developed later than the first. The interval between the two cannot be determined.

(iii) Another set of lineations generally formed by regularly spaced puckers (1" - 1½" wave length) is found tangential to the granite contact. It is totally absent in the thin zone of massive hornfels but is best developed in a narrow belt outside this zone between the area of East Doon Lough and SE Terrylagh (no rock exposures in the area south of Sheshkinmore Lough). The pitch is low and never exceeds more than 15 - 17 degrees towards the south or southwest directions. In this small area, east and north-east of Doon Lough, where the andalusite hornfelses are best exposed, this particular lineation probably coincides partly with the second lineation mentioned above.

(iv) A finely grooved or striated lineation pitching vertically to 80 degrees is seen in the massive hornfels only at or near the granite margin. This is never found to occur in the schist away from the contact and is observed only on the vertical or steeply dipping cleavage planes well exposed in the ridge southeast of the Narin Hill, and on both sides of the road northeast of Doon Lough continuing in the southerly direction to the Sheshkinmore Lough. The intersection of a vertical radial cleavage and the vertical tangential bedding cleavage would produce a linear structure such as observed in the area under discussion. Similar structures are reported by Martin (1952) in a description of the granite margin at Flamanville in northwest France. He describes these as a cleavage.

Lineations (iii) and (iv) mentioned above are very possibly related to one another and to the granite tectonics.

(v) Throughout the area another lineation of striations or ribs trending at 265 - 295 degrees and with low westerly pitch is also observed. It is faint to nearly absent in the westernmost portion of the Dawros Peninsula, and is more prominent in the central, northeastern and southern regions.

When it is best developed, as for example in the central area, it probably coincides with the first mentioned lineation. This coincidence is common in the region of Loughs Birroge and Doon. But the two lineations can easily be differentiated if they have different amounts of pitch, as is the case in the Dawros and Rosbeg areas. Two such lineations can be seen in the same outcrop just west of Doon Lough. In the Doon and Birroge region these structures are like ripple marks or parallel ribs running 265 - 275 degrees. The pitch is rather low and never exceeds more than 20 degrees, and is generally horizontal to 10 degrees to the west.

In the area east of Doon Lough in the andalusite hornfels an interesting phenomena is observed. As shown in the diagram (Fig. 8 ...) and plate (No. 4..) one of the E - W lineations is strongly deflected by the growth of large andalusite crystals whilst another poorly marked lineation 205 degrees is apparently unaffected.

From this, <u>two</u> facts are clear.-

(i) the growth of these two lineations is of different age.

(ii) the growth of the andalusite crystals is at least independent of one of these two lineations,

The foregoing description of the different lineations lead to the following conclusions.

(i) The ages of most of these lineations are different;

(ii) The first described lineations is the Earliest of all and being parallel to the fold axis is the 'B' lineation produced by the northward movements accompanying the main regional metamorphism;

(iii) The second lineation described, though also regional, is best developed in the western portion of the area. It is formed by a puckering of the early bedding plane schistosity. It is definitely absent from the hornfelses. In the limestone group it produces a smearing of mica and striates the graphitic bands at right angles to the strike;

(iv) The third mentioned lineation is prominent in a limited belt around the granitic contact, actually in the outer portion of the andalusite hornfels. The puckers are developed by the upward intrusion of the granite. This structure is tangential to the granite margin and will be

referred to as the 'tangential' lineation. It is later than the first two and is concurrent with the granitic intrusion;

(v) The fourth mentioned lineation is also restricted to the contact zone and definitely related to the granitic intrusion. It is called the vertical (granitic lineation;

(vi) The development of the andalusite can also be correlated with the granitic intrusion and is simultaneous with the production of the tangential and vertical lineations in time;

(vii) The chloritic prisms or the felspathic streaks in the metadolerites are probably due to the introduction of material which must have been active during a later metamorphism. It is again interesting to record that chlorite of this type is not found to occur in the massive hornfels or in the thin belt with the tangential lineation around the granite contact. It is therefore suggested here that the growth of this mineral is probably earlier than the intrusion of the Ardara granitic pluton;

(viii) The fifth mentioned lineation is apparently the latest tectonic feature in the complex metamorphic

(viii) - contd.

history of these metasediments. The time relationship of this structure can be inferred by the fact that all the country rocks and the granite pluton are affected by two or three minor faults which are probably along the radial joints of the granite. Slickensides along a few of the radial joints show a similar pitch to this fifth lineation (which is also present in the massive hornfels around the granite contact). Such slickensides are best developed in a granite quarry about half a mile west of the main Ardara road (on the map given as Craig's Town, south of Kilclooney Church). These are definitely due to some later movements affecting the granite and, as they are identical with the last (v) lineation, it is thought that this is also post-granite.

B. Major Structures:- In the limited area surveyed by the writer, there are no major structural features determinable. The absence of any definite marker horizons, coupled with a wide covering of sand and peat in the southern area, have added to the difficulty in unravelling any concealed structure.

(i) Marker horizon:- Except for the boundary of the limestone and pelitic schists of the Rosbeg group and the contact zones of the metadolerites, there are no other important Marker-horizons in the northern portion. As is clear from the main geological map, the sheets of metadolerite, because of their irregular distribution can not be regarded as of much importance as marker horizons. The best developed sheets of Narin-Portnoo and the central part of the Kiltooris area, though continuous and concordant, are present for comparatively short distances or over small areas.

The best marker horizons of metamorphosed sediments can be taken to be the three irregular bands in the Dawros and Rosbeg areas, where ellipsoidal chloritic spots are especially conspicuous. It has already been mentioned earlier that there are three bands of calc-semi-pelitic schists associated with elongated and

and lenticular bodies of epidiorites. One of these bands forms the coastal cliffs in the central portion of the northern coast line of the Dawros Peninsula. The other two, closely spaced bands, are exposed in the southern and western coast lines of the Rosbeg areas, and in the archipelago of the small innumerable islands running from Rosbeg to Portnacally at the south coast of the Dawros peninsula; another band runs from Rosbeg to Craig's Town (Kiltoris *hill top) or* Portnatrawbane and thence to Pollmurry in the east, just south of the Kiltooris School. These bands (with chlorites) are never more than a hundred yards or less than 20 yards in width. The dip varies from 90 degrees at Pollmurry to 30 degrees (South) in the Rosbeg or Dawros areas. They follow a sinuous course and are very irregularly exposed in scanty outcrops between the Rosbeg and Dawros areas (see enlarged map No. Fig. 9), and are possibly due to the bands becoming separated by later shears or faults along the joint planes. It is generally seen that associated with each band is a lenticular body of metadolerite, in which also chlorite (after garnet) or rounded garnet crystals up to half a centimeter in diameter are found to occur (as at Pollmurry and Portnacally).

The northern band is very dislocated being broken into small segments by late minor faulting along the 210 - 220 degrees joints. These joint-faults are of moderate displacement (see geological map) and the limited extent of the outcrops of this band may possibly be due to submergence of the dislocated portions in the eastern portion of the northern coast line of the Dawros Peninsula.

(ii). Minor folds:- The thick limestone of the Portnoo group is characterised by its rigidity, and by an apparently simple structure. A closer scouting of its outcrop and investigation of the mutual relationships of the different structural elements (described above) reveal that the rocks of this group have been thrown into gentle undulating folds. The distance between the axial planes of these folds (or their wave length) is nearly one and a half furlongs. The axes of the three such anticlinal folds are well exposed in the rocky coast between Portnoo harbour and Blue Hole. The crests of these folds are occupied by quartzose dyke-like structures more than 10-15 feet thick, running at 265 deg., 250 deg. and 260 deg. The thin partings of the pyritiferous shales are well lineated with parallel striations in 265-295 deg.

directions and with a westerly pitch varying between 5-20 deg. (see enlarged map No. Fig. 19). The other lineation(s) with minute puckers or dragfolds are almost at right angles to the first and show pitch both to the north or south. The southerly pitch is up to 30 degrees, while the northern never exceeds 12 degrees.

Just at the foot of the coastal cliffs north of Narin Church two such vertical quartzose veins occupy anticlinal cores and are 130 yards apart. The length of their outcrop is not more than 30-50 yards in the direction of 285-295 degrees, while a lineation on the quartz rock pitches at 40-45 degrees in the ESE direction.

The limestone exposed at Dunmore Hole does not show such beautifully developed minor folds. This may probably be due to the thinly banded nature of the limestone, the bands of which are themselves very contorted (see pages 35 : 36 and sketch map No. Fig 10 : 4).

Very few well defined folds are observable in the Rosbeg schists, a fact probably due to the more plastic nature of the original sediments. Sometimes these crystalline schists are seen to be tightly and isoclinally folded. At other localities, as for example

with calc-schists at Sauncy Hole, the schists exhibit an irregularly looped nature, (~~Fig. ...~~). Thin quartz - garnet vein-like bands occurring along the Rosbeg - Elagharania coast line are similarly crumpled.

At this last locality, parallel bands of white quartz-garnetiferous material occur in the sheared chloritic calc-semipelites. All these bands are spaced at intervals of 30 to 50 yards, and have the same constant dip and strike as the country schists. Further south, near the south-west cape of Elagharania, three 1 - 2 yards thick, and more than 50 yards long parallel quartz reefs or dykes (cut by later lamprophyres) are also present at an interval of 50 to 60 yards. Like the quartz-garnetiferous bands, these are also parallel to the banding of the schists. From the nature of the occurrence of these thin quartz-garnetiferous bands and the quartz reefs it is suggested that:

(1) Their formation is coincident with the development of the schistosity in the country rocks - a result of orogenic movements;

(2) The quartz-garnet bands are formed in the tightly closed cores of the isoclinal folds, and the quartz reefs may be a result of the crystallisation of silica also in the cores of these tight folds, which

may be similar to the quartzose cores (already mentioned above) of the limestone anticlines.

If repetition, at a fixed interval, of semi-pelites and the quartz-garnet bands in the calc-semipelites is a result of such folding then this is to be contrasted with the rigid nature of the limestone series.

(iii) Fractures and dislocations.- As has already been stated in the description of the limestone group and the metadolerites, internal sliding along the bedding planes and the development of different structural features (already described) during the main orogenic episode were confined mostly to the banded limestone and their schistose intercalations. On the other hand the schists of the Rosbeg group were thrown into highly folded recumbent or isoclinal folds and thus were fractured with parallel and cross fractures. The limited yielding of the hard rigid rocks has resulted in either large gentle open folds (described as minor folds) or fractures at right angles to the direction of shear (strike). These fractures associated with those developed at right angles (cross) probably due to subsiding movements of this major episode have provided very suitable locations for the intrusions of the later lamprophyric or granitic material.

The lamprophyres and the felsites which are very common both in the limestone and the schists (comparatively more so in the schists), and are also found cutting the metadolerites, lie parallel to the main strike of these country rocks. Though sheets with low dip are also present, the majority of these have a very steep inclination (70 - 90 degrees). Their contacts are sharp and both in the field and in a microscopic section the reaction at the contact planes is negligible. From this fact and their attitude in the field, it is evident that these rocks were intruded along already existing cracks or fractures - the strike joints. This was followed by the development of early cross joints along which the later felsites are found, cutting even the first set of lamprophyres.

(a) Faults.- These are not very large in number. Those present are of comparatively minor importance and can be classified as (i) strike faults (ii) cross faults.

The strike faults lie almost parallel to the strike of the schistose beds in which they are found to occur. In a general way these faults can be traced from the schists of the western coast to the granite in the eastern

portion of the area. The amount of their displacement is not very great. They can be made out in the field by the difference in the amount of dips on both sides of the fault plane, and by the deep gullies along them, or by low irregular gaps in the massive hornfels at the granite contact.

The first important fault trending E.-W. separates the Dunmore plateau from Aghros Hill. The rocks in the 100 ft. high vertical northern face of Aghros Hill dip at 25 - 30 degrees towards the south, while the flaggy pelitic schists and the limestone on the Dunmore side have a low dip of only 5 - 10 degrees towards the south. Again, a felsite dyke cutting through the Aghros Point peninsula is not seen on the Dunmore side. Just at the northern foot of Aghros Hill a good vertical section of more than 100 ft. high (from sea level to 100 ft. contour level) is well exposed by the side of the sea beach. This deep gully with the sea beach continues towards the east and runs for more than a mile till it crosses the main Portnoo - Rosbeg road near the southern tip of Pound Lough and thence runs in between the road (E -W branch) and Birroge Lough towards the northern edge of Doon Lough. In this region, the trend of the hillocks,

minor deep gullies and the dips with the strike of the schists are very variable, showing that this is a small zone of dislocation in which the huge brecciated blocks probably make the hillocks.

North of Doon Lough is a wide semicircular plain whose eastern part is studded with irregular hills, the doleritic or schistose rock of which is impregnated with granitic material and in which large flakes of dark biotite nearly 5 m.m. in diameter can easily be made out. Further east, where the E.-W. road crosses the massive hornfels through a narrow gap, these hornfelses at the granite contact do not show a very marked weathering effect, and the general level on both sides of the road is low. The strike on the northern side of the road is NNE-SSW with a dip of 70 degrees to the east, on the south side in the fields these hornfels are partially exposed with an irregular dip of 20 - 90 degrees and a NE - SW strike. On crossing the hornfels towards the granite there is a marked change of level. From this evidence it is concluded that the road passes along a fault.

Another fault trending WNW - ESE gives rise to deep gullies on both coasts, at the north-eastern junction

of the Dawros Peninsula with the main land. This displacement cuts through the northern extension of the Kiltooris sheet and thence passes through Lough Dowen and probably joins with another E - W fault running from Kiltooris Lough up to the southwest coast of Summy Lough. Except for the massive and gently sloping area of Lefrin Hill, Meendooish Hill and the Kiltooris sheet, the whole region between Lough Dowen and Terrylagh is studded with numerous hillocks and carries many ramifying rivulets; the tract just south of Doon Lough up to the northern portion of Terrylagh on the other hand is mainly swamp in which only a limited number of exposures occur. Considering the general nature of the topography and the rock outcrops, this contrast is probably the result of another zone of dislocation. Narrow irregular gaps almost in an E - W. direction, one just east of the "Bawn" and the other near the southwestern shore of Summy Lough cut through the massive hornfels lying on the western side of the Lough and may represent fracture zones.

(b) Dislocation of the Granite.- In the granite region, slickensides trending in an E - W direction and with a pitch of 5 - 7 degrees to the west are seen in a

quarry just south of Craig's Town (about half a mile south-west of Kilclooney Church). This quarry is situated in a steep granite ridge facing north. When traced westwards the trend of this ridge is in line with the fault cutting the southwest coast of Summy Lough and passes through Moone's Lough (a small Lough in the N - S swamp cut by river Duvo flowing southwest and passing near Kilclooney Church).

Another such steep ridge with slickensides forms the northern bank of the river Abberachrim for a mile from Kilclooney Bridge. Further south, the high ridges along the narrow swamp of the Beha river may possibly be due to a dislocation similar to those mentioned above in the granite. The direction of movements and the slip along these in the granite region alone is not clear. From the nature, trend and the inter-relationship of the strike faults of the meta-sediments and from the comparison of these with the dislocations of the granite, it is clear that these latter faults or dislocations are along diagonal or radial joints, formed due to movement in the late stages of the cooling of the granite pluton.

(c) Cross faults.- On entering the area just east of Narin Church, the road takes a sharp bend, and then rises abruptly by about 50 ft. This bend and its rise are caused by a fault running NNE.- SSW. On the north side the fracture gives rise to a narrow valley which joins with the sea beach; towards the south it cuts the Narin - Cashel range and probably joins with the fault north of Doon Lough already described. On the eastern side of the above bend, just at the north foot of Narin hill, the limestones with their intercalated schists are exposed in an area 200 yards to 300 yards which gradually rises from 50 to 150 ft. in height. The strike of the rocks is E - W. or a maximum of 100 degrees (ESE) direction and with a dip of 45 - 75 degrees to the south. On the western side on the road bend the width of the limestone and the schists is not more than 150 yards at the coastal cliffs, which are also cut by several minor faults, possibly running parallel to this main fault. The dip of the rocks varies from 30 degrees SW to 90 degrees and the strike is NW - SE. Certain changes of level and the changing dip and strike, almost half way between the church and Portnoo P.O. suggest a fault running N.E.- S.W.

The elevated terrain, in between these two faults, seems to have been pushed forward, and thus the meta-dolerites making the coast line lie against the limestone on the sea shore.

Westwards, the triangular area between Portnoo P.O.- Pound Lough and Sand Hole is badly exposed, but one can make out the disposition of the limestone and the meta-dolerite outcrops. The former, horizontal near the stream on the west side of Pound Lough, suddenly becomes steep and shows a southerly dip of 30 - 35 degrees to the south, as seen in a quarry near Pound Lough. The wide meta-dolerite outcrop of Cashel Hill on the east coast of the lough when traced towards Dunmore Hill thins out considerably almost immediately west of the road. These factors indicate that there is a NE - SW concealed fault running practically in line with the road, i.e. the road itself is probably on the fault zone.

Further west, the horizontal or low-dipping beds of the Dunmore area are traversed by two N.E.-S.W. narrow deep gullies running from the west coast through the Dunmore tableland to the western boundary of the alluvial land mentioned above. Of these two the one passing through Free Lough to Sand Hole is seen displacing the partially

exposed metadolerites by about 300 yards. The origin of Free Lough itself may be due to this dislocation coupled with the later action of the Pleistocene glaciation. The western coastal cliffs are very steep and thus a true picture of these two faults could not be obtained.

In the schists of the Rosbeg group the cross faults are so numerous that it is almost impossible to describe them individually. Such minor faults are present all along the coast line and are responsible for the details of marine erosion such as the small islands and the 'geos' and narrow inlets. The amount of displacement along these faults is small; their hade varies from 60 - 90 degrees. The importance of such faults has already been pointed above (pages.[illegible]). In the Rosbeg area the irregular sinuous trend of the calc.-semipelitic schists is mostly due to the displacements along such cross faults.

Considering the sigmoidal cleavage, drag folds and the nature of slickensides both in the metasediments (including the metadolerite) and of the granites, it is clear that the movements were due to a couple of force or shearing stresses acting in a clockwise direction, in

which the easterly force was acting SW and the westerly force NE., Due to this the eastern blocks either remained stationary or moved southwards. Similarly the horizontal or east - west slip along the strike faults is also not very marked particularly in the southern granitic area, while in the north the shift is definitely more than 30 to 50 ft.

C. Metamorphism and Tectonic History.

It will be advantageous to give here a full statement of the complete metamorphism and tectonic history of the writer's region.

The sedimentary rocks of the Portnoo District originally consisted of a thick though thinly banded graphitic limestone followed by a still thicker rhythemically banded shale, which is often calcareous or carbonaceous in character. The latter is rarely interbedded with more calcareous mudstone.

The major metamorphic events and their effects on the above mixed types of country rocks include:-

Table No.1.

No.	Event.	Effect.
I.	Intrusion of Basic Sills after or during the deposition of sediments.	No marked metamorphic effects. Most important is the baking and induration of the host sediments, sometimes producing a flaggy character in the pelitic or semipelitic rocks and causing minor silicification of the limestones.

No.	Event.	Effect.
II.	Orogeny.	(i) The sedimentary rocks including the basic sheets were folded and suffered a medium (mesozonal) grade of metamorphism. In the pelitic rocks structures such as drag folds, cleavage and schistosity along with the 1st and 11nd lineation were developed and the sediments were recrystallised becoming schists.
		(ii) In general the limestone and basic sills acted as competant beds and suffered the least deformation, these along with basic sills were separated to form the lenticular bodies.
		(iii) Mineralogically, the pelitic and semi-pelitic deposits were converted to garnet - biotite - muscovite schists or calcite - garnet - biotite schists. The limestones were recrystallised as marbles and the basic sheets (partly) lost their ophitic texture and were altered to hornblende schists or amphibolites.
III.	Phyllonitisation. (cause unknown though of equal effect over the whole area).	(i) Production of minute crinkles in the schistosity of the metasediments and the impression of a lineation due to these crinkles on the bedding plane surfaces. (Across cutting 'fracture' or secondary cleavage).

No.	Event.	Effect.
III.	Phyllonitisation (Cont'd).	(ii) Formation of the porphyroblastic 'New Chlorite' in the crinkles of the pelitic or semipelitic metasediments (iii) Breakdown of biotite and the regional garnet to rounded chlorite.
IV.	Intrusion of Lamprophyre and Felsites.	Very minor effects including the occasional production of clinozoisite, zoisite in the limestones and the destruction of 'New Chlorite' or its transformation to a biotite lying across the foliations of the semipelitic or pelitic metasediments. No marked (even under the microscope) are shown by the metadolerites; but when the xenoliths of metadolerite are engulfed in a lamprophyre the hornblende of the metadolerite shows all stages of its alteration to biotite.
V.	<u>High Grade Metamorphism.</u> Intrusion of Explosion Breccias.	No marked effects generally visible but occasionally the following changes were effected. (i) At one place development of cordierite, sillimanite and hornfelsic biotite in the pelitic sediments.

No.	Event.	Effect.
V.	High Grade Metamorphism. Intrusion of Explosion Breccias. (Cont'd).	(ii) Porphyroblastic flakes of biotite and acidic andesine are produced in metadolerite.
		(iii) The xenoliths of lamprophyres show the conversion of the hornblende to a diopsidic pyroxene and the formation of brown pleochroic sphene.
		(iv) Destruction of 'New Chlorite' in the metasediments.
VI.	High Grade Metamorphism (Cont'd) Emplacement of Granitic bodies.	(i) Country rocks were converted to hornfelses.
		(ii) Transformation of the metadolerites to coarse amphibolite.
		(iii) Destruction of early schistosity, drag folding, etc.
		(iv) Probable production of cleavage around the pluton.
		(v) Development of IIIrd and IVth lineations.
		(vi) Deflections in the regional strike.
		(vii) Mineralogically - the formation of sillimanite, staurolite, garnet, andalusite and 'New 'Biotite' in pelitic

No.	Event.	Effect.
VI.	High Grade Metamorphism (Cont'd) Emplacement of Granitic bodies.	vii.(Cont'd) rocks; brown-green hornblende, sphene in metadolerites; clinozoisite, zoisite and diopside and other skarns in the calcareous rocks.
		(viii) Destruction of 'New chlorite'
		(ix) Production of a hybrid diorite series by assimilation. A marked variation in the microcline or potash felspar and quartz content of the granitic rocks suggest a late potash and silica metasomatism.
VII.	Dislocation and late hydrothermal metamorphism.	(i) Alteration of sillimanite etc. to muscovite in the pelitic and semi-pelitic rocks.
		(ii) Scricitisation of the plagioclase both in granitic and other country rocks.
		(iii) Production of epidote in the metadolerites.
		(iv) Granulation of quartz and formation of perthitic microcline.
		(v) Production of shear zones mainly in the granites with chloritisation of biotite and amphibole.
		(vi) Twisting of twin lamallae in micas and felspars.

No.	Event.	Effect.
VII.	Dislocation and late hydrothermal metamorphism (Cont'd).	(vii) Tourmalinisation.

Finally, the metamorphic history of the Portnoo District can be divided into two distinct phases, first, a stage of folding accompanied by regional metamorphism in the late stages of which phyllonitisation and chloritisation were probably effected, though the cause of this late retrogression is not clear. Of the second phase the most important events are the intrusion of the granitic magma followed by late hydrothermal activity.

VII METASEDIMENTS.

The succession of strata in the Rosbeg District has been described before (Chapter IV) and is as follows:-

YOUNGEST.

Rosbeg Pelitic Semipelitic group (with metadolerite).	3. Dawros - Rosbeg banded Semipelitic schists.
	2. Aghros Hill - Eden House Semipelitic schists.
	1. Dunmore - Doon Lough Pelitic phyllites.
Portnoo Limestone group (with metadolerite)	5. Blackish grey flaggy limestone.
	4. Pelitic schists (pyritiferous)
	3. Massive blue limestone.
	2. Semipelitic pyritiferous schists
	1. Banded limestone.

OLDEST.

The metamorphic character of these rock groups is now described.

A. The Portnoo Limestone.- This important member consists of a thick series of massive grey marbles intercalated with pelitic and semipelitic schist bands. The former are described first.

The marbles are compact and uniform and are of comparatively simple composition. They provide a suite of rocks of low metamorphic grade except sometimes at contacts with lamprophyres or granitic rocks where skarns are rarely developed.

Occurrence.- As has already been stated (pp. Pt.IV), these rocks are best developed in continuous bands at Narin, Portnoo, and in the Dunmore Plateau. These are a westward continuation of the limestone occurring north of Clooney Hill (east of the area under discussion). The same view was expressed by the authors of the Survey Memoir (1891, p.33). At Narin the narrow outcrops along the shore are truncated by faults and are invaded by metadolerites. The strike is East - West and the dip is steep (65 - 75 degrees) towards south. Near the Church at the foot of the sea cliffs outcrops of the limestone series are restricted to two very thin linear bands of small length. Westwards, with the exception of two small exposures of crushed dark-grey limestone west of the Church, outcrops of the limestone series are absent until the vicinity of Portnoo P.O.. Limestone occupied a wide area from Portnoo Harbour to the Pound Lough and thence westwards to the Atlantic coast.

On the rocky beach west of Portnoo Harbour, and between Dirty Rock and the coastal cliffs west of Sand Hole, the limestone is present as lenticular bodies (aligned generally in E. - W. or NW. - SE.) engulfed in the metadolerite and even in granitic intrusives, as at Dirty Rock.

In the Dunmore plateau and on the western coast line as far as Dunmore Hole the limestone, intercalated with the metadolerite, forms the high cliffs. In this area, the rocks of this group are exposed in a belt about half a mile wide forming a continuous outcrop from the junction of the road (west of Pound Lough) in the east to Dunmore Hole in the west. Here the dips are generally very low ranging between horizontal and 10 - 12 degrees to the south.

From the nature of its occurrence and its distribution the apparent thickness of this limestone group cannot be less than 1000 or 1200 ft; this thickness may be partly a result of isoclinal and recumbent folding which is seen at several localities in these rocks (referred to on pp.72-75 of Pt.VI).

General characters and structural features:- In addition to the sheets of metadolerites, at least three intercalated bands of pelitic and semipelitic schists of considerable thickness occur. The one at the top is thickest being 30 - 40 ft. in thickness, and is more pelitic than the others occurring at lower levels. The bottom intercalation is about 25 ft. thick, while the middle band is nowhere well enough exposed to show

its true thickness but it divides the limestone group into two almost equal halves. Lithologically the Portnoo Limestone series consists of the following types. (I) Banded limestone with typical textural gradation, the bands usually exhibiting minor folding (2) a massive blue sugary limestone with current bedding (3) a dark grey flaggy limestone particularly favoured for early metadolerite sheet intrusions. In a general way the stratigraphic succession is :-

(i) Thick series of graphitic banded limestone.

(ii) Massive limestone.

(iii) Thicker series of grey banded limestone.

The banded limestones forming the lowest and uppermost members of the series are characterised by thin graphitic bands up to 1½ft. in thickness, of lead grey colour and graphitic in lustre, alternating with massive crystalline limestone of a dirty grey to buff colour. This banded limestone gives a typical ribboned appearance and is best exposed at the narrow stony beach at the back of Portnoo Harbour, in irregular patches enclosed in the complex rocks between Dirty Rock and Sand Hole (see enlarged map, Fig.19), and at Dunmore Hole. The massive limestone in this banded

series is buff to brownish grey or bluish grey in colour. It is a coarsely crystalline marble with occasional rounded grains of quartz, felspar, and mica and occurs in 1 - 2 ft. thick bands, while the darker bands are generally between 6" - 10" thick. Sometimes a graphitic band is found grading into the limestone.

These graphitic bands are very fine grained and clearly indicate the bedding planes. They are knotted and twisted and exhibit at least two sets of lineations. In the siliceous limestone these are far more numerous and more closely spaced than in the upper beds which are comparatively pure and more compact limestone. Deformation in the massive bands is shown by the drag folding of thin quartz intercalations and the presence of rounded or oval shaped quartz boudins, etc. (fig.2 e,f) These thin bands of quartz vary in thickness from a few millimeters to 5 centimeters.

The massive blue limestone is almost entirely composed of pure calcite and has a sugary grained crystalline character. The grain size is from fine to medium. The best outcrops of this limestone are near Portnoo P.O., west of Pound Lough and in the Dunmore plateau. The colour of this current-bedded limestone varies from a pale yellowish

blue to greyish blue, while occasional altered varieties (very few in occurence) show a dark grey colour due to fine elongated granules of iron oxides. Towards the top of this main massive limestones and intercalated with it, there occur darker graphitic bands which are very similar in character, but thinner, than the lower series of banded limestones. These bands also occur with a greater interval between them. The pure limestone bands are generally more than 4 - 5 feet thick while the graphitic bands never exceed 6", (e.g. in the quarry west of Pound Lough). The deformation is shown by the presence of low buckled folds, and by the lengthening or the shortening of the current bedding laminae (Figs. 3 B.&C..). The amount and direction of the pitch of these folds are similar to those shown by the dragfolds or the lineations of the banded limestone. At the roadside near Portnoo P.O. such a current bedded limestone also show buckles or low folds of an amplitude of 1" - 2" with intervals of one foot to eighteen inches. The crest of these buckles are cut by small subparallel, bifurcating quartz veins of hydrothermal origin of

half an inch to one inch in thickness. Along these veins the current bedding is dragged as shown in figure (3A)..... These quartz veins are formed along the tension cracks, which seem to be connected with the major joints. Tortuous calcite veins run parallel to the bedding and show a ptygmatic fold structure which appears on the weathered surfaces. Similar occurrences of current bedding and ribbed limestone are found in the coastal cliffs just north of Dunmore Hill (near the large xenolithic felsite dyke). Here the beds are 'upside down' on the evidence of the current bedding, which is deformed (Fig .3B...).

In the banded or the massive limestone a flaggy type is found to occur in comparatively thin bands at the contacts of metadolerite sheets, the rock is fine to medium fine in texture. These bands are common on thenorthern slopes of Narin Hill, at the lowest levels of the metadoleritic cliffs at Dirty Rock, in the small hillocks north of the Mullayala Lough (N.W. of Pound Lough), and in the different levels of the Dunmore Plateau. On the weathered surface the colour of these bands is dark bluish grey. In a vertical section the rock shows a

fine interlamination of dark and lighter colours. The bedding plane is marked by the presence of elongated grains of ores galena, pyrite, chalcopyrite etc. The flaggy limestone at Dirty Rock and Narin Hill also show a linear arrangement of the oval-shaped quartz and calcite segregations occurring in the bedding planes. Another set of such elongated spots is oriented at 40 - 50 degrees with the bedding plane.

The flaggy nature may be an effect of an induration, or impregnation or soaking associated with the basic intrusions.

Mineralogy and Petrography:-

Of the specimens collected from the limestone series about 20 of the normal limestone types were sliced. The following minerals occur with the predominant calcite; quartz, plagioclase, potash felspar, biotite, muscovite, chlorite, apatite, epidote, pyrite and graphite.

Except for readjustment of some minerals, there is little change in the matrix of the limestone series and this recrystallisation is the result of simple regional metamorphism, the effects of which are always

apparent away from the influence of the later intrusions. The Sp. Gr. of all such low-grade marbles varies from 2.725 - 2.2776.

Recrystallisation or low grade metamorphism of the limestone.- Under the microscope (Slice Nos. 1/10,17,28,69, 4/34,8/114) the average specimen of crystalline limestone shows a mosaic of equigranular calcite of somewhat elongated nature. The longer diameter of the rhomboidal grains varies from 5 - 75 mm. The crystals are arranged in planes apparently parallel to the bedding. Most of the calcite grains are subangular to subrounded.

Quartz and felspar are present as rounded, oval-shaped blebs enclosed in the calcite crystals. A few grains of these occur interstitially between calcite, and their longer axis are generally parallel to the longer axis of the calcite grains. The felspar is probably a plagioclase (the species could not be distinguished even under the high power) and is very subordinate. The size of the quartz and felspar grains is very variable i.e. from fine dusty particles to comparatively large identifiable grains. Generally all the larger and rounded quartz grains show an undulose extinction, while

the felspars are turbid. Sometimes comparatively larger serrated grains of quartz occur aligned parallel to the foliation and may be due to silicification of the limestones consequent to the intrusion of the first metadolerites (see page .53.). In the siliceous bands, layers of the original quartz grains are of uniform size and almost equal in amount to the calcite. ~~(slice 287~~ In a few grains the twin lamellae of the calcite are seen to be twisted (Slice 2/17) and dislocated (Slice 4/34). This rare phenomenon may be a result of a later dislocation or cataclasis.

The micas are very subordinate in amount. Most important are thin lath shaped flakes of muscovite which are more common than the associated brown to brownish green biotite. The flakes of muscovite and biotite are arranged parallel to the longer diagonal of calcite grains though a few flakes, particularly of biotite, are found in a random fashion. These are generally split by thin wedge-shaped flakes of green coloured chlorite, probably penninite; in both biotite or chlorite flakes of minute dark inclusions or haloes are present (red or dark brown ores are associated with the mica and sometimes occur in the mosaic of calcite).

Such inclusions are also particularly marked in the quartz where they have a subrounded form. Sometimes thin irregular flakes or bands of graphite are also seen marking the bedding planes. These graphitic bands are crooked or twisted showing that the limestones have been subjected to severe strain.

From the foregoing, it is apparent that the regional metamorphism of the limestones is a matter of simple recrystallisation of the primary constituents, no reactions taking place. This fact becomes important when it is realised that the associated pelitic rocks have attained the so-called mesozone with the abundant development of garnet and biotite.

B. - The Pel'tic a d Se ipelitic Rocks.

(a) Intro ucti n.

It has already been emphasised that the succession of the sediments is a continous one but that this succession can be divided into two dominant rock series. The calcareous rocks of the Portnoo Limestone group, best developed in the northern portions of the area, have been dealt in the previous section, but to avoid unnecessary repetition, the description of their intercalated pelitic or graphitic bands is included in the present section which deals mainly with the pelitic and semipelitic rocks of the Rosbeg group. The rocks here dealt with are described under the following heads:

1. Pelitic and Semipelitic schists of the Portnoo Limestone group.
2. Schists of the Rosbeg group.

These rocks are characterised by different facies of medium grade metamorphic types and a general account of their lithological characters has already been given on pages (37-40) dealing with the sediments. The schists of the Portnoo Limestone group form two or three (banded) pelitic and semipelitic bands. The lower bands are more pyritiferous and siliceous, while the uppermost is comparativly thicker and high in graphitic content. The rocks

of the Rosbeg group are more uniform and grade from rather pelitic to semipelitic schists. The lower horizons are micaceous phyllites and the rocks of the southern or upper horizons are composed of thin alternate silvery grey to whitish pelitic and grey to pinkish grey semipelitic or even granulitic bands.

(b) Occurrence and Distribution.

The schists of the Limestone group, like the thick bands of the limestone, are a westward continuation of the andalusite schists of Clooney Hill. It is not possible to correlate the bands in detail due both to the paucity of well-defined exposures and to their thinning and disturbance north of the Narin-Cashel range by several minor dislocations and by the emplacement of the Ardara Pluton. However, two or sometimes, three clear bands of uniform thickness are noticeable in the cliffs near Narin church, at Portnoo Harbour, in a quarry near Pound Lough in the fields N.W. of Portnoo P.O, on the coast north and N.W. of Dunmore Hill and in the Dunmore plateau.

As already noted a three-fold division of the Rosbeg Pelitic-Semipelitic group has been made, utilising the areal distribution and the dominant rock types in the nomenclature: the classification is:-

(iii) Dawros- Rosbeg banded biotite-muscovite-schist.

(ii) Aghros Hill-Eden House Semipelitic schists.

(i) Dunmore-Doon Lough Pelitic phyllites.

The lower and northern Dunmore-Doon Lough phyllites lie conformably on the blackish grey flaggy Limestone and extend from Lough Free and Realt to Scoltnaling in the west and through Mullanard, Lough Birroge to the Doon Lough region. The succeeding Aghros Hill-Eden House semipelitic schists are best developed in the region between Spy Hill in the Dawros area in the west and Terrylagh in the east; this sub group forms the Lefrin and Meendooish hills. The third subgroup (Dawros-Rosbeg banded schists) occupies the whole of the Dawros-Rosbeg regions and the area south of Kiltooris Lough and extends upto the eastern tip of Carrickalagh peninsula. On the main geological map, these subgroups have been shown by the same ornament, as the divisions are rather arbitrary and, except for the intercalated calc-pelitic bands, no key-beds can be mapped.

(c) General Characters.

The pelitic and semipelitic rock types of the whole area have also originated from the same general type of sediments. This is best confirmed by the similar rock-types met with both in the Portnoo Limestone group and the Rosbeg series. Mineralogically and lithologically, there is

no distinction between them. The divisions given above are based upon the slow and gradual appearence of new lithological and mineralogical characters. Carbonaceous and micaceous rocks are more characteristic of the northern portion of the area while banding ~~(plate ———)~~ is more prominant in the southern rock facies, and is often accentuated by the formation of small cavities due to weathering of rounded pseudomorphs of garnet. These are generally more distinctive in the rather psammatic bands; on the other hand the laths of New Chlorite are dominant on the weathered surface of grey to silvery grey micaceous bands.

The schistose rocks of the Portnoo Limestone group are of minor importance. The thickness of individual bands does not exceed more than 40 ft. Unlike the Rosbeg schists, they are characterised by brownish to dark grey rocks richer in pyrite, iron oxides and carbonaceous matter and by the lack of well defined banding. The cleavages, foliations, drag folds, lineations etc. well displayed by the thin graphitic bands of the limestone are also exhibited by these thicker pelitic or semipelitic rocks. In a thin section, they are characterised by chlorite-muscovite-biotite assemblages. In specimens collected near the Andalusite schists, porphyroblasts of oligoclase-andesine are common with a well developed biotite.

The schists of the Rosbeg group are dominantly semi-pelitic in nature. In the northern or lower horizons (Dunmore-Doon Lough area) they are silvery grey phyllites and have well developed fracture and slaty cleavages and schistosity trending parallel to the bedding. Mineralogically, they are muscovite-rich phyllites with the occasional development of graphitic matter in which porphyroblasts of New Chlorite or oligoclase are very often embedded. The rocks of the Aghros Hill-Eden House group are more siliceous and massive in nature. They are characterised by their grey to dark grey colour, the development of New Chlorite, rounded chlorite and almost equal amounts of biotite and muscovite associated with quartz, and plagioclase. On the other hand the Dawros-Rosbeg banded biotite-muscovite schists are usually typified by thin bands sharply contrasting in colour. At certain places, as for example in Spy Hill and South of Terrylagh, the individual bands show a sort of flow in which the thin bands appear to be pinched and swelled or thin siliceous bands are shattered.

In the field it is easy to distinguish the cavity-free pelitic phyllites of the lower horizons from the spotted and banded semipelitic schists with rounded cavities of the upper Rosbeg group. In some localities, andalusite schists and hornfelses have been found well away from the Ardara granitic

pluton. These are of very local and minor importance but broader expanses of similar rocks are developed around the above mentioned pluton. It has been considered better to exclude these high grade rocks from the present discussion; They are treated with the contact metamorphic effects of the granitic intrusion. It may be mentioned here, however, that wherever the andalusite schists or hornfels are encountered in these medium grade schists, the two characteristic regional minerals New Chlorite and the rounded chlorite (pseudomorphs after garnet) are destroyed or converted to biotite.

(d) Mineralogy and Petrography.

1. Pelitic and Semipelitic Schists of Portnoo Limestone group:

These rocks are grey to blackish grey soft fissile schists. Their texture is fine and generally no minerals could be identified in a hand specimen. At certain localities the rock is only slightly schistose and then looks like a mudstone (e.g. at the head of the Dunmore Hole). On the weathered surface the rocks are brownish to reddish brown in colour and soil the hands, while a fresh fractured piece is leaden grey in colour and marks paper. From this it is evident that they are rich in carbonaceous material. Generally these rocks are highly puckered, cleaved, lineated

or drag-folded. They sometimes exhibit graded bedding, the coarse quartz-rich portion of the band being lighter in colour; such grading can often be seen in thin sections. Sometimes the fresh rock shows knotty and striated linear marks in the bedding planes due to the development of a porphyroblastic biotite or chlorite (actually the New Chlorite and the IInd. lineation) e.g. near Free Lough, S.W. of Dunmore Head. As has been stated earlier, the lowest intercalated bed in the limestone is more siliceous than the upper two and consequently is less rich in carbonaceous matter and is a lighter brownish grey in colour. In it, instead of the IInd. lineation the 'down the dip roddings' are nicely developed e.g. immediately below Portnoo pier.

In a thin section a typical rock is composed of muscovite, biotite, chlorite, quartz, felspar, pyrite, carbonaceous matter, iron oxide, and minor tourmaline. The siliceous portion of the rock is richer in quartz and poorer in the micaceous and carbonaceous matter.

A pelitic specimen collected from the quarry on the road side near Swan Mount (N. of Pound Lough) is very well foliated and, due to later shears and movements, exhibits a herring-bone (wavy) pattern. The folia are made up of grey coloured carbonaceous and muscovitic material. In places the folia are crinkled and thus make a lineation at 30 degrees -

45 degrees angles with the schistosity. Thin lenticular grains of quartz and possibly felspar are the other important constituents of the rock. Of the minor and subordinate minerals the most important is a light green porphyroblastic chlorite. It occurs in elongated tabular flakes growing in the 'kinks' or crinkles of the foliation (Plate 12, Fig. 7). Sometimes the schistosity of the rock seems to have been pushed aside due to the growth of this mineral, while at other times the foliations and trails of dark graphitic or carbonaceous matter seem to pass through the porphyroblasts. Of these two cases, the latter is the more common and from this it is evident that the growth of the chlorite is later than the development of the schistosity. Possibly the porphyroblasts have taken advantage of the 'kinks' for their growth. The other minerals include cubes or elongated and altered grains of pyrite, which is uniformly distributed throughout the rock. Zoned and Unzoned tourmaline is the common accessory component.

In another typical slice from the Dunmore area, porphyroblasts of a light pale brown biotite are common instead of the chlorite. The mica does not occupy the crinkles, but in these are set rounded or oval shaped augen of a plagioclase (oligoclase-andesine). The elongation of these augen is parallel to the general foliation of the rock and they are filled with strained granulated quartz and micas.

Another slice from the Dunmore plateau shows good sub-rounded porphyroblasts of plagiclase.

A specimen collected from near Dirty Rock exhibits shimmer aggregates probably after andalusite. They are seen pushing aside the biotite and chlorite foliations of the rock. There are no chlorite porphyroblasts, but instead there occur light brown porphyroblasts of biotite. The formation of these two minerals i.e. the andalusite and biotite seem to be the result of granitic intrusion at Dirty Rock. The felspars of the rock are better developed and are oligoclase-andesine in composition.

Summary :- The rocks are carbonaceous in character and it appears that this carbon content has played some part in the metamorphism of these rocks. They have a fine texture, and only porphyroblasts of chlorite are found developed in general. These porphyroblasts are formed after the development of the foliation and it seems likely that the higher minerals have altered to chlorite. Brown biotite is scarce and the porphyroblasts of brown biotite or shimmer aggregates are of local occurrence. In short, these rocks exhibit a low-medium grade of metamorphism, corresponding to the chlorite-biotite zone of pelites. They can be called carbonaceous muscovite-chlorite schists.

2. Schists of Rosbeg group.

(i) Dunmore-Doon Lough pelitic phyllites:-

The rock types included in this group both mineralogically and petrographically are very similar to those described from the Portnoo Limestone group on the one hand, but as they are more siliceous and biotite-rich, they resemble also the rocks of the Aghros Hill-Eden House semipelites. These rocks thus form an intermediate type connecting the two main rock series of the area. From the schists of the Limestone group, they differ in being not so uniform in their carbonaceous or iron oxide content. The rocks of the lower horizons are almost silica free pure silvery grey muscovite phyllites. They are soft and shining with a silky lustre. When in contact with the intercalated metadolerites, they become flaggy. The fresh flaggy phyllitic rocks of the upper horizons are grey to brownish grey in colour and usually have a bluish red hue. This grey colouration is similar to that of the semipelites of the Aghros Hill-Eden House Subgroup, which are more carbonaceous and richer in silica.

In a thin section, a carbon free phyllite shows a nice herring-bone texture. The later shears and the foliations make an angle varying between 35 degrees - 55 degrees. The rock is chiefly composed of fine fibrous milky sericite

and the slender fibres can be traced from end of the silce to the other. The crinkles with their porphyroblastic chlorite or biotite so common in the pelites of Portnoo group are seldom seen. In flaggy rocks or the dark coloured phyllites from the top of a hill about one furlong north of Aghros Hill, minor crinkles are formed. In some of these are located small circular or oval shaped augen (not more than 0.2 m.m. in size) of a rounded chlorite. Towards the south or towards Pound Lough, near the road, the size of these oval bodies is increased and they are seen to enclose fine granules of quartz. Sometimes in these rounded chloritic spots are fine irregular fragments of an isotropic mineral (probably garnet).

Other minerals of minor importance, more particularly in the flaggy types are small flakes (0.02 m.m.) of biotite, rutile, haematite and probably black oxides of iron which sometimes seem to follow the foliation planes of the rock.

(ii) Aghros Hill-Eden House Semipelitic Schists:-

These rocks have a wide range of semipelitic types. All samples collected from different parts of the area are decidedly schistose in character. The colour varies from light grey to almost greyish black. The more gritty rocks are light grey in colour and massive, while the mica-rich varieties are more fissile, schistose or flaggy. Like their

lower pelitic counterparts described above, they are carbonaceous or siliceous in character. Still others are rich in dark micas and chlorite, in which upto 1 cm. long porphyroblasts of New Chlorite (described below with the rocks of the Dawros-Rosbeg group) are common. Those rich in micas have leaden grey shining surfaces while others are dull and earthy in appearance. Towards the upper half of the group, small rounded cavities due to the weathering out of the rounded chlorite pseudomorphs after garnet, are very prominent and suggest that these semipelitic rocks gradually grade to rocks rich in that mineral.

A typical thin section exhibits a schistose to herring-bone texture with granoblastic aggregates of quartz and plagioclase. The kinks so common in Portnoo Limestone series are present but are not so well developed. In some slices the percentage of felsic minerals is smaller while in others the femic constituents only give a trace of a schistose character, and the rock resembles a granulite. In a few sections the quartz is far more abundant than the plagioclase, in other slices the reverse is the case. Generally othoclase is absent, but in a few rocks some microcline and myrmekite are seen. In almost all cases, the plagioclase is sericitized oligoclase-andesine in which twinning is very faint. When comparatively fresh, its composition is found to be from An_{10} to An_{30}. Quartz forms elongated grains and

shows strain effects; the larger grains are parallel to the foliations of the rock.

Of the ferromagnesion constituents, the most notable are the common components biotite and chlorite. The former is a pale pinkish or reddish brown type, occurring with an ordinary biotite. Chlorite is of three different types at least; one as an alteration product of biotite, a second is the "rounded chlorite" (after garnet) and a third is a porphyroblastic "New" chlorite similar to that found in the crinkles of the Portnoo Limestone schists. Sericite and muscovite, though present, are not so abundant. In some cases muscovite makes an integral part of the foliations, while in most sections it is found in larger flakes developed from sericite (an alteration product of felspars).

In a few cases particularly towards the southern region of L. Birrage, east of Meendooish Hill or near Lough Donven, the New chlorite so common throughout these rocks is absent and its place is taken by a light pale yellow biotite. A similar occurrence of biotite is found very close to the laccolithic boss of xenolithic lamprophyre near Aghros Hill. Associated with this biotite, as in other rocks more particularly towards the western or southern regions of Doon Lough, irregular and rectangular shimmers of sericite are very common. In most of the irregular shimmers are dusty to

shapeless patches of iron oxide and ilmenite, sometimes altering to lencoxene. In the more pelitic types generally with these iron-oxides are present some unoriented and shapeless biotite flakes. From the nature of the occurrence and their shape it appears that these shimmers, with or without biotite, are due to the alteration and deformation of the iron rich lumino-silicate staurolite. This mineral has been seen occurring in the shimmers in the andalusite schists near the granitic boss of Terrylagh, or on the road side near Pound Lough. In contrast, Square or rectangular shimmer may be after andalusite. From this fact it is evident that the formation of stausolite (present in these local areas) is not connected with the formation of andalusite i.e. the late granitic intrusion. The absence of New chlorite in the rocks from the region between Doon Lough and Terrylagh or east of this region may be due to its transformation to pale biotite now occurring across the foliations.

(iii) Dawros-Rosbeg banded biotite muscovite Schists:-

The rocks of this group are grey to silvery schists with a pinkish hue. They are characterised by thick or thin bands of varying colour and composition. The rock types met with vary from siliceous granulitic schists to mica-rich biotite-muscovite schists, in which alternate bands of micaceous or siliceous rocks occur together. On the weathered

surface, they show a spotted appearance due to cavities of chlorite (pseudomorphs after garnet). On a fresh surface the spots are of green to dirty green in colour, some are upto 0.5 m.m. in diameter. At places yellow-brown garnet is visible surrounded by irregular chlorite and shows a pinwheel structure. The number and size of the spots is larger in the siliceous bands. The individual bands are undulating and show a pinch and swell or flow structure. The rock is hard to break, but a broken surface reveals a fresh graphitic or leaden grey to dull grey rock. The lustrous bands are more pelitic (micaceous) and the pinkish grey bands are more siliceous and brittle. Towards the southern regions of the area, south of Kiltooris School, a few bands are brownish grey in colour, due to the evenly distributed iron ores now altered to limonite. On the silvery grey or light bands, both across and parallel to the schistosity are good prismatic crystals of green coloured New chlorite upto 3-5mm. in length. It has also been noted that in the same outcrop and in the same hand specimen, both aligned and irregularly arranged crystals of New chlorite are present.

In thin section, the rocks show a typical 'herring-bone pattern' due to the foliations and a well-formed strain-slip cleavage. Within 2 cm. about 15-20 such designs can be made out. The minerals present in these rocks are the same as in

the other rocks just described. The relation between the rounded chlorite (after garnet) and the composition of the band observed in the field is thus confirmed. The size of these chlorites is much larger in the crenulations than in the planes of foliation. The amplitude of these crests or troughs with chlorite or garnet varies from microscopic dimensions up to asmuch as one and a half inches. Ordinarily the micas form the main mass in a pelitic band, while in the psammatic layers quartz is the chief constituent, in which sporadic flakes and porphyroblasts of chlorite, biotite and muscovite are common. Most of the quartz grains are uniform in size and are free from inclusions. Along the planes of foliation the ratio of elongation of the grains is 2:1 to 4:1. Almost all these grains show strain effects. At no place in the psammatic bands is a good felspar grain found.

On the basis of their mineralogical constituents and petrographical characters in this major subgroup the following varieties of rocks can be distinguished:-

1. Quartz-felspar-muscovite granulites
2. Quartz-felspar-muscovite-biotite granulites
3. Quartz-felspar-biotite-sericite schists
4. Quartz-felspar-biotite-chlorite-(garnet) schists
5. Biotite-chlorite-muscovite schists
6. Carbonaceous mica schists.

The Porphyroblasts of Chlorite and Biotite: Before actually dealing with the different minerals present in these rocks, the writer wishes to comment on the porphyroblasts so well developed in these and other rocks. The porphyroblastic minerals present are generally (i) rounded chlorite, (pseudomorphs after garnet), (Plate 13), (ii) well developed green to light green flakes of "New" chlorite lying across the foliation (Plate.17...) and (iii) a light pale yellow biotite (Plate.12-5/8.) occurring in the same manner as the second chlorite.

These porphyroblasts, originally observed in the Portnoo Schists, are however not so well developed in that group but when present are always associated with a crinkle or kink in the foliation.(compare plates .12.14....) The "rounded chlorite" can scarcely be made out in those rocks or even in the pelitic schists of the Dunmore-Doon Lough region. In the Aghros Hill-Eden House semipelitic schists however both types of chlorite can be identified and they become best developed in the semipelitic schists of the Dawros-Rosbeg subgroup. From these facts it is evident that whatever be the origin of these minerals, they are of regional importance. Usually, both types are present in the same slice, and except for the schists at the contacts of the lamprophyres and in the granitic aureole, these porphyroblasts are constant constituents of all the

argillaceous rock types. Sometimes e.g. in the Aghros Hill, in addition to these two there is a third (not so important) porphyroblast of biotite. In many cases where it is present, it seems likely that the flaky chlorite is an alteration product of this biotite, while at others the biotite appears to be formed after the chlorite. But taking the majority of cases and the association of other rock types in the vicinity into account, it is more likely that the biotite porphyroblasts are a transformation product of the "New" chlorite.

The rounded chlorite is a retrogressive product of a brown to reddish brown garnet. In most of the cases, particularly in the Dawros area and the S.W. Rosbeg region, caves of unaltered garnet are very common. In other regions, where the garnet is totally chloritised, the mineral shows a spiral or pin-wheel structure, but chlorites with polygonal outline are also not uncommon. In the granulitic and siliceous bands the euhedral garnets are either unaltered or are partially changed. From this it is clear that the siliceous and semipelitic quartz-rich bands acted as comparatively competent beds. The pelitic bands were more plastic and the garnets were rolled. This is confirmed by the trails of iron ores or the curving foliations around the chlorite or partially altered garnet spots. As shown above

these knots are always situated in 'kinks' of the schistosity so it is certain that the schistosity is earlier.

The porphyroblasts of '<u>New chlorite</u>' or <u>light pale biotite</u> are formed along the cleavage or shear planes. They always make an angle of 30 degrees - 55 degrees or 60 degrees to 75 degrees with the plane of foliation. The trails of iron oxides and sometimes the cleavages or planes of foliation of the rock seen to pass through the porphyroblasts. Their length and breadth are very variable. In a graphitic schist of the Dunmore-Doon Lough, they are visible only under the microscope but in the pelitic rocks of the Aghros Hill or Dawros areas their size is a maximum (1 cm. x 5 m.m.). In a typical pelitic rock this chlorite is a <u>penninite</u> with pale to light green in colour and has a pleochroic formula of x = light green, y = green and z = pale greyish green; the R.I. is Ny = 1.588-1.579. The interference colours are greys to ultra blue. The mineral is optically positive but flakes with a negative sign are not uncommon. In one slice, two flakes appeared to be of higher refractive index and possessed a hour-glass structure, suggesting chloritoid, but unfortunately in these two cases the optic figure and the angle could not be obtained.

The porphyroblasts of <u>biotite</u> are pale cream or light brown in colour. So with x=y=light brown and z=pale colour-

less. The 2V=2-4 degrees and the sign is negative. As with the chlorite, in some cases trails of iron oxide lie parallel to the planes of foliation. These porphyroblasts of biotite are more common east of Meendooish Hill and near Doon Lough.

C. Calc-Pelitic* Schists.

Introduction.

The rocks included in this subgroup are very limited in their occurrence, being confined to three irregular thin bands in the Rosbeg group. It is to be noted that these three calc-pelitic bands are associated with thin lenticular basic sills, independent metadolerite sills being absent. Both in the metadolerites and the sedimentary bands, a peculiar type of contaminated or hybrid rock, rich in hornblende and pink garnet, is developed.

Field Characters:- In the field, the calc-bands are characterised by their greenish grey to dirty green colour, which on a weathered surface appears earthy brown to dark grey. Unlike the other sedimentary or basic igneous rocks, they appear spotted or display an uneven honeycombed surface. A fresh rock is rich in large (more than 1 cm. in diam.) rounded or oval spots of dark green colour (Plate 3), in the core of which sometimes a light pink colour is visible e.g. at Pollmurry, on the hill near Portnatrawbane etc. These pseudomorphs or partially chloritised garnets are embedded in a matrix of greenish grey to

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* This term, used early in this investigation, is perhaps not entirely suitable; the rocks could be better termed impure calcareous schists.

dark green colour. The associated basic rocks are also rich in similar garnets. Infact, sometimes the larger masses of metadolerite are seen to grade into highly garnet and hornblende rich schists e.g. near Rosbeg P.O., Kiltooris Hill, Portnatrawbane etc. At other places e.g. in a small peninsula near Sauncy Hole, both rocks present a very knotted appearence, and do not seem to grade into each other. In this latter locality, there are thick and thin alternating irregular bands or " apophyses" of both types of rock. These rocks therefore in general exhibit a banded or blotchy appearance.

Occurrence and Distribution:- The most important occurrences of these bands are on the north and south coastline of Dawros peninsula, several islands in Dawros Bay near Rosbeg pier and in the region south of a line joining Rosbeg P.O. and Kiltooris Hill. In the Dawros peninsula, on the north coast, a thin band, not more than 20-30 feet in width, extends for about three-quarters of a mile and, along with its associated metadolerite, forms the higher cliff-line, roughly between Illanglass and upto a small triangular peninsula (half way between Crockacuon and Carrickuna. At several places, this band is faulted by minor faults along the cross joints (i.e. in 210 degrees - 225 degrees direction). The other two bands are on the south coastal cliffs between

Portnacally and Polladingdaung and the other almost a furlong and a half north of it and extending upto Kates' Strand, are exposed in irregular outcrops running in a N.W.-S.E. direction. Further east, the same types of rocks are seen to make the several islands between Kates' Strand and Rosbeg pier. In the region south of Rosbeg-Kiltooris Hill, the calc-pelitic schists with their associated garnet-rich amphibolites crop out on both sides of the Rosbeg road and these outcrops continue up to Kiltooris Hill. The other occurrences of importance are those on the coast near Port-alirabane (South of Rosbeg pier), Portnatrawbane, Pollachoor, Polmurry and Elaghrania.

At all these localities, the structural characters of these rocks appear to be the same as those of the country metasediments. The lineations so nicely displayed by the pelitic or semipelitic bands are perhaps not so marked and, due to the irregular nature of the outcrops and lack of regular bands, the dip and strike seem to be changing with the shape and size of the outcrop. But on plotting the structural features of the outcrops it has been found that they are approximately the same as those of the surrounding metasediments.

Petrography:-

In thin sections these rocks show all gradations from

pure metamorphic schistose pelitic rocks and calc-pelitic schist to coarse amphibole-rich rocks, in which no parallelism of the minerals can be made out. These coarse amphibolites and the metasediments have different proportions of the same mineral constituents. The rocks of the calc-pelitic bands have a good schistose texture and generally exhibit a herring-bone pattern in which the minerals like the porphyroblasts of New chlorite or the pinwheel structure of the garnets are best displayed. The other minerals include chlorite, bluish-green hornblende, calcite, andesinic plagioclase, quartz, epidote clinozoisite sphene, apatite, ilmenite and pyrite, biotite and muscovite along with chlorite form the foliation. The same minerals are present in the coarse amphibolites, which show an ophitic to porphyroblastic texture in which porphyroblasts of pinwheel garnet are embedded in a matrix of quartz, bluish-green slender prismatic crystals of hornblende and subordinate ilmenite. Associated with each of the garnets are crystals of calcite and epidote or sphene. In sections from Portnatrawbane and Polmurry, small aggregates of a pyroxene probably diopside are present associated with the green hornblende.

At most of the localities the garnet-rich coarse amphibolites are fine grained and all the garnets are

altered to chlorite, but at Portnatrawbane near Rosbeg P.O. and at other localitites, the alteration of garnet both in the pure calcite-rich pelitic band or in the amphibolite is partial. Near Polmurry and Portnacally, the garnets are chloritised (Plate 3-A) only along their edges and are embedded amongst prismatic or partially broken and aligned hornblende crystals. From this it seems likely that the sediments were more plastic than the dolerites under metamorphism.

Again the 'New chlorite' so commonly seen in the pelitic and semipelitic metasediments can hardly be made out in the coarse amphibolites, but in the case of the sheared types it is well developed and lies at angles of about 30-45 degrees to the schistosity (as in the case of metasediments). This shows that its formation is due to later retrograde metamorphism.

The close association of garnetiferous amphibolite and garnetiferous metadolerites described above raises problems which require further study. Provisionally, the writer suggests that some kind of exchange of material has taken place between the basic sheets and the calcareous rocks. The time of this exchange could be either that of the intrusion of the dolerites or of the impression of the metamorphism. From the textural evidence of the rocks the

second alternative is preferred.

D. Regional Metamorphic History of the Sediments.

In earlier pages, petrographical accounts have been given of the various metasedimentary rocks. These rocks have suffered at least two regional metamorphisms and, in certain areas have undergone in addition local thermal meramorphism due to the widespread lamprophyres or the Ardara granite pluton. This thermal metamorphism is dealt with in later pages and in this present section the regional metamprphisms only are considered.

It has been seen that the country rocks have attained the mesozonal grade of regional metamorphism. This is marked by the development of biotite, garnet, rare staurolite in semipelitic and pelitic rocks. Accompanying this mesozonal metamorphism was the main orogenic movement, registered by the formation of schistosity and cleavage parallel to the bedding. Porphyroblasts of oligoclase are developed in the foliations which they do not displace.

Following this episode there was one of retrogression to epizonal conditions. This metamorphism was of a regional character and affects all the country-rocks of the area. Movements during the retrogression developed widespread shearing which was on the earlier schistosity and cleavage, producing what has been called "crinkles" or

"kinks" and "herring bone textures". Mineralogically it was noted by the formation of chlorite and destruction of garnet, staurolite and biotite.

The question of time relations of the two episodes of regional metamorphisms is one of difficulty. Retrogression is certainly the later process, but what span of time separates the two episodes is a matter for discussion. It appears that a similar retrogression has affected great areas of North-west Donegal and we are faced with the difficulty of separating two regional metamorphisms which have operated over the same great area. To the writer, it seems preferable to suggest that the two episodes were not widely separated in time. The retrogressive epizonal metamorphism may be considered as due to the dying forces of the orogeny which was responsible for the first mesozonal metamorphism. If this is not the case then somewhere in Donegal there should be found an area where only one metamorphism has operated. So far as the writer knows, such an area has not yet been discovered, but further search in Donegal may reveal one. Provisionally, we may consider the two regional metamorphisms in the Portnoo area to be successive phases of the same event.

The metamorphic history is therefore one of folding and impression of schistosity and cleavage with the development

of porphyroblasts of garnet, biotite and staurolite followed, with no great effect by shearing movements which was responsible for the breakdown of garnet and biotite to chlorite.

VIII. METADOLERITES.

(a) Introduction.

In a previous section (V) of this thesis, it has been shown that the metasediments are intercalated with dark sills and sheets of doleritic composition. These basic rocks were intruded into the sediments before these rocks suffered any regional metamorphism. From a study of the nature of their occurrence, mineral composition, etc., they appear to have undergone the same metamorphic changes as the sediments (now called metasediments). Anologous to the term "metasediments", these metamorphosed dolerites are called "metadolerites". Both in their structure and mineral composition, these metadolerites of Donegal are identical with the epidiorites of the Scottish Dalradian series. In describing the corresponding metamorphic rocks of the Scottish Highlands, some writers, including Read (1927, p.351), consider the metamorphosed basic igneous rocks to belong to/a geosynclinal phase, whilst others believe them to have been intruded long after the deposition of the sediments.

(b) General characters.

In the present area, the metadolerites occur as lenticular sills or elongated concordant sheets to small detached lenticles. Usually these bodies are thickened

and thinned along the strike, but boudinaged structures, a feature of the metasediments are also met with.

The various sheets and lenticles of these rocks are dark melanocratic massive, hard and compact but varieties with a lighter colour and strongly foliated (e.g. in the southern parts of Dunmore plateau;) or with well developed streaks of felsic material (e.g. in the Kiltooris or Narin sheets) are also common. Near the granitic bodies or in the aureole around the granitic pluton, a recrystallisation of the metadolerites has taken place - so that in these portions coarse amphibolites with well developed hornblende crystals are formed e.g. in a quarry immediately south east of Summy Lough. These coarse grained rocks are still darker in colour, and this variation can be seen even within a few inches of a felspathic streak. The specific gravity is not greatly variable, ranging between 2.86 and 3.02.

Chilled edges are rarely preserved but nearly all the larger sheets show comparatively fine-grained margins and in the case of smaller bodies, a foliation, due to the parallel alignment of hornblende is developed. This foliation is generally parallel to the foliation of the metasediments. At some places, e.g. in the Narin hill, in addition to the faint foliation a lineation, due to the streaks and blebs of felspathic minerals and almost parallel

to the 3rd lineation of the metasediments, is also developed. This lineation is more prominent towards the nearby granitic bodies and hence it is certain that this feature of the metadolerites is a structure complimentary to the 3rd lineation of the metasediments. In other areas, e.g. W. of Doon Lough, the impregnation of felspathic material is very irregular and the whole massive rock appears to be a fine whitish calico print on a dark coloured base.

Usually the rocks are medium to coarse grained and exhibit an ophitic or porphyritic texture in which the original femic constituents are only rarely visible, as relicts, in a hornblende-rich matrix. But in the central portions of the thicker bodies the rocks are fine to medium in texture and, except for the recrystallisation of the original dark constituents as a fine mosaic of equigranular green to bluish green amphibole or other minerals such as epidote or ilmenite, do not show any marked change. At a few localities (1) at the head of Polmurry (S.of Kiltooris School) and (2) in several minor exposures between Saucy Hole and Portnacully, (3) at Portnatrawbane and along the roadside south of Rosbeg P.O., the changes observed are most characteristic. In all these areas, in a very coarse grained rock, rounded crystals of a pink garnet up to

1½c.m. in diameter are found embedded in a matrix of prismatic crystals of hornblende up to one and to one and a half inch in size. These are the localities of the irregular exposures of calc-pelitic schists of Rosbeg, and the changes produced may be connected in some way with one type of rock and the other.

Metadolerites that have entered into the thermal aureole of the Ardara pluton or have been involved in contamination and agmtitisation are described in later section of this Thesis.

(c) Mineralogy & Petrography.

In a thin slice, the massive dark green rock has a typical ophitic texture and is mainly composed of turbid andesine - labradorite (An.35 to An.45) and ferromagnesian minerals. The felspar generally alters to aggregates of granular epidote. Very often, fresh sodic plagioclase with rare inclusions of clinozoisite and light green epidote is seen to replace the calcic plagioclase laths. The ferromagnesian constituents include subhedral grains of pinkish augite suggesting a titaniferous variety. Along its edges and cleavages, it alters to bluish brown amphibole, the first stage being marked by the formation of a granular or fibrous uralite of brownish colour. Very often this amphibole forms a rim around the pyroxene, while in other cases e.g. in a specimen from Maynor (W.of Lough Birroge) the uralite is enclosed in a second rim of a bluish-green actinolitic hornblende which is also

altering to chlorite, flakes of which extend even into the ophitic plagioclase. The last stage of this alteration is reached when the pyroxene is totally uralitised (e.g. in a small massive sill almost half-way between Loughs Birroge and Doon) or is completely replaced by a bluish-green hornblende, so common throughout the present area. In these latter types, the calcic felspars are more turbid and subordinate to the clear fresh oligoclase enclosing larger plates of clinozoisite and better developed epidote. The amphibole is entirely actinolitic and has a pleochroism in pale blue green, olive green and straw or yellowish green. In all these varieties small and larger grains of ilmenite and magnetite are distributed throughout the rocks and sometimes mould the amphibole. Skeletal forms of ilmenite are commonly seen. In the rocks rich in uralite or in the varieties in which there is no augite visible, ilmenite alters to sphene and the latter sometimes forms rims around the ilmenite with which may be associated a little of red coloured rutile.

Interstitial Quartz is an accessory and often intergrows with the saussuritised plagioclase. The other notable accessories are euhedral crystals of apatite and epidote, mostly found in the acid plagioclase. In the amphibole-rich rocks sometimes a few flakes of biotite are seen. These rocks can be called <u>epidiorites</u>.

The other type of metadolerite, representing the chilled edges of the intrusions is the hornblende schist. This rock is of local occurrence and is a typical green schist. In thin section, it is characterised by the well developed foliation given by chlorite and subordinate amphibole and biotite. Such a feature has also been recorded by Wiseman (1934, pp.354-417). The felspars are drawn out as lenticular aggregates but still contain large plates of epidote and clinozoisite. The Chlorite, giving the foliation and marking the shears, is fibrous and flaky and exhibits a violet and indigo blue pol.colours. Sometimes it is associated with sphene, rutile and iron oxide. Green biotite is parallel to sub-parallel to the schistosity and is subordinate to chlorite and amphibole. From the texture of the rock it is clear that the mica is a later mineral formed probably due to the potash metasomatism. Large crystals and plates of epidote are strongly pleochroic and are seen to replace the plagioclase.

The metadolerites from the Kiltooris and Narin-Cashel Hill regions are very similar in their petrographical characters, the only difference being that the rock from Narin is much richer in biotite and acid plagioclase, while the rock from Kiltooris is hard, compact, speckled, with fine streaks of felspars and is slightly lighter in colour and finer in grain.

A typical specimen from Narin-Cashel Hill region with specks and augen of whitish or pale white felspar does not show any schistose texture; on the other hand it has a somewhat ophitic tendency. The amphibole is darker in colour, platy in shape, with good cleavages, and is sieved by quartz, felspar and sphene. The euhedral plates or larger plates with subhedral form are not sieved and the pleochroism ranges from bluish green to pale green or straw colour. In the specks or augens, basic oligoclase (Ab.70-75) forms a mosaic of equigranular grains which are partly saussuritised. Quartz occurs in interlocking grains with the plagioclase. Occasionally, within the felspar grains are enclosed a few pink garnets partly altered to chlorite. The shape of the garnet is idiomorphic and the mineral is generally not sieved, but sieved grains may also be present. Around the felspars, the amphibole is granulated and alters to a brown-green variety, while other grains alter to brown to deep brown biotite which itself changes to chlorite. The other minerals included are sphene as rims around ilmenite, epidote and apatite.

It should also be noted that transition from one type to the other are very common in both the Kiltooris and Narin-Cashel regions.

(d) Summary & Metamorphism.

The basic igneous rocks present a series of rocks,

the least altered of which is a metadolerite with labradorite and ophitic pyroxene. This has given rise to two types of rocks; first a predominant epidiorite in which the original amphibole has changed to aggregates of plates of hornblende prisms and the calcic plagioclase includes within them a fresh secondary felspar. The next stage is represented by the growth of acicular crystals of hornblende filling into the felspar, which itself is being replaced by clear re-crystallised oligoclase. This type is comparable to the amphibolite type of Read (1923, p.7). When the schistosity is developed, the rock can be named a hornblende schist. In this stage and in the felspar rich varieties though biotite is present, it is in minor amount, subordinate to amphibole on the one hand and the felspar on the other. The occurrence of this mica can be compared to the biotite in the epidiorites of the injection complex of Sutherland (Read 1931), where it has been shown that it is a product of potash, metasomatism. Im the present area the development of biotite can be connected with emanations and intrusions of potash-rich magma of a later episode in the history of these rocks. Finally the production of granet gives rocks of the alamandine zone of Wiseman (1934, pp.407-409).

The retrograde metamorphism so nicely seen in the pelitic and semipelitic rocks can hardly be made out in

these basic sheets. It appears to be recorded by the saussuritisation of oligoclase, alteration of biotite and the chloritisation of the garnet. The occasional occurrence of chlorite parallel to the shear planes may be similar to the porphyroblastic chlorite present in the pelitic sediments.

IX LAMPROPHYRIC AND RELATED DYKES AND SHEETS.

A. Introduction.

As already stated, the metamorphic rocks are invaded by a great series of dyke rocks which can be shown to have been emplaced before the intrusion of the Ardara pluton. The rocks of this group are very varied. They differ widely in their occurrence, form, appearance, texture and mineral composition. Usually they are dirty grey to light grey or greenish in colour, but there are some which are pinkish white to dirty pinkish grey. They are mostly fine grained though sometimes porphyritic and are massive and compact in hand specimen. Spherulitic and xenolithic types are not uncommon. This variability is emphasised where a single intrusion changes from wholly fine grained to porphyritic; it may become xenolithic or grade from a more acid type to a basic variety. The composition of the rocks considered here varies from pure quartz bodies through granitic or granophyric acid types to basic amphibole-rich rocks: hornblendites or spessartites. The different types recognised in the field are :-

1. Quartz-rich dykes, sheets or bosses.
2. Grey massive lamprophyres and Felsites (Non-Xenolithic
3. Greenish grey spherulitic felsite sheets. (Xenolithic
4. Green (Xenolithic) lamprophyres.
5. Porphyritic felsite dykes.
6. Sheared lamprophyres (sometimes xenolithic).

Generally, the differently coloured types appear to be independent of each other and show cross-cutting relationships.

The best exposures of these bodies are found along the irregular coast-line, where their mutual relationships and contacts can be seen in detail. On the coast, particularly in the Dawros and Rosbeg areas, the steep dykes or their junction planes, like the joint or fault planes of the country rocks, have provided weak planes for marine erosion. The country rocks are thus dissected into sea caves, small islands and other inlets or peninsulas which trend in the strike or dip directions of the country rocks.

B. Mode of Occurrence and Field characters:-

These dominantly intermediate intrusive rocks occur in both the main stratigraphic groups of the

district, but due to their comparatively steep dip and better exposure in the pelitic or semi-pelitic areas, they appear to be more concentrated in the Rosbeg and Dawros regions. Most of these hypabyssal bodies have a low dip. They may be concordant sills, or dykes; they may traverse the country rocks in a totally irregular manner. In general, their strike is NW - SE to NNW-SSE. A few felsites in Dawros area and two sheared and xenolithic lamprophyres strike N-S or at 215 - 220 degrees, and the dip of these bodies is very steep. Other sills or dykes, with steep dips, have their dip either to the south or north varying from 45 degrees to vertical. The low sheets appear to follow the flat lying joint planes of the country rocks. These flat lying sheets are concordant and discordant to the bedding planes, but all seem to crop out parallel to the strike of the sediments.

Individual dykes or sills are thin, their thickness seldom exceeding a few feet, and they are generally uniform in thickness for considerable distances. Some display a pinch and swell structure

and a few are laccolithic. The late felsitic or acidic bodies are thicker, more uniform and have generally a steeper dip than the lamprophyric or basic types. The maximum observed thickness of the massive portion of a felsite (e.g. at Pollateda or north of Dunmore Hill) is more than 20 ft. while the minimum is never less than 1 - 2 ft. The thickness of basic types, particularly the green lamprophyres, seldom exceeds 5 - 6 ft. and is frequently reduced to less than half an inch. This latter phenomenon is especially marked by the fraying (Fig. 11 D,E) and branching of a massive body, where it attempts to cross another competent rock body - generally another dyke or sheet. Examples of such fraying are common in the Carrickalagh peninsula, at Portnacully, N.W. tip of Altrageeragh peninsula, Illanglass, Scoltaworth ~~of~~ in Dawros peninsula and at western tip of Ellagharania ~~of~~ in Rosbeg area and at several other places in the Portnoo, Narin or Dunmore areas.

The lengthwise extensions of a dyke or sheet are generally limited and individual intrusions cannot be traced for long distances; but sometimes isolated outcrops of similar character show a linear extension (Fig. 11 D)

suggesting continuity. This latter feature is more common in the flat lying grey compact sheets e.g. three or four grey felsite - lamprophyre sheets could be traced for more than half a mile in the area immediately south of Dunmore Hill. A pair of similar grey coloured felsites extends from a hillock about 1½ furlongs east of Rosbeg P.O. to the middle western coast of Kiltooris Lough. From these facts it is likely that these bodies probably extend for long distances.

The terminations of these intrusives are also very varied, sometimes subrounded, or tapering and wedging out or divided, ending in thin branches or fine stringers. It is not always necessary that these branches should follow a joint or fault plane. Splitting up and separation into droplet-like masses are seen in a few cases e.g. from the head of a large xenolithic felsite sheet (at Dunmore coast) four or five 1 - 3 ft. thick sheets with several minor stringers are found following the bedding planes of the limestone. Sometimes, the small cracks or crevices of the country rocks are filled with fine

grained grey or pinkish grey material e.g. in the schist of the east coast line of Portawand (S.W. of Dawros Hotel), east of Pollmurry on the rocky beach near Trawmore Strand, (Fig. 11 B).

Many sills or dykes show a simple flow structure. A few sheets, particularly the grey spessartites, show parallel foliation, which under the microscope is made up of opaque foliaceous or micaceous matter. The central portions of the spessartites are massive. In felsite dykes at Rosbeg pier, or at Pollasteda elongated phenocrysts of felspar or dark minerals are arranged parallel to the contact.

Other intrusions have complicated structures such as folds, minor faults or angular breccias at their contacts with the country rocks. The sills or dykes of greenish colour are more irregular both in their form and other structures. At places they are fine grained and show somewhat spheroidal weathering, at others they are very rich in xenoliths and heterogeneous in colour. Generally their edges are irregular and sometimes thin stringers or bulbous bodies seem to penetrate the country rocks, (Fig. 11 B, D & E).

In the vertical coastal sections, the structures

of these intrusives and their relations with the wall rocks are clearly visible. From these exposures, it is clear that characters such as discordant relations, bulging or pinching, off-shoot dykes, offsets or warped contacts may occur in any part of a sill or dyke. Though they seem to have taken advantage of the early joint planes, it is evident, from the way that they fill cracks and show mutual criss - crossing relationships, that they have been intruded forcibly.

C. The Walls of the Dykes.

In the majority of cases the dykes or the sheets have absolutely sharp and chilled margins. Often there does not appear to be any contact effect, though de-coloration of the country rocks may occur. Sometimes the chilled edges of the intrusives appear to be drag folded or studded with xenoliths, which are occasionally drawn out parallel to the strike of the intrusive mass, e.g. about 2 furlongs S.W. of Dawros Hotel, in an island on the beach, angular xenoliths are aligned or sub-aligned almost parallel to the contact.

Rarely, thin apophyses of the intrusive material are injected into the country rocks, extending a few inches. In particular, at the margins of the felsites,

detached angular pieces or small blocks of country rock seem to be about to be floated off. Sometimes the dyke makes minor offsets (Fig 11A) e.g. in the Rosbeg pier felsite, Pollateda dyke or other felsites on the northern coast of Dawros peninsula. In general, if the intrusive rock is removed, the gap could be filled by remoulding the wall rocks back into their original position. Similarly the felsite dyke at Pollateda is actually made up of two or three parallel dikelets. Sometimes these finger-like apophyses or branches touch one another (Fig 11C) though they never seem to intermingle. The edge of each dikelet is sharp and chilled, and nowhere is any contact reaction seen. Sometimes, the dikelets occur as a series of en echelon lenses which are offset to either side e.g. at the rocky edges of the beach of Pollmurry.

In some occurrences, particularly of the green lamprophyres but also of other types, "pebbly" and brecciated zones up to 1½ ft. thick may be present adjacent to the chilled edges. Layers of similar breccia may also occur within the sill or the dyke e.g. in the felsite dyke north of Dunmore Hill and in the green xenolithic lamprophyre near Rosbeg harbour as

dealt with in the next chapter. The pebbly breccia of the Rosbeg dyke grades into a laminated rock in which a parting is produced by the planar orientation of the dark minerals. The parting surfaces are thought to be discontinuous planes of differential movement during intrusion. (Tweto, 1951 pp.507-532). Some of the sills appear to be stratified due to such a lamination; the phenocrysts of fermic minerals are concentrated in bands, often parallel to the contact. This may also be a structure due to flow.

D. Mutual Relationships of the Intrusions.

The green lamprophyres in particular, when crossing or cutting through any competent layer such as any other type of dyke or sheet, are frayed into thin stringers and become gradually lost e.g. on the S.E. coast of Carricklagh, at various places in Dawros peninsula, on the limestone exposures north and east of Narin Church. It is most common, however, for the various dykes or sheets to cross-cut one another and show a complexity of time relationship. At most localities, dykes or sheets are seen to be cut by exactly similar rocks. The most important examples of this type of cross-cutting are those (i) on the

beach immediately south of Kiltooris school where two low dipping grey spessartite sheets show this relationship (ii) N.W. tip of the Carrickakuna peninsula on the northern side of Dawros Island. Here two grey spessartite dykes are cross-cutting and make an angle of anout 60 degrees (Fig 12A, Pl .6B....). Similar minor cross-cutting pairs of dikelets or veinlets are also seen at the stony beach on the other side of Portnoo Pier. Such paired cross-cutting sheets or dykes or veinlets of identical composition are here referred to as 'twin' dykes, sheets or veins. They indicate that cross-cutting relationships may not be an entirely decisive factor in deciphering the history of these hypabyssal bodies - there were probably several injections of the same and different magmas over a rather extended period. Besides, portions of the same magma may reach the same parts of the crust at slightly different times.

Other cases, where the cross-cutting sheets or dykes are of different nature, are very common. The most notable instances are :-

1. A three to four feet thick felsite sheet cutting a 2 ft. thick grey lamprophyre sheet immediately at the coast (near water line) halfway between Carrickakuna and Dawros Point.
2. A massive grey lamprophyre dyke cuts a thin quartz vein; the dyke itself is cut by an irregular 1ft. - 3ft. thick green xenolithic lamprophyre and by another 1ft. thick spherulithic felsite sheet, at a south-facing wall of a sea inlet S.E. of Aghros point, (Fig. 12 D).
3. Five closely spaced east-west-trending grey coloured, 3 - 5 ft. thick, steeply dipping felsite dykes are cut by several N-S quartz sheets and veins at the rocky beach of the rectangular peninsula north of Scoltraling near Aghros Point.
4. A 10ft. thick felsite dyke cuts through the above mentioned quartz veins in the vertical section at Scoltnaling almost halfway along the coast between Mullanard and Aghros Point.
5. A grey, 2½ ft. thick, lamprophyre dyke cuts a 3ft. thick lenticular steeply dipping quartz sheet at Crocarkun peninsula (north coast of Dawros peninsula) (Plate 6 c).

6. A 6 - 8 ft. thick irregular xenolithic green dyke cuts through a dark grey felsite, about 4½ - 5ft. thick, in an island close to the road, about 150 - 200 yds. north of Rosbeg pier. The same green dyke probably cuts through the pale pink felsite on the main land on the north side of the Rosbeg pier.

At other places these dykes, sheets or sills are either constricted, deflected, or diverted against an early sheet or dyke e.g. on the coast-line S. of Portawand a dolerite dyke hovers on both sides of an early pink felsite. There are many other examples throughout the area.

Jointing in the sheets is generally uncommon. However, in some of the sheets and more often in the grey lamprophyres or the felsite dykes, two directions of joints have been noted, one parallel to the dyke wall rocks and another almost at right angles to their length. In many cases, particularly in the grey massive lamprophyres or felsites, the cross joints are parallel to those of the country rocks.

E. Classification.

Like the physical and structural features, the

mineral composition of these rocks is also very varied and on the basis of the constituent minerals and their textures it is hardly possible to classify all these different intrusive bodies. Their cross-cutting relations to one another give some idea of their mutual age and the classification given below is an attempt to combine the mineralogical and field relations.

None of these dykes or sills can be called a typical lamprophyre, rich in phenocrysts of either the felspathic or dark fermic minerals, as defined by Tyrrell or H.G.Smith. Again they can not be called diorites or microdiorites, as there is either a preponderance of basic or acidic minerals or they show a somewhat porphyritic texture - a criterion excluding microdiorites. In a broad way, most of the basic types are here termed lamprophyres and include such rock types as spessartites, kersantites, odinites, vogesite or minettes. On the other hand acidic varieties include the pure quartz dykes or sheets, and others of felspathic composition, which can be called felsites, porphyritic felsites, micro-granite, micro-diorite, granophyre or apłogranite.

On the basis of their mineral composition and mutual cross-cutting relationships these hypabyssal sheets, sills or dykes can be grouped as :-

1. Early Quartz dykes.
2. Grey dykes and sheets (some "twins")
   (a) Lamprophyre Suite.
      (i)Spessartites (Hornblende-rich).
      (ii) Kersantites (Biotite-rich).
   (b) Grey Felsites.
3. Grey Spherulithic felsites.
4. Pale pink felsites.
5. Late Quartz veins.
6. Green Lamprophyres.
7. Late Porphyritic dykes.

F. Detailed Descriptions of Dykes and Sheets.

(1). Early Quartz dykes are mainly composed of white quartz though very small amounts of metallic ores may occur, such as magnetite, pyrite and galena with very subordinate dark green chlorite or micas. The larger bodies are slightly irregular in shape and are very often stained with a pale reddish hue. At their contacts, the margins are generally sharp and the rock

does not show any appreciable reaction. In the case of larger dykes e.g. at Ellagharania and Pollcarricksheshkin, the walls are irregular and detached pieces of the country rocks are found attached or partly engulfed in the quartz rock.

(2). Grey dykes and sheets.

(a) Lamprophyre Suite:

Rocks of this group seem to be of two different ages and hence with two different habits in the present area. The earlier types may be regarded as the basic continuations of the grey felsite sheets, while the others are an independent group of green coloured transgressive sheets, which seem to be the latest of the lamprophyres.

(i) The Spessertite sheets are exposed throughout the area. They are massive compact and light grey to greenish grey in colour. As has been pointed out on an earlier page they seem to grade laterally into the grey felsites and this transition appears to be a common phenomenon. Such sheets are most abundant on the Dawros coast line, here one spessartite sheets cuts another similar rock and also cuts a grey felsite of group 2(b).

A typical sample collected from the N.E. coast of Dawros peninsula near Crocakuna exhibits a micrographic intergrowth of quartz and felspar. In some cases the two are so intermixed that it is difficult to identify them. Hornblende of light green to brownish-green colour in idiomorphic crystals or irregular laths forms more than 60% of the rock. Sometimes it is associated with biotite and chlorite. The texture is porphyritic with phenocrysts of amphibole, but types with non- porphyritic texture are not uncommon, Hornblende of both green and brown types occurs in prismatic crystals and makes the groundmass with plagioclase and quartz. Biotite is scarce in proportion. It is a dark brown type and generally alters to chlorite.

In the groundmass the plagioclase is a zoned oligoclase - andesine variety. It is partially saussuritised. Quartz is very subordinate and appears to be interstitial. Epidote is secondary and is an alteration product of hornblende. Calcite of late production is abundant in many slices. Ilmenite and Magnetite are the other accessory minerals.

In another specimen collected from another dyke from the same locality, the elongated hornblende phenocrysts

of brown-green colour are mostly altered to chlorite, but can be identified by small relicts. These phenocrysts show a sort of parallelism due to flow. In another portion of the slice the felspars are in stumpy crystals and are completely saussuritised. These are set in a micrographic quartz-felspar groundmass.

In contrast to the above types from the Dawros area, sheets with very coarse texture are very common in the Dunmore and Portnoo areas. The phenocrysts of amphibole and felspar are set in a medium to coarse matrix. Hornblende of brownish green colour is still the chief constituent, occurring in clusters and idiomorphic six-sided crystals. The smaller laths of the clusters are more chloritised, while in another sample only about 100 yds. away from the first, the phenocrysts of amphibole are more altered. The felspar phenocrysts enclose many small crystals of micas. They occur in euhedral zoned crystals embedded in a fine groundmass. The accessory and secondary minerals include calcite, epidote, ilmenite, lecoxene, apatite and very minor sphene. These are the types which can be named 'camptonite' (of G.W.Tyrrel, 1938, p.122. and F.F.Grout, 1932, p.91).

The other hornblende-rich varieties have a mineral composition ranging between 50 - 90% of mafic constituents. They are light greenish grey to green in colour and medium to coarse in grain. They show hornblende to be by far the dominant constituent followed by plagioclase; the texture is poorly ophitic. Under the microscope the hornblende is rounded or oval in shape, and almost each patch encloses a central core of a colourless to light green colour. This is in marked contrast to the chlorite which has been formed due to the alteration of the amphibole. In a few cases e.g. from a dyke cutting through the schists at the eastern portion of Carrickalagh or in a sheet at Elaghanania, this core mineral could readily be identified as a colourless monoclinic pyroxene comparable to augite. In these cases the hornblende is dark brown and shows idiomorphic crystals. The plagioclase is a minor constituent and forms the matrix of the rock. It is highly saussuritised and appears to be an oligoclase. Interstitial grains of quartz are usually present. Apatite, rutile, epidote and minor sphene are the common accessories. Another specimen collected from a thin irregular sheet occurring in the schists at Mullanard is rich in augite;

dark brown hornblende in euhedral crystals is very common, in addition to those partially altered to chlorite.

A dark brown dyke occurring about 200 yds. W. of Dirty Rock on the sea-coast is a very beautiful Vogesite. The rock is rich in prisms of hornblende and is so coarse that it might be called an appinite. The felspar groundmass is allotriomorphic in which the dark minerals occur in medium to large crystals, the smaller ones exhibiting a radiating tendency. A similar sheet but with brown crystals of hornblende intergrown with definite crystals of greenish - to pale green augite forms a cliff in the eastern portion of the Carrickalagh peninsula.

Another example of a pyroxene-bearing hornblende-rich sheet comes from the Kiltooris area. On the north-east side of Kiltooris Lough, in the fields a thin light to dark green dyke has similar microscopic characters as described above. The texture is porphyritic and the rock is mainly made up of up to one c.m. long idiomorphic olive green crystals of hornblende - and smaller reddish brown biotite laths embedded in a matrix of the same composition, in which the felspars are acid

plagioclase. Sometimes the larger patches of highly altered felspar are visible. Larger crystals of amphibole are sometimes zoned and are seen to have a flow orientation. Along its cleavages it breaks down to chlorite and epidote. Associated with some of the larger crystals of amphibole is another dark brown hornblende showing a micrographic intergrowth with plagioclase. This fact suggests that probably these types are the early basic differentiates of the grey lamprophyres and sheets, or the spessartites, and hence can be regarded as Markfieldite.

Another peculiar phenomenon commonly observed in this type of sheets is the occurrence of a few angular to subangular xenoliths of a pinkish white quartzite. Around the xenolith is a marked 2 - 4 m.m. thick rim of dark green colour, which gradually becomes lost in the hornblende rock. This rim is composed of a diffuse mixture of hornblende, biotite, chlorite, sphene and very fine granophyric material of unidentifiable character. The felspathic patches seen in the hornblende-rich rock are somewhat similar in character. The quartzite consists of medium coarse equigranular recrystallised quartz, rare plagioclase and iron ores. Close to the rim are several irregular patches of biotite-

hornblende rich material, similar to those of the main dyke mass, but these are slightly richer in granophyric material. Here the proportion of green and brownish green laths of biotite is far greater than in the matrix of the main dyke. Similarly in the rim the biotite laths are closer to the quartzite. Other important accessories include good wedge-shaped crystals of sphene, acicular apatite penetrating through biotite or the granophyric matrix. In short this rim is very similar to that described by Pitcher and Read (Geol.Mag.,1952.) and to rocks dealt with in the next chapter.

(ii) The biotite-bearing Kersantites are generally confined to the Portnoo L.St. group. They are very few in number and are less developed than the spessartites described above. Their shape, size and form are very irregular and their thickness varies from fractions of an inch to more than a foot. Generally they are dike-, vein- or stringer-like and seem to be intruded along previously existing shears or joint planes. Due to this circumstance their dip and strike are very variable. Like the grey felsites or the spessartites, these dark bodies are also seen cross-cutting each other or branching and being lost in the country rocks. All these phenomena are nicely

visible in the stony platform immediately north of Portnoo pier.

In the hand specimen, the rock is dark brownish grey in colour, and shows dark brown flakes and laths of a few millimeters in size. In thin sections, rock types rich in both hornblende and biotite are common. Such varieties can be considered to be the link types between the Kersantites and Spessartites.

A specimen collected from a one foot thick faulted dyke between Portnoo Pier and Dirty Rock, in a micro-section exhibits a porphyritic texture, in which the phenocrysts of biotite are embedded in a felspathic matrix. The rock contains up to 65% of either fine grained or porphyritic biotite. The biotite is pale yellow to pale brown in colour and alters to titanite, magnetite and chlorite. Inclusions of sphene and magnetite are very common and pleochroic haloes are well developed. Two types of felspars are subordinate to biotite in amount and form the matrix of the rock. Micrographic intergrowths with quartz are very common, at other places grains of quartz are present as inclusions in the plagioclase. The first type of felspar takes part in the intergrowth and is an unzoned oligoclase (Ab.74).

A second type is often showing at least three zones in the one crystal; the core is unaltered albite (Ab.95), and the outer rim has a composition with Ab.90, the middle zone being highly turbid and sericitised. Other accessory and secondaries are a little epidote and few crystals of apatite.

(b) Grey Felsites.

Felsitic types of rocks are very common throughout the area, and form an important suite of acidic to intermediate varieties. They are mostly whitish grey to grey in colour, and have a white or pinkish white weathered surface. They are mostly compact, hard and massive rocks of hypabyssal structure. In a hand specimen phenocrysts of white felspar and sometimes of femic minerals are commonly seen. Zoned or unzoned plagioclase with minor quartz are the chief constituents. Under the microscope, the texture varies from fine grained to porphyritic with conspicuous phenocrysts of felspar. The dark mafic minerals are very minor constituents and are sometimes absent. The textures of these rocks can be described as granophyric, equigranular or panidiomorphic and even aplitic or coarse granitic.

It has been commonly noted, that the same dyke or sheet exhibits at least two types of textures.

These felsites are the predominant acidic hypabyssal sheets found throughout the area. Their outcrops are broad, and they are rarely seen as dykes. Like the previous two types, the strike is parallel to the country rocks and the dip is seldom more than 50 degrees to the south. They are fine grained, compact, massive and have a dull to vitreous lustre. The rock weathers with a whitish grey to white colour, and is difficult to distinguish from other more acid types. The margins are almost glassy but at places a fine foliation is visible indicating a kind of flow.

A specimen collected from a sheet about one and half a furlongs east of Rosbeg P.O. is light grey to pinkish grey in colour, and appears to be of felspathic in composition. It is vitreous in lustre. In thin section the rock appears to be crystalloblastic and palimpset in texture but some of the plagioclase and the ferromagnesian minerals still retain their flaky or crystal form. There are still others, in which the texture is microgranitic.or equigranular and hypidomorphic.

The chief constituent minerals of these rocks are felspars, hornblende and biotite with subordinate quartz, apatite, epidote and iron ores, magnetite and ilmenite. There are others in which calcite, sphene, and pyrite are also very common.

The plagioclase is the most abundant mineral. Usually it has irregular margins, but regular edges are not uncommon. The grains are zoned and have a composition of An.30-35 in the cores, while the marginal zones appear to be An.15%. Sometimes the crystals show both lamellar and carlsbad twinning, the twin lamallae of either type are very often dislocated and curved - indicating that after the intrusion of these sheets they have suffered some movement. Quartz also gives an undulose extinction. Biotite is yellowish brown to greenish in colour and enclose acicular crystals of apatite, surrounded by good pleochroic haloes. The mica alters to epidote or chlorite. In most of the slices the former is in high proportion along with irregular patches of calcite. The other accessory minerals very commonly present include light pinkish-brown irregular patches of sphene, cubes of pyrite and euhedral to subhedral or irregular grains of magnetite or ilmenite altering to leucoscene.

It is worth recording that the rocks richer in hornblende than biotite always lack calcite and pyrite and may not have any sphene. Both biotite and hornblende are generally present, the one or the other predominating. The biotite occurs in flakes, which may be regular or ragged. The amphibole is either green or brown and sometimes occurs in idiomorphic prismatic crystals. Several of these grey felsites, particularly those richer in hornblende, serve as a transition to spessartites of the same group No.2. Grey dykes and sheets.

3. Grey Spherulitic felsites.

The grey spherulitic felsites are greenish grey in colour and on weathering exhibit a dirty buff to brownish grey colour. The weathered surface always gives a whitish grey circular spotty appearance. With this characteristic feature they are never mistaken in the field. Though they are common in the whole district, they are best exposed in the semipelitic schists of the Rosbeg group. These felsites commonly occur as sheets of 1 - 3 ft. in thickness. But sheets, dykes or veins of less than one inch or more than 3 - 4 ft. are not uncommon. Their strike is also similar to that of the country rocks and the dip is very low. They seem to occupy the flat lying joints of the country-rocks.

The best examples are these of the various sheets occurring in the three small islands at Portnatrawbane. The rock is massive, compact, hard and difficult to break. Under the microscope these types show an allotriomorphic texture of irregular and ragged laths of plagioclase. The spherulitic structure so common on the weathered surface is hardly recognisable. Irregular quartz grains seem to be present but are not definite. Irregular to idiomorphic prisms of a pale green hornblende which is altering to chlorite are abundant. Pyrite, haematite and a little magnetite are the common accessory minerals.

4. Pale pink felsites.

The pale pink felsites occur generally as dykes. They are comparatively few in number. Their strike is roughly parallel to the strike of the country rocks and the dip varies between 50 degrees to vertical. The thickness varies from 3ft. to 10ft. In the present area only four or five such independent dykes have been located. Of the others the most important is the one occurring north of Dunmore Hill which as it is very similar to the xenolithic or brecciated bodies, is dealt with in the next chapter on "Explosion Breccia". Like the other dykes, they are also divided or frayed (Fig .VF.).

Xenoliths of the country schists are not rare and from the nature of their parallel orientation to the dyke walls, it is clear that the dyke material was intruded as magma. The margins are chilled, but phenocrysts of white felspar or elongated dark-coloured minerals are common in this chilled zone.

The examples of such dykes are :-

(1) An E - W 3½ft. to 5 ft. thick pink felsite dyke occurring at the stony coast line between Pollachoor and Pollcarrick-Sheshkin (in the southern Rosbeg area).

(2) A 3 ft. thick E - W dyke immediately east of Rosbeg pier.

(3) A greyish pink 5ft. thick E - W dyke, in the small islands about 150 yds. north of Rosbeg pier, and close to the road near Rosbeg cottage.

(4) A group of four moderately dipping sheets of 1½ - 2½ft. in thickness, near the main xenolithic Felsite.

In thin section, the rock is medium-grained, equigranular and shows an allotriomorphic texture. The porphyritic texture so widespread in the earlier types is here very uncommon.

Plagioclase is abundant and forms the main mass of the rock. It is accompanied by quartz and a little potash felspar. Biotite in well-formed flakes is fairly common. Subhedral to euhedral plagioclase is highly zoned. The core is richer in the anorthite content being usually between 30 - 35% and the mantle varies between 15% - 25%. In a specimen from the felsite sheet north of Dunmore Hill the An content of the core is 55% and the mantle being generally 30%, The potash felspar occurs as an accessory. Biotite is reddish brown and is spotted with pleochroic haloes. Small crystals of apatite, epidote and iron ores are common.

5. Late Quartz Veins: included under I.

6. The green lamprophyres are the last hypabyssal types met in these lamprophyre suites. In contrast to the dykes and sheets of the previous groups, they are very characteristic in their nature, colour, form and mineral composition. In the field they are distinguished by their pale green to green colour, marked flow structure, and penetrating and transgressive forms. Mineralogically, they are composed mostly of hornblende and chlorite with minor plagioclase, along with iron oxide, pyrite cubes and biotite as accessories. Xenoliths of the sedimentary rock

and early basic types are common and are seen at several places. The contacts are irregular and very often thin stringers penetrating the country rocks. At their contacts in the country schists, there appears to be a development of rocks composed of quartz, plagioclase and long prismatic crystals of hornblende. Sometimes irregular pockets of similar material are found within the lamprophyre dykes themselves. The contacts with a metadolerite are not easily discernible as simple re-crystallisation of amphibole has taken place.

The best examples of these rock types are :-

(1) A 4 - 5 ft. thick green dyke cutting through the banded limestone near the western end of Portnoo pier.

(2) Several irregular transgressive sheets at the head of Dunmore Hole.

(3) A 20 - 30ft. thick dyke or sheet, frayed, deflected and intermixed with the country rocks, on the low stony beach S. of Aghros peninsula.

(4) A one to three ft. thick transgressive dyke and sheet about three furlongs west of Scoltia, on the north coast of Dawros peninsula(Plate 7B).

(5) A 2½ft. thick dyke immediately north of Dawros Point. Examples other than these are also common. They are generally xenolithic in nature and one such xenolithic dyke is dealt with in the section dealing with 'explosion breccias'. It should be again remarked here that where-ever the rocks of these characters are present pyrite in good enhedral cubes (up to 1cm.sq.) is developed both in the country rocks at their contact and in the hybrid types produced doe to their intermixture.

(7) The latest porphyritic dykes are represented by the four NNE-SSW dykes almost at regular intervals and thus dividing the Dawros peninsula (where they are confined in the present area). The easternmost also seems to cut through the Aghros peninsula, when it is lost against a fault (running E - W at Mullanard). These intrusives are more or less regular steeply dipping dykes with minor branchings and bifurcations. Except for local variations, all the four are almost of uniform thickness and have the same direction - a structural control of these is therefore evident. It appears that they have been intruded along the cross joints to which they are parallel and which had already developed in the country rocks.

The rock, making these dykes, is composed of a light-coloured, fine to medium grained biotite porphyrite and is in sharp contact with the country schists. In a thin section, this rock is fine-grained, equigranular, allotriomorphic to porphyritic in texture. The minerals present in the groundmass include dominant plagioclase, minor potash felspar (orthoclase) and quartz, in which are abundant and well developed, but slightly rounded porphyroblastic phenocrysts of an unzoned plagioclase (acid andesine) and an altered femic mineral. Other minerals of the fine matrix are biotite, epidote, very minor chlorite and iron ore, epidote and saussurite. It is interesting to record that around the biotite phenocrysts the other small phenocrysts of felspar show a sort of flow structure. The groundmass varies from felsitic to microgranophyric or even apologranitic.

The contact reaction with the country schists is almost nil. Only within two or three millimeters, the rounded chlorite and New Chlorite of the schists are destroyed; the former is much broken and partly digested in the acidic intrusive material. At the contacts much iron oxide and chlorite is formed.

6. Remarks.

Of the grey lamprophyres and felsites (groups 2a and b), more than three-fourth of the specimens in the collection are of spessertites (basic) and granodiorites or porphyrites (acidic), while others include minette, kersantite, and a few hornblende-rich types like vogesite, camptonite and still others can be called as soda minette or even markfieldite. All these different varieties of intermediate igneous rocks are characterised by a typical granophyric texture set in a fine matrix of plagioclase, quartz, ferromagnesian constituents, iron ores, apatite and secondary calcite. Almost all are rich in phenocrysts or porphyritic crystals of plagioclase, hornblende or biotite.

These intermediate igneous bodies of this part of Co.Donegal, except for their trend are comparable to the dyke swarms of Southern Uplands, where they form a well-marked petrographic province, (Bailey and others 1916; Blyth 1940; Eyles and others 1929; Flett 1900 and 1935; MacGregor 1930, 1936 and 1948; and Richey 1939). Some of the acidic types are ~~very~~ identical with the detailed descriptions of Blyth, while the basic varieties are similar to those of others. In Co.Donegal itself identical rock types have been described by McCall (1951) and Cheesman (1951).

As regards the age relationship of these bodies the rocks from Scotland are dated as Lower Old Red Sandstone or Upper Silurian. Considering the similarity in their petrographical and mineralogical characters, the lamprophyres and felsites of group 2 can also be assigned O.R.S. age. All other types are seen to cut these earliest intrusives and hence must be later in origin.

X. Explosion Breccias.

A. Introduction.

Like the dykes and sheets described in the previous section, the bodies dealt with here are very varied in their form and mineral composition. They are characterised by rock-types produced by processes of contamination by many different kinds of xenoliths. These interesting complexes are readily distinguished in the field by their differential weathering, generally resulting in small elongated mounds or hillocks surrounded by swamps or bogs. In the present area, these breccias make bodies small or large in size, irregular or regular, circular or elliptical in shape; in addition laccolithic, boss like, sills or dyke forms have been discovered. In almost all cases, the bodies considered here are rich in xenoliths or mobilised country rocks.

The xenoliths present include those of unaltered blocks of limestone or altered calc-silicate rocks, angular, fragmentary or partly digested metadolerite, rectangular pieces or irregular blocks of pelitic and semipelitic schists, lamprophyres, and angular or rounded pieces of quartzites. The smaller xenoliths, though of irregular shape and size are generally subrounded

or grooved, and covered with a thin film of brownish colour. The size of the xenoliths is very variable. They may be as small as peas or make huge blocks up to 20 - 30ft. in length and 8 - 10ft. in width. Generally the larger xenoliths are those of the local country rocks, but the smaller ones include pieces of foreign rock material, not encountered in the rock series of the area under investigation.

The nature and amount of matrix are also very variable. It may be of dirty pink felsitic or granophyric or varigated or greyish lamprophyric or purely granitic material. In short, xenolithic complexes of very diverse nature, form and mineral composition are present as minor bodies throughout the area occupied by the country metasediments and metadolerites.

The occurrence of what appears to be a similar xenolithic lamprophyre dyke is mentioned by H.B. Muff (1908, p.119) in the quartzite of Glen Creran, Argyllshire. He writes that it is so rich in fragments of quartzite that it resembles a breccia. In County Donegal itself and close to the occurrences of the present area, related xenolithic bodies have recently been described from the Gweebarra area by Gindy (1951 A & B).

Firstly at Tallabrista (north coast of Gweebarra bay), a sill consists of xenoliths of quartzite and a light green amphibole-rich rock embedded in a fine grained felspathic matrix. In another case at Cor (1951,B) on the north side of the Gweebarra estuary, diopside, garnet - epidote-rich skarns occur associated with hornblendic rock formed probably as the result of the diffusion of trondhjemitic material at the contact of limestone and epidiorite. Very recently Pitcher and Read (1952) have described an intrusion breccia at Kilkenny near Maas. Here the breccia is made up of quartzite or calc-silicate fragments cemented by a granophyric or appinitic matrix.

B. Occurrence and Distribution.

As has been described in earlier pages, the country rocks are a series of Dalradian limestones, schists and intercalated sills of metadolerite. Their thickness is about 13000ft. in the present area. The xenolithic rocks under discussion are found to occur at all horizons, but are best developed in the lower banded limestone and almost all the levels of the Rosbeg pelitic or semipelitic schists. At least eight such brecciated or xenolithic zones have been mapped. There does not

appear to be any discoverable relation in their distribution. It may be suggested at this stage that there might be a connection between the formation of these breccias and the intrusion of a certain group of felsites or of the Ardara granitic pluton itself.

It has already been mentioned in the previous section of this thesis that some of the lamprophyres and a group of felsites are likewise rich in xenoliths. For the purpose of description a few such xenolithic hypabyssal bodies have also been included in this group of intrusives. In fact, with more detailed work, it might be possible to prove that these xenolithic or agmatitic dykes or sheets are connected with the early phases of the granite emplacement or with some stage of the intrusion of the lamprophyres.

Without going into the details of this complicated problem, the author has included in this section bodies of apparently related characters. The chief of these are:-

1. The great xenolithic felsite dyke north of Dunmore Hill.
2. The green xenolithic lamprophyre sill near Rosbeg pier.
3. (a) Xenolithic Laccolith at the Road side north of Lefrin Hill.
   (b) Xenolithic Laccolith in Aghros Hill (W.of Mullanard).
4. Explosion Breccia of Doon Lough (North & South portions).

5. Explosion Breccia of Con Lough - Narin Hill.
6. Hybrid granodiorite of Cashel Hill - Swan Mt.
7. Dirty Rock - Sand Hole Complex.
8. Hybrid rocks of Narin Church area.

At all the above mentioned occurrences, a first glance at the rock - exposures gives an impression of highly fractured zones in which the broken fragments of the local country rocks are cemented by intrusive material. But on closer examination it is found that in almost all cases the xenoliths are not made up only of the local country rocks. For example, in a few cases angular fragments of quartzite (totally absent in the present area) form an ingredient of the breccias. Because of this varied nature of these bodies, it is considered best to give a separate account of each occurrence.

Descriptions.

1. The great Xenolithic felsite sill on the coast north of Dunmore Hill.

(a) Field characters:- At the edge of the limestone cliffs standing high on the southern shores of Gweebarra Bay, immediately north of Dunmore Hill, there occurs a thick massive felsite sill. It is about 350ft. long and

runs approximately in an E - W direction. The eastern portion is at sea level while at the western end the sill rises in the cliffs. The dip varies between 35 - 45 degrees to the south. Near its eastern termination, the sill is dislocated by two parallel faults running in a 345 degrees direction, with an interval of about 80ft. between them. The smaller eastern block has been shifted to the south and the western major sill has moved to the north. As the cliffs are vertical for more than half the distance along the sill, the exact nature of this large block could not be ascertained, but it appears that the eastern low level of the major portion is also due to a fault or other dislocation. In one of the two visible fault planes there is intruded a quartz vein of about 2 - 5 ft. in thickness. Small irregular and angular blocks of felsite material are embedded in this vein, (Fig. 13).

On both sides of this quartz vein the country rocks - banded limestones - are exposed. On the eastern flank of this vein and below the upthrown felsite block, the limestone makes a low and comparatively wide platform. Its strike is between 195 - 210 degrees and the dip varies from 10 - 20 degrees to the N.N.W; while on the western side of the quartz vein lie broken and unoriented fragments

of the same type of banded limestone. The actual outcrop of banded limestone (in-situ) seems to be present at the foot or even at a lower level than the massive felsite sill, (See enlarged map, fig.No.13.). At its western terminal end, the massive sill overlies the banded limestone, which itself overlies a pelitic schist band. The strike of the country rocks at this end is between 295 - 310 degrees and the dip varies between 25 - 45 degrees to the south. The beds are overfolded and the axis of the fold seems to plunge into the Atlantic ocean.

The felsite sill consists of two main portions, one a pinkish grey massive portion of 16 - 25 ft. in thickness, and another major and more interesting portion filled with broken and angular blocks of limestone. Actually the cliffs forming this portion of the coastline are made up of similar irregular fragments of the xenolithic material (country rocks) or the main felsitic body.

In between these brecciated and fragmentary rocks (Plate 8B) at first sight no cementing material is visible, but on a closer examination, small irregular pockets or dikelets (in 260 - 290 degrees strike) of felsitic material are

present (a few such bodies are shown in fig No. 13.). Sometimes out of these pockets thin irregular and branching dykes and veins of felsite are observed to be following or cross-cutting the bedding or foliation planes of the country rocks on the limestone platform near the western end of the felsite sill.

The explosion breccia occurs on both the upper and under sides of the massive sill. At the lower side, its thickness never exceeds more than 3 - 5 ft. and it seems to be made up of smaller blocks. In the upper cliffs above the massive intrusive rock, the brecciated zone is up to 50ft. thick. The individual blocks or fragments in the brecciated portion of this body exhibit all the characters of puckering, drag-folding, banding, foliations, lineations, etc., similar to those shown by the main limestone at Portnoo or any other locality. The length of these blocks is very variable and xenoliths more than 20ft. in length are common. A few up to 30ft. by 4ft. were measured very close to the quartz vein. Smaller fragments are generally more numerous and lie in a haphazard manner, but the strike of the larger ones is almost parallel to the length of the sill. From this fact it may be

suggested that they have been oriented by some kind of flow. Sometimes the smaller pieces show a coarse texture and it appears that this feature is due to the recrystallisation of the limestone. In places, the edges of the fragments, particularly those rich in graphitic bands, are bleached and altered. Usually, the smaller blocks or fragments are stained and give a dirty brownish grey colour and soil the hands with clayey matter. They are so friable and soft due to weathering that there does not seem to be any cementing material in between these pieces. To obtain a specimen of such brownish grey with or without the matrix is a difficult operation.

The massive portion of the sill is regular in form and has a uniform thickness. The rock, both at the edges and in the interior of the body, is similar, but very often the edges gradually merge into the brecciated portion of the sill. It is rarely that the sharp edge appears to be chilled. Nearly in the middle portion of the sill, where it is in contact with a band of pelitic schist, the margins either diffuse against country rocks or are sharp and exhibit a chilled effect. In between the schists and the massive sill the width of the lower brecciated zone is thinned to about 2ft. Here in this region the

massive rock is partly porphyritic, with elongated phenocrysts of felspar arranged parallel to the strike of the sill.

(b) Petrography:- Under the microscope the massive portion of the sill is fine to medium grained equigranular and idiomorphic to hypidiomorphic in texture. It is almost a monomineralic rock and is composed of enhedral crystals of plagioclase, a little quartz and iron oxides. The plagioclase is sieved, zoned and exhibits a good crystalline form. The core is very calcic with 50 - 55% anorthite content, while the mantle has only 20 - 25% anorthite. On the average, the felspar can be said to be an andesine - labradorite. The crystals are partly scricitised and sometimes lath shaped flakes of white mica can be made out, together with a little biotite. Quartz is very subordinate and occurs in irregular grains. Biotite in the matrix of the rock is rarely present; when it occurs, two or three flakes lie in close proximity and their parallelism gives an idea of flow. The mica alters to chlorite and iron ores, Iron oxide, including ilmenite and magnetite, with a little secondary calcite are accessory components.

The massive portion of a limestone block does not

show any marked change. A few laths of fibrous wollastonite, diopside, zoisite and clinozoisite are present in a mosaic of calcite in a marginal zone only a few millimeters in thickness.

From the above description of both the brecciated and massive portions of this particular sill it is clear that both these portions are two different types of the same intrusion. The occurrence of the xenolithic portions suggests that the intrusion of the proper sill was preceded by an 'explosive' action due to which the country rocks were fragmented and brecciated.

2. The Green Xenolithic sill near Rosbeg pier:

(a) Field Characters:- In the small peninsula and small islands close to the N - S road near Rosbeg harbour, the country rocks are the metasediments of pelitic and calc-pelitic composition. These rocks are typical of the area and run in a general N.W. - S.E. strike.

On the pier side, about 50 yds. W. of the road and about 100 yds. west of the newly constructed house near Rosbeg Cottage, two small islands are almost wholly formed of a markedly grooved, notched pebbles. The pebbles are mostly of a whitish quartzite, pelitic schists and green calc-silicate-rock. The detailed mapping of these islands

and the subordinate peninsulas of the region has shown that the brecciated rock is definitely in-situ. In both of the two islands, the breccia body is lenticular in form and in each case more than 30ft. by 10ft. in width. In each of the islands and in the peninsula the strike is at 210 degrees and it is possible that the same body occurs south of Rosbeg Cottage.

Like the breccia of the Dunmore coast, here also this xenolithic rock consists of a minor 'brecciated' part of angular quartzite fragments embedded in a light green hornblendic matrix with other fragments of calc-silicate and schistose rocks, (Plate 9 A).

The quartzite pieces are about 2 - 6 inches in length, the average length being 3½ inches. The individual fragments show a flaggy or slab like form with clear bedding. There is no definite orientation in the blocks, but their longer axes are moderately parallel to the strike of the dyke. The edges of the fragments are sharp and only rarely is any reaction seen; such as occurs is not uniform at all margins (see plate No. 9 B..).

The xenoliths next in abundance are of the pelitic schists. These xenoliths have absolutely sharp margins, and, except for the presence of pyrite crystals, do not show any obvious reaction. They are angular to subangular or

sharp edged lenticle like in shape. Their size varies from a fraction of an inch to more than a foot. Though the smaller fragments are arranged in subparallel fashion, the longer ones are not so aligned. From the nature of the smaller xenoliths an idea of flow is obtained. The margins of the intrusive are foliated and this foliation is parallel to the foliation of the country rock. In the same way around the schist xenoliths some linear bands of dark green colour are sometimes seen which may give an eye-shaped structure. These bands and the foliations may be due to flow.

The remaining few xenoliths are green in colour, well rounded, and coated with a thin film of dark green coloured ferromagnesian material.

(b) Petrography of the Breccia.

The quartzite xenoliths are almost entirely made up of quartz grains generally equigranular, but often elongated and serrated at their margins. The subordinate minerals include a sericitised plagioclase felspar, pale-green chlorite formed due to the partly altered biotite and iron ores. Of the latter cubes (up to one cm) of pyrite are very common and alter to haematite and limonite. The banded nature of the quartzite is due to a band of graded bedding, of which the pure band is wholly composed

of lenticular quartz grains and the impure bands are rich in felspathic and micaceous material. The small cubes of pyrite are arranged parallel to the bands.

The dark coloured partial rim that gives rise to the notches around the quartzite piece is made of a prismatic hornblende, chlorite and a little biotite and sphene with very subordinate plagioclase of oligoclase composition (Ab.22). Dusty iron oxides complete the full composition of the reaction rim.

Xenoliths of pelitic schists or similar rocks at the contact are partly digested or injected and have a gneissose texture. Such rocks are pale green to brownish in colour; on broken fresh surfaces it is buff coloured, and prismatic crystals of chlorite, flakes of biotite with rounded chlorite can easily be distinguished.

Under the microscope, this injected rock is seen to be made up of plagioclase, quartz, biotite, chlorite and hornblende. The texture is gneissic, in which the biotite and plagioclase produce the foliation. The felspar is an oligoclase - andesine type (An 75%) and is turbid and partly sericitised. Quartz occurs in between the folia and is subordinate to the felspar.

Biotite is of two types; the dominant form is a brown variety altering to chlorite; the less abundant type is pale brownish in colour and occurs in subparallel laths, a habit comparable with that of the lath shaped chlorite which it seems is analogous to the 'New Chlorite' - Unfortunately the crinkles with which the 'New Chlorite' is usually associated are not present in this case. It may be possible that the sudden intrusion of this brecciated rock may have destroyed such structures. As only a few slices of these xenoliths or of the contact rock are available, it is possible that in the larger blocks of the schist the crinkles may be present. Hornblende is subordinate and occurs in slender prismatic crystals. Cubes of pyrite are very common and are uniformly distributed in the rock. Iron oxides, apatite, epidote and sphene are also present.

The calc-silicate xenoliths occur in groups of a few or of many pieces in the breccia. They are made up of acicular radiating or platy crystals of light green hornblende embedded in a matrix of subordinate plagioclase and quartz. The amphibole forms enhedral plates, which are better developed when they are in association with plagioclase. A few of the plates

and prismatic crystals show zoning. The darker or lighter colour may be in the core or one edge of the needle. Along the cleavages the amphibole alters to chlorite which is associated with a highly refrangent colourless mineral that may be diopside. Accessory minerals are pyrite, iron oxide and sphene.

The matrix around the quartzitic or schistose xenoliths is fine to medium grained and patches of light or dark greenish material are present in the uniformly dirty green mass. It has a granophyric to porphyritic texture. The chief minerals are intergrown acid plagioclase and quartz and biotite. Embedded in this mass are sometimes euhedral to subhedral crystals of oligoclase. Sometimes in the fine grained portion some larger grains of quartz are present. These are probably the small recrystallised pieces of quartzite. Biotite is yellowish to greenish brown in colour. It occurs in minute laths and often forms irregular aggregates, which probably produce the patches seen in the hand specimens.

In this connection it will not be out of place to mention here that very close to this occurrence and about 100 yds. south of Rosbeg P.O., on both sides of the road, similar calc-silicate xenoliths with very minor xenoliths of a banded quartzite are found in the

dark green epidiorites. These occurrences are considered in the section dealing with the Appinites.

As already mentioned, the major part of the brecciated rock is made up of the fine matrix and the quartzitic blocks. In the area dealt with here, there are no quartzites present amongst the exposed country rocks. The occurrence of calc-silicate parent rocks may be doubtful, but these might possibly have been derived from the calc-pelitic schists occurring in the Rosbeg group.

Regarding the source of the quartzite blocks the nearest quartzite occurrences are at Cor on the north coast of Gweebarra Bay. The depth at which this Cor quartzite may be expected in the writer's sector would be of the order of 25,000ft. - the present level of this exposed breccia is very near the top of the Rosbeg Semi-pelitic series. On this fact alone, it seems fairly certain that these quartzite blocks have been blown up to the present level with some violence; and hence their complex is included in the Explosion Breccias.

3.(1) Xenolithic Laccolith at the Road side near Lefrin Hill:

(a) Occurrence:- Almost a mile from Portnoo P.O. at

the road bend of the Portnoo-Rosbeg road north of Lefrin Hill there is a small E - W hillock of about 120 yds. in length and 30 yds. in width. Actually, the bend in the road is due to a transverse cut across the hillock. At the northern and on a small scale on the southern edges of the E - W section of the road there are seen rocks related to explosion breccias. The elongated hill is surrounded by a low marshy depression and at no place are the rocks of the hill seen in contact with the country-rocks. On the south-eastern side of the road bend, there is a small E - W hillock of the country-schists likewise surrounded by swamp or alluvium.

(b) Field Characters:- On the weathered surface, the rock of the hillock is dirty brownish green to buff in colour. The surface is very irregular and the whole hill is found to be made up of large or small rounded, pitted, striated, grooved and irregularly sub-rounded or oval shaped xenoliths in a scanty matrix - this is the explosion breccia. The size of these xenoliths is very variable. They range from minute subangular fragments (Plate to a few almost 1½ft. in diameter. On the average the size is generally 1½inch to 3 inches in cross-section. At a glance and without breaking the rock, the exposure

looks like a heap of road-metal left unused for some time. A broken fresh surface shows that the xenoliths are very varied in nature. They are embedded in a light greenish grey medium to coarse grained matrix which is also made up of two portions - are with coarse euhedral crystals of hornblende surrounded by a white quartz-felspathic material and the other of a fine to medium grained material of a light dirty green colour, also made up of hornblende crystals and rich in pyrite. All these characters are perfectly visible both in the field and in a hand - specimen.

The types of xenoliths are very varied. They include both pieces of the adjacent country rocks mostly metadolerites with metasediments and also of quartzite, calc-silicate-rocks and a pale brown very friable limestone that are not represented in the immediate area. The abundance and relative frequency of these xenoliths can be illustrated by the number of xenoliths counted in two small blocks built into the road wall. In one case in a block of about 2ft. x 1ft. at least 88 xenoliths of 2" - 3" in diam. could readily be made out. Of these, 20 are of a medium - coarse grained dark green metadolerite. Generally these are subrounded to subangular. The outer surfaces are notched and pitted, but the core of a broken

surface is fresh, fine-grained and massive. Their size is comparatively small being between 1" - 2" in diameter. Around these is a mantle of dark blackish green colour about ½ a cm. in thickness. These are followed by those of quartzite - 12 in number - generally subangular to subrectangular in shape. The size varies up to one and a half inch in diameter. These are also surrounded by a thin mantle of dirty bluish green colour. Other two xenoliths are definitely calc-silicate-rocks, being 3" in diam. and 2 inches x 1 inch in size. Both of these are rounded or oval in shape. The body of the xenoliths is injected by felspathic material. Towards the contact with the matrix of the block the subrounded corners of the fragment are spongy. There are another two xenoliths of a dirty greenish grey colour. They are also rounded and spongy but the core is massive and does not seem to be affected by the matrix. The mantle is almost circular and more than a cm. in thickness. Probably these are also of calc-silicate-rock. Only one definite xenolith of a schist could be made out. It is subangular in shape. The edges are comparatively sharper than the others and the margin is surrounded by a narrow shell of light green colour. It is also injected with dirty pale white material in which small hornblende crystals seem to be present.

The rest of the 51 xenoliths are smaller and irregular in size. They are generally dirty green in colour and they seem to be mixing readily with the matrix of the breccia. The matrix is almost 50% of (felspathic) white material and the rest 50% of a light green colour. A few xenoliths are cut by half an inch thick white granitic vein. Similar material is commonly seen around the metadolerite xenoliths.

In the other smaller block, the xenoliths of similar rocks are as follows:-

Metadolerite - 25 and up to 1½inch in diameter,

Quartzite - 6 none more than 1" in cross-section,

Pale brown L.St. - 3, ¾ inch diameter is the maximum,

Schist - 1, 3" x 1" very similar to the first described.

(ii) Xenolithic Laccolith in Aghros Hill:-

There are two small occurrences of the same type as the one described above. The larger of these forms a ridge immediately west of the western most abandoned quarry at Mullanard; and the other is in a small exposure about 50 yds. north of the top of Aghros Hill. The shape of both these bodies is irregular and they protrude out of the marsh like small intrusive bodies of lenticular shape.

Petrography:-

With a view of a better study of these xenolithic rocks, a 3" x 3" thin section was prepared so as to include the matrix and the different types of xenoliths in their natural positions. The specimen 4/49 comes from the road side, (Plate 10 B).

In thin section, the matrix is of acidic composition and includes quartz, orthoclase, myrmekite, plagioclase, biotite, hornblende, chlorite, pyrite, magnetite and calcite. It has a granophyric texture.

The felspar is enhedral and platy, and shows a sieved texture; it is oligoclase - andesine in composition. The edges are sharp and clear and have a mantle possibly of potash felspar. The inclusions are of sericite, muscovite and a pale biotite altering to chlorite. At places the felspar is replaced by orthoclase, which is comparatively fresh. The Myrmekite is more abundant in some portions of the slice and the plagioclase is then very subordinate. Lobes of myrmekite are seen penetrating the plagioclase, quartz and some of the biotite flakes.

The amphibole is very variable in character. It shows the closest possible relation with brown biotite. Generally, the hexagonal crystals are colour-zoned and the dark or light colour may be present both in the core

or at the edges. In the fine-grained portion of the matrix, needle-shaped crystals of green hornblende are more common. When in association with the felspars or the quartz, they alter to a brown variety. Sphene, scarce epidote, ilmenite and pyrite are the common accessories.

The xenoliths of all the types seem to be partly or wholly recrystallised and show a crystalloblastic texture.

The metadolerite xenoliths under the microscope show all the stages of alteration shown by the metadolerite sills of the area. The amphibole is colour-zoned, the crystals are large and prismatic. In most cases, the plates are surrounded by andesine plagioclase. The central core portion of the actinolitic hornblende is generally light brown and the rim is light to bluish green. Along its cleavages there is a slight alteration to chlorite. Sometimes secondary calcite is also present in the cleavages. The larger plates are generally free from inclusions but others with inclusions of sphene or iron ores are also common.

The limestone or calc-silicate xenoliths are very similar to those described from the Rosbeg area, the only difference being that here the alteration is incomplete; in

the central portion calcite is almost undisturbed. Towards the outer rims of the inclusions the carbonate is being replaced by felspar, biotite and actinolite hornblende. This amphibole is lighter in colour, smaller and more slender than that of the metadolerites. Associated with the calcite and the orthoclase felspar are irregular plates of scapolite which are characterised by their brilliant polarisation colours. Other patches of slender actinolitic hornblende distributed in the matrix of the breccia presumably originated from smaller fragments of the limestone.

Another xenolith of a buff colour is wholly made up of small grains of interlocking quartz, plagioclase and orthoclase felspars. Evenly distributed in this matrix are flakes of biotite, muscovite and amphibole. From the nature of these minerals it appears that the xenolith is derived from a semipelitic rock, in which recrystallisation has taken place; though the xenolith appears to make a sharp junction with the matrix of the rock, under high power the biotite and the brown hornblende both of the matrix and the xenolith seem to be merging into each other. Around a portion of this xenolith margin, there is a dirty green mantle of 3 mm. in width; the remaining portion of

of the envelope is made by a calcite-film. This calcite is secondary and another fine vein of similar carbonate also cuts through the greenish rim. The rim is richer in mafic minerals, but where the calcite ~~m~~ is present, the dark minerals are less abundant. It is therefore thought to be possible that calcite of the vein is secondary.

4. Explosion Breccia of North and South Doon Lough regions.

(a) Occurrence:- On the north and south sides of Doon Lough the area is swampy and peaty. From this low ground, several small hills protrude in a haphazard manner. The shore line of the lough is itself very crenulated and innumerable small islands studded in the lake look like large boats. The lake is said to be shallow. This topography suggests that the area may be one of explosion-breccia developed on a wide scale.

(b) Field characters and Petrography:- Immediately at the back of the solitary house north of Doon Lough and about 75 yards south of the E-W road is a low hill. The west and SW. sides of the hill are made of the country rocks but the eastern half exposures are mobilised and agmatitic blocks cemented in a granitic matrix are present. The area covered by this mobilised zone is about 75 yards by 30 yards. The

The size of the individual blocks is very variable. Most of them are nearly rectangular and a square yard in area. But blocks of far greater length and width are also common. The biggest single block observed measures 15 ft. by 9½ ft. It is composed of banded, drag folded and lineated brownish or chocolate brown hornfels. Associated with it are several other smaller ones. No preferred orientation of blocks is visible. Towards the eastern marginal slopes of this hill the banded hornfelses are hard and massive. At places they are injected and possess a gneissose structure. Other common xenoliths are of dark green metadolerites. Only one small greyish brown xenolith of lamprophyre could be discovered.

In thin section the metasediment is a garnet-sillimanite biotite-hornfels similar to those described later from Ardara Pluton aureole. The northern exposures of the metasediments are of andalusite-muscovite-biotite schist. On the western shores and in the various islands irregular pockets, upto 3 inches wide, of coarse granitic rocks rich in prismatic crystals of hornblende, microcline and biotite are very common. The country rocks at the SW coast and by the side of these granite bodies are fine grained, compact, massive hornfelses of sillimanite-garnet-staurolite-biotite grade.

Coming to the southern swamps upto Terrylagh the hillocks are few and are composed of very fine grained mobilised ~~(Plate~~ metasediments (Pl.9B). The xenoliths are small, angular and elongated. At no place is any xenolith found to be larger then 10 yards by 3 yards, and such big blocks are few; they do not show any reaction with the matrix. In some examples, similar rock fragments are rounded and show a gneissic character.

The matrix is dirty brownish grey to buff in colour. It is granitic in composition and consists of angular microscopic comminuted material of sedimentray or igneous origin. Even in hand specimen dark brown lath shaped flakes or books of biotite are clearly visible. The green or brown hornblende occurs as broken fragments. In short the texture of the rock is tuffaceous.

A xenolith of andalusite-biotite-muscovite schist is unaffected except that its colour is changed to dull whitish grey. The original lineations present in the schist are preserved. The only differences observed between this fragment and the country schist include the destruction of "New chlorite" and the partial alteration of rounded chlorite (after garnet) to biotite.

Finally, this example of explosion-breccia illustrates once more the great variety of processes and products concerned in this phenomena.

About 150 - 200 yards north-east of Doon Lough north of the solitary house there extends a broad plain. Close to the N - S. hill range made up of hornfels (around the Ardara Pluton) and on both the sides of the E - W. road are several irregular low hills which are scattered in this plain and run almost to the southern foot of Marin Hill. These hillocks are mainly composed of disturbed metadolerites and schists at the base of which occur irregular pockets of granitic material, the whole providing a vast explosion-breccia. Sometimes thin veins or stringers of the latter are seen penetrating through the blocks of country-rock and the granitic pockets, books of dark mica (upto 1½ cm. in width) and sometimes dark green hexagonal crystals of amphibole can easily be made out. The hybrid rocks are dirty green hornblendites; the amphibole is either elongated or occurs in stout idiomorphic crystals. The euhedral crystals are enclosed in a granitic groundmass, in which the large plates of green amphibole often exhibit growth-zoning. The central portion is dark green while the marginal zones are invariably lighter coloured. Sphene and iron ores are common accessory minerals. Biotite is also in two forms, one green type growing freely along the cleavages of the amphibole while the other occurs in dark-brown flakes surrounded by orthoclase and quartz. Around each of these large flakes are small

fibres of actinolite, which seem to have been completely altered to the biotite. Associated with biotite or amphibole are irregular grains of pyroxene. Sometimes the actinolite grows in continuation with the larger hornblende prisms. Orthoclase is fresh and is always associated with a little quartz. Microcline is a rare accessory (8/59). Sericitised and saussäritised andesine is the common plagioclase, very often surrounded by orthoclase, indicating that the potash rich solutions were later in action. Sphene, epidote, ilmenite with pyrite altering to haematite are also common.

From the nature of these occurrences, these phenomena are similar to those of the mobilised and brecciated rocks expose on the north side of Doon Lough or near Terrylagh. Whether these are part of the same brecciated zone or a separate occurrence is difficult to say. If they are part of the same Doon Lough occurrences, the whole area south of Narin Hill upto Terrylagh can be regarded as a separate aureole, in which solutions or emanations rich in potash and alumina have played the most important part. The irregular hillocks of mobilised rocks are then to be considered as the mobilised zone of a partly weathered top of another pluton. However, the lack of better exposures precludes the expression of a definite

opinion on this aspect.

5. Explosion Breccia of Lough Con - Narin Hill:- Immediately west of Narin Hill top is a 200-250 yards wide tableland. It narrows towards the west and extends upto Lough Con. It is surrounded on all sides by the country rocks. In its widest portion is an irregular swamp studded with small low hillocks composed of mobilised and recrystallised country rock. The size of the hillocks varies widely extending from a few feet upto 50 yards. A narrow irregular E - W gully about 150 yards long and not more than 15 yards in width connects this swamp with another small subcircular swampy area on the west side. This again narrows and continues westwards through low alluvial land to Still and Con loughs. These two lakes are separated by a thin and low ridge not more than 30 ft. in width.

The hornfelsed country rocks occur around the swamps and the gully. The hornfelsing action extends laterally upto a maximum distance of 30-40 ft. obscuring the structural features such as drag folds etc. of the country rocks. These rocks consist of greenish-brown to bronze coloured sillimanite, cordierite, andalusite assemblages. Within short distances they grade into andalusite schists and dark green massive to foliated metadolerites. The foliation due to the streaks or 'augens' of felspathic material in

the basic rocks, runs approximately NNE - SSW. In both the metasediments and the basic sills another weak lineation in a E - W direction is also present. A 3 - 5 Ft. thick white to stained granite dyke occurs towards the NE corner of the eastern larger swamp. It is exposed in an angular manner for about 35 ft. where it is again lost in the peat.

Petrography:-

In the hills and mounds of the swamps and the ridges on both sides of the gully the country rocks are mobilised, partly digested and injected with pale buff coloured or whitish granitic material. The xenoliths are very heterogeneous not only in colour and form but also in their size and mineral composition, indicating that the action of the solutions was limited and the smaller fragments due to their size were completely transformed under the new conditions. The permeation of the silica and potash-rich solutions is more predominant along the bedding planes or the pre-existing foliations, which has given a gneissose structure to the metasediments. Whitish or dirty grey blebs of quartzo-felspathic material ranging upto 1 cm. in diameter occur in abundance both in the rocks of the mounds or the country-rock walls.

Under the microscope these rocks exhibit a tendency towards granophyric texture (e.g. 8/143). Rounded or oval

plates of potash felspar with enclosed plagioclase, biotite or quartz are seen distorting the very thin foliation of biotite, the rock is almost wholly composed of orthoclase and dark brown biotite; quartz and iron ores occur in accessory amounts. The potash felspar is usually fresh on the outer margins while it is cloudy where it replaces the plagioclase. Preferential replacement along the cleavages of the plagioclase is common. Frequent chloritisation of biotite due to secondary solutions is seen along the cleavages, the pleochroic haloes being, however, retained by the pseudomorph. Iron ores, irregular plates of sphene with apatite and a little epidote are the common accessories.

In another section (8/139) from the same type of another hillock, the rounded potash felspar is surrounded by cloudy to fine grained pockets of ilmenite and magnetite and inclusions of thin primary flakes are present. These flakes are generally associated with small grains of quartz. Another section (8/146 from the large rounded hillock near the western margin of the swamp near Narin Hill) shows an example of migmatisation, in which most of the felspars and quartz are not well developed. The larger plates of felspar enclose fragments of biotite-rich country-rock which are partly granitised and sometimes also show rims of brown -green amphiboles formed due to the metasomatic processes. Sphene and iron ores usually occur in association.

One more specimen (8/84) taken from another mound from the same swamp is made up of angular to subangular spindle shaped or rounded pieces of metadolerite and shapeless fragments of dark-brown to dark coppery grey metasediments cemented in brownish to buff coloured granitic material. In all respects the rock appears to be a medium to coarse grained agglomerate in which a recrystallisation of certain constituents has taken place. This is best marked by brown, hexagonal plates and books of biotite, which sometimes grow even upto 0.5 mm in diameter. Under the microscope, fine grained brown hornblende and potash felspar form rims around the metadoleritic xenoliths - although slightly away from the contact, euhedral crystals of zoned hornblende are abundant. Smaller fractured grains of amphibole are usually crystallised to a brown variety. In other parts of the slice, brecciation and granulation of quartzo-felspathic minerals accompanied by the recrystallised sediments is the rule. Where the country-rock is pelitic or semipelitic the development of garnet and sillimanite is common. The texture is very variable. For all practical purposes the rock can be considered to be a typical tuffaceous rock produced in a shatter zone. The fragments of country rock have been broken up and by the explosive action of the intrusive granitic material, in which they have partly recrystallised and cemented. The matrix of the

rock can be best described in the words of Kennedy and Read (1936, pp 132-3) when they write, "It consists of a mixture of igneous and sedimentary material so intimate that it is often impossible to tell whether it represents a contaminated igneous mass or a highly altered sediment".

Two small exposures of an appinitic rock are seen in the centre of the larger eastern swamp and in the western sloping plain near Lough Con. As at other places, the contacts of these rocks with the country-rock are obscured by swamps and alluvium. The rock is injected by medium to coarse grained stringers of whitish or stained pegmatitic material. In the hand specimen (8/102) collected from the exposure near Lough Con, the rock is made up of well developed crystals of polygonal or acicular dark green to black hornblende upto one and a half cm. in cross section. This rock is very similar to that seen in the appinites from the large sheet between Kiltooris and Terrylagh (described later). In places the rock contains inclusions of white quartz upto 5 inches across. These, when in contact with hornblende are stained and the amphibole is actinolitic in composition. In another portion the amphibole-rich rock is medium to coarse-grained and exhibits all gradations in grain-size. Under the microscope the larger or medium sized crystals of zoned hornblende are always surrounded by a granophyric

quartz-felspar rich material. In its appearance and composition the rock is analogous to the markfieldite-pegmatite described by Reynolds (1938, p.59). The minerals present include stout prisms of brown-green hornblende associated with actinolite and tremolite. Soda-potash felspars and quartz occur roughly in equal amounts. The plagioclases are sericitised while the orthoclase is fresh. Irregular broken plates or grains of diopside are usually associated either with chlorite or the amphibole. The common accessory minerals are pyrite, ilmenite, sphene, apatite and epidote. At the quartz and amphibole contact, orthoclase crystals are sometimes better developed, and the felspar may be present even as rims or circular patches replacing the quartz. This structure may perhaps have resulted from the operation of metasomatic solutions.

Small exposures of a coarse white to whitish grey syenite outcrop towards the southern slopes of the tableland; light or dark grey to brown patches similar to those in 8/152 and 8/74 or 8/84 are common. Hexagonal books of biotite upto 1 cm. in diameter and slender prismatic crystals of dark green amphibole are invariably present. Other minerals include brown sphene, iron ores, epidote and small amounts of apatite. The rock can be called a biotite-syenite. As in the previously described rock, in this syenite also occurs

an irregular colourless to pale yellowish mineral, which is probably diopsidic pyroxene.

Remarks:-

From the above descriptions of these peculiar and variable occurrences from the Narin and Doon regions it is clear that the minerals formed are of diverse nature but seem to have been largely recrystallised in a potash-rich solution due to which a mobilisation of the country rocks has taken place. The unusually large flakes of biotite or amphibole are clear evidence of a recrystallisation from the already broken fragments of the country rocks. Further, the fragmentary nature of the xenoliths indicates that the country rocks were broken up and later recemented by a felspathic matrix. The rounded felspars with inclusions of quartz, micas and plagioclase, suggest the formation of replacement rims due to the introduction of alkali and alumina-rich solutions into an originally pelitic or semipelitic rock. The biotite syenite present at the southern slopes of the swamp may either be (a) a totally replaced xenolith of metadole -ite or (b) some metasediment engulfed in a granitic magma.

6. Hybrid Granodiorite of Swan Mt. and Cashel Hill:-

The country rocks, andalusite-biotite-muscovite schists and the dark foliated metadolerites west of Lough Con, are the continuations of the Narin Hill formations. These schists

are traversed by small dykes or pockets of a pale white granite, exposed near the summit of Cashel Hill, in the low hills between the E - W road and the Cashel Hill to the south and continue upto Swan Mt. NW of Portnoo Hotel. Both in the granite body and in the veins fragments of country rock are not uncommon. The larger blocks are compact, hornfelsed and darkened in colour, while in the veins they are represented by irregular patches of green or dark-brown biotite. Near the granite contacts a hybrid rock similar to the coarse pink granodiorite of the Sheshkinmore region (described later) is formed.

Petrography:-

The country metasediments immediately at the contact are marked by whitish ovoid spots made up of cordierite and oval orthoclase felspar embedded in a biotite-rich matrix.

The dark coloured metadolerite is rich in porphyroblasts of biotite and actinolitic hornblende. Some of the mica is an alteration product of the amphibole, which is rather coarse-grained and occurs in large idiomorphic slender crystals sometimes surrounded by the felspar. The hybrid rock is hypidiomorphic in texture and is chiefly composed of orthoclase, microcline, quartz and subordinate andesine. A dark brown biotite and brown-green actinolitic hornblende with sphene are the main mafic constituents. Well developed

crystals of apatite are generally associated with epidote and occur as accessories. Opaque minerals include ilmenite, pyrite, magnetite and haematite. The mutual relations of the chief constituents are very similar to those of the rocks described from the Narin Hill area. The development of large crystals of mica or amphibole, the occurrence of both potash and sodic felspars and the biotitisation of amphibole bear testimony to the alkali metasomatism of the country rocks.

7. Dirty Rock -- Sand Hole Complex:-

The association of different rock types on the coast and in the fields immediately west of Portnoo harbour upto Sand Hole or even beyond -- i.e. NE of Dunmore Hill, is very complicated (see enlarged map No. 10....). The country rocks include the banded limestone and the associated meta-dolerite sheets. They strike roughly E - W and have a low dip to the south. The rocks are intensely folded, the axial planes of the folds being occupied by a fine-grained granite. These country rocks are traversed by several cross-cutting thin to thick veins or sheets of lamprophyre and felsite. All these rocks are affected by several minor faults.

In addition, these rocks of this part of the coast display other varied but characteristic phenomena. Among these is the occurrence of huge xenoliths of banded limestone

in dykes, veins and irregular bodies of white granite which cut across the limestone and metadolerites at Dirty Rock and north of the harbour. These dykes or bodies vary in thickness from about 4 ft. to 20 ft. Immediately at the back of the pier on the stony beach a 4 ft. to 8 ft. thick granite dyke makes a wall, against which the sea waves strike at low tide. The wavy or crenulated dyke runs approximately WNW - ESE and is seen for about 50 yards beyond which it probably continues towards Dirty Rock. Within 30 ft. of its central portion it makes a structural 'W' or 'M' like form. The limestone which forms the country rock here is recrystallised (as seen on the southern side of the dyke). A 30-50 yards long narrow peninsula, between Dirty Rock and the stony beach with the above mentioned dyke, is completely composed of a white granite and its associate hybrid rocks. This granite and the mixed rocks making the peninsula can be seen to continue in the cliffs on the main coast. The main features of geological interest of this granite or granodiorite and the country rocks are shown in the diagram (~~Fig. Pl..5..~~) and enlarged map(Fig.10..) In the granite complex of the peninsula and the cliffs, angular to subangular or rounded xenoliths of metadolerite of variable size occur in abundance(Plate). A few irregular or somewhat rounded xenoliths of granite are also present (~~Fig.....~~) near about the middle of the peninsula. Various stages of granitisation

of these xenoliths of metadolerite can be observed. Associated with these are a few small and angular xenoliths of banded limestone. Slightly towards Dirty Rock, three xenoliths of banded limestone (upto 30 ft. long) of semicircular shape are present. Granitic material seems to have penetrated along the fissures or bedding planes of the limestone blocks and in one exposure in the cliffs its emplacement appears to have produced an anticlinal structure. At other places the junction is sharp and except for the darkening or recrystallisation of the limestone no change is apparent. The granite at the contact is dirty greenish white in which brown sphene and some pink garnet can be made out. In a thin section the contact rock is rich in calcite, garnet, diopside, wollastonite with minor tremolite in addition to the usual minerals, potash felspar (mostly microcline), quartz, apatite, epidote, sphene, pyrite and galena.

Between Burnfoot and Sand Hole similar large xenoliths of limestone are common. About 100 yards east of Burnfoot and almost half way between Burnfoot and Sand Hole, pink garnet-diopside-rich skarns are developed along the granite contact. The size of the garnets may go even upto one and a half inch in diameter. East of Burnfoot in a narrow ridge immediately at sea level is a brownish grey coloured amphibolite rich in stout black hornblende crystals upto ½ cm in length.

It makes a sharp contact with a white band of limestone. By the side or almost in contact of this ridge is a 4-6 ft. thick granite dyke. In a thin section the granite does not show any unusual constituents. It is a pure microcline-plagioclase biotite-muscovite rock with some iron ores as access-ories.

Near Sand Hole and NE of Dunmore Hill in the granite rounded or elliptical 'Geode' like bodies are very common. These nodules when broken show a cavity, lined with pink crystals of garnet followed by light green layers of wollastonite diopside and fibrous tremolite. Towards the outer mantle is a layer rich in diopside and prismatic light green hornblende. At other places in the same area slender prisms of light green actinolitic hornblende are grown in a criss-cross fashion. The size of these crystals is largest (even upto 2") when they are in association with the pink granitic pockets. Away from such pockets or stringers the size of these crystals becomes smaller. Under the microscope these crystals seem to be embedded in a granitic matrix of microcline, myrmekite and a little of oligoclase, quartz, and biotite. The accessories include sphene, apatite iron ores and epidote.

A similar coarse-grained rock with criss-cross hornblende prisms occurs immediately at Portnoo harbour.

8. Hybrid Rocks of Marin Church area:-

Rocks similar to those described from the Dirty Rock - Sand Hole coast line, are present (not so well-exposed) on the north side of the road near Marin Church. These are best exposed in a small quarry on the road side about 150 yards west of the Church. The rounded xenoliths of metadolerite are embedded in a pale yellow granitic matrix. The two acid and basic rocks usually show a good admixture and the metadolerite is completely granitised. Small outcrops of coarse appinitic hornblendite are seen near the western road bend (east of Church). Both in its appearance and mineral composition this hornblendite is similar to that described from the Lough Con - Marin Hill area.

9. Conclusion:-

From the foregoing account it will be seen that the phenomenon described are very varied but appear to be united by the general character of a "brecciation" of one type or another. It is possible that there have been grouped together in this Chapter of the Thesis, complexes that might prove on further investigation in Donegal to be more widely separable. The writer has considered together three main classes of these "brecciated" rocks, first lamprophyric and minor granophyric intrusions, second, developments of fractured and mobilised country-rocks -- the explosion-breccias proper -- and , lastly,

granite-country rock complexes. These have been treated together because in all cases they show a fracturing and brecciation of country-rock and the cementation of this fragmented material in "igneous" matrixes of various kinds, depending often on the lithological nature of the xenolithic material.

The occurrence of xenoliths of both local and far-travelled rocks in many examples is a character that links these bodies with the intrusion-breccia phenomena described by Pitcher and Read from Maas and by Gindy from Letter-mackaward. It is clear that there exists in Northwest Donegal a large suite of xenolithic complexes . The present writer suggests that the emplacement of these complexes spans the time between the intrusion of the early lamprophyres and felsites and that of the Ardara Pluton. The place of formation of the breccias differs in the different examples; sometimes the breccia is in its place of production, sometimes it has moved as a portion of an intrusive "magma". In some cases, it is clear that the granophyric or hornblendic nature of the matrix is the result of comminution and alkaline soaking of xenoliths of special types, siliceous or calc-silicate,as Pitcher and Read have proposed for the Maas example. It may be suggested that non-xenolithic intrusives of similar type may have been produced at lower levels by

similar processes. It may thus be possible that as detailed research into these very complex bodies progresses, some light may be thrown on the origin of the felsite-lamprophyre group of rocks in general. The foregoing account is provided to facilitate these future researches which, as has already been indicated, may disentangle the separate types of phenomena here grouped together in this reconnaisance study.

XI. APPINITES.

1. Introduction.

The rocks dealt with in this group are very varied in their nature of occurrence, physical and mineralogical characters. Usually they are very coarse grained hornblende rich rocks (Plate 11..) but types somewhat felsitic in composition and coarse to medium in grain size are also common. Some of the varieties if not all are comparable to the famous 'Hybrids of Ach'uaine Type' of central and South Sutherland (Read 1925, pp.45-51; 1926, pp.154-166; 1931, pp.165-173) or 'Hornblendic complex' of Bettyhill area - north Sutherland (Cheng 1941, pp.67-85). Mineralogically and petrographically, their characters are also very similar to the appinites of the S.W. Highlands (Bailey and others, 1916. pp.167-169; MacGregor & Kennedy, 1931 pt.II. pp.106-107; Holgate 1951 pp.433-460). In Co.Donegal itself these rocks can be compared with the coarse amphibolic rocks of Cor (Cole, 1905, pp.117-123; Gindy 1951,A, pp.55-59 and B.pp.103-112). Further, while dealing with the "Lamprophyric intrusives" and the "Explosion Breccias" in the present work references to appinitic rock types have been made at several places. From the nature of the different rock types, their totally or partially altered xenoliths and almost identical mineral compositions of these rocks from

different localities, the writer is inclined to believe that these appinitic coarse grained rocks have been produced by the admixture of original country rocks and inclusions brought from below in an acidic magma. But, in view of the incomplete data with regard to their field relations with the country rocks, the question of their origin must be left open until more detailed investigations are possible.

2. Nature of Occurrence, Distribution, Field & Mineralogical Characters:- These complex types of appinitic rocks are found distributed in all the horizons of the district. They appear to be connected with some of the lamprophyric or explosive activity, so nicely portrayed in the area. The nature of these occurrences is very variable, from dyke like bodies to small laccolithic bosses or sheet like forms to small patches found throughout the area. Roughly they can be divided into two main types:- (i) those occurring as small patches or large sheets roughly parallel to the strike of the country rocks and (ii) those occurring as cross-cutting irregular dyke-like bosses lying across the strike.

(i) Patchy & Sheet like occurrences.

(a) The patchy occurrences lie scattered all along the north coast of the area and are found at some of the localities where 'explosion breccias' are well developed.

The most important outcrops of these patches are those near the Narin Church exposed on the road side cliffs and sloping land (near the sharp rd.bend), coastal cliffs near Fairy Coves (immediately north of Church), immediately south of Portnoo harbour and on the raised beach between Burnfoot and Sand Hole. As would appear from the descriptions of the different explosion breccias, these minor patches may be connected with the formation of those bodies. Other similar occurrences are also present in the Narin-Cashel region and the N.Doon Lough areas. In the rocks from these bodies ~~up to 1" long~~ acicular prismatic and stout crystals of brown-green hornblende up to 1" long are embedded in a ground mass of medium to coarse texture. Generally the patches are not to be connected with any of the major country rock types, but near Sand Hole and the Narin Church banded limestone and massive metadolerites form the country rocks, the xenoliths of which are very common in granitic bodies and show almost the same mineral composition.

(b) Kiltooris Mass:- Of the large sheets, the best developed occurrence is in the region between Kiltooris Hall (large house on the Eastern coast of Kiltooris lough) and Terrylagh. This is the largest mass of the type and occurs almost parallel to the regional strike of the country rocks.

In the area between the eastern part of a range made up of Lefrin and Meendooish Hills on the north and the lowland with sand-dunes and the hilly region north-west of Sheshkinmore & Doo Loughs in the south, is a good arable table-land studded with small hillocks. In all these hillocks dark coarse grained hornblende-rock is exposed. The southern slopes of the range referred to above are made up of the Kiltooris Metadolerite sheet and towards the eastern portions the semipelitic country schists lie exposed up to Terrylagh. Immediately at the foot of the range the appinitic sheet is separated from the middle eastern shore of Kiltooris Lough to almost west of Terrylagh. Similarly near the southern edges of the tableland the coarse hornblendic rocks also appear to have been affected by another minor E-W fault and are separated from the metasediments. Thus at no place is the appinitic sheet seen in contact with the country rocks.

The best exposures of this sheet are on both sides of the N-S road near Kiltoorisia Hall. Here the very coarse rock is made up of large stout prismatic crystals of hornblende embedded in a scanty to negligible matrix of whitish grey to greenish grey colour. At places irregular pockets of pinkish-white granitic rock are present from which up to 2" thick stringers or veins of granite are thrown into the basic rock.

These veins are never seen traversing the amphibolic rock for distances longer than 2 - 10ft. and they run in irregular directions, but most of them in an E-W direction. Sometimes crystals of hornblende similar to those of the hornblende rock are also found in these veins but are rare. At no place is a xenolith of any type visible. Occasionally thin parallel lines (in E-W) of a dirty green colour are also visible running for a few feet, and it is only rarely that the hornblende crystals appear to grow across these.

North and N.E. of the Kiltorisia Hall (in the farm) and near the southern crags of the tableland along the N-S road, the size of the amphibole crystals is much larger being almost $\frac{1}{2}$ to $\frac{3}{4}$ inch in cross-section. In these patches the felspathic matrix or spots are seldom visible. In fact the rock appears to be monomineralic.

(c) Lough Doo Mass.

Another group of small outcrops of a similar coarse hornblendite occurs about two furlongs east of the eastern-most exposure of the above sheet (near the dilapidated houses in the fields south of the E-W road) and probably continues in an Easterly or south-eastern direction, for another group of small exposures crop out immediately east of Lough Doo (N.W. of Sheshkinmore Lough). These irregular outcrops are in belts each about 100 yds.long and some

20 - 30 yds. wide. As in the above described sheet, here also the rock is made up of stout prisms of amphibole and is traversed by thin stringers not more than half an inch thick arising out of pockets of granitic material. Unlike the rocks of longer outcrops near Kiltoorisia Hall, along the edges of the pockets or by the side of the veins larger crystals of hornblende and flakes of biotite are formed. The transition from one type to the other may be gradational or sharp. Though never in contact, the country schists and hornfels and the hybrid rocks of the granitic pluton are exposed nearby. Of the other country rocks in the vicinity, a thin band of crystalline limestone is exposed very nicely in a small quarry on the north side of the road (north of Cromer Houses) and in a partially exposed NNE-SSW ridge west of Lough Doo.

(d) Summy Dyke.

Of more interest, is another dyke-like out-crop E.N.E. of Summy Lough, of a coarse hornblendite about 50-75 yds. in length and nearly 35-40ft. in width partially exposed in the foliated tonalites. This coarse rock is blackish green to dark green in colour and is highly susceptible to weathering and gives a honey-combed surface. The stout hornblende crystals are up to one inch in cross-section and the rock is similar to those described from the

above two localities except that the granitic cementing material is almost wanting. There is only a small irregular patch of this material from which a few thin stringers run into the hornblende rock. The surrounding tonalites, which form the country rocks of the locality, are also rich in similar xenoliths and segregations of biotite and hornblende. Near the southern tip and immediately east of Summy Lough small lumps of a dark coarse amphibolite probably metadolerite modified by the granitic veins are exposed. Associated with the rock is a narrow outcrop of a flesh coloured coarse garnet rock at the western slopes of the lough. This is almost a monomineralic rock but in thin section it is seen to contain brown stained grains of diopside, clinozoisite, zoisite, flakes of mica, quartz, calcite and apatite included in a matrix of grossular. Probably this is the garnet skarn produced by the contact effects of the granitic intrusion and now is a part of the aureole (see also pp .360.-361. in section XII of this thesis).

(e) Petrography:- The Appinitic coarse hornblendic-rocks from the above occurrences are alike in their texture and mineral composition. The rock from Summy area appears to be little changed by its enclosure in the Foliated Tonalite.

The latter does, however, show minor changes viz. small grains of diopsidic pyroxene are enclosed in a rather basic felspar (calcic andesine) which occurs with the normal oligoclase and microcline. The plates of hornblende, present in the tonalite also enclose and are changing to biotite. The country tonalite is speckled with patches of brown-green biotite and amphibole and is rich in sphene, epidote, apatite and iron oxide. All these mineral constituents lie in a coarse matrix of quartz and porphyritic microcline - microperthite. The latter generally moulding the grains of earlier formed minerals such as quartz and plagioclase. Away from the contact the clots and patches of hornblende decrease till the rock is a normal Foliated Tonalite. Similarly, the amphibole is in good idiomorphic crystals near the contact, but becomes allotriomorphic within 50 yds. of this. This hornblende is light green and gives a pleochroic formula as L - pale yellow, B - bluish green and V - bright green to greenish brown, $Z \wedge c$ - 19 to 23 degrees.

The granitic rock occurring as veins in the appinite is very similar to the tonalite. The hornblende crystals are colour zoned with generally two and sometimes three colours. Usually the cores are brown to brownish green and the marginal zones are deeper green. The pleochroism

of the core is L - pale brown, B - greenish brown and V - dark greenish brown with ZAC - 23 degrees. The darker zone has x - greenish yellow, y - olive green and z - bluish green with a maximum extinction of 25 degrees. As in the oridary tonalite, sometimes fine grains of pyroxene are present in both the plagioclase and the hornblende. Biotite is associated with the amphibole and is enclosed in large plates of microcline, microperthite and quartz. Accessories are the usual sphene, apatite, epidote, allanite and iron ores.

The coarse grained <u>appinitic hornblende-rock</u> is made up of stumpy prismatic crystals of dark green hornblende up to ¾" in length set in a rather scanty light green to pinkish felspathic material. The pink felspathic material also forms a fine network of thin stringers often surrounding the hornblende crystals. In a slice the prisms of hornblende show a composite nature and are embedded in a scanty granophyric matrix of light green colour composed of amphibole, diopside and plagioclase. The larger stout prisms of hornblende are zoned and sieved with irregular light green granular diopside which is concentrated in the core of the prisms. Thin fine prismatic flakes of dull brownish green biotite are grown along the two sets of cleavages of the larger prisms.

In the zoned crystals of hornblende all stages between

dark green to brownish green hornblende and actinolitic hornblende and even tremolite can be made out. It is interesting to note that in these irregularly zoned prisms fibrous actinolite sometimes forms the core whilst brownish green amphibole forms the outer margins. In other cases hornblende and diopside form the core and actinolite or tremolite occurs at the margins. A typical hornblende has γ - green, β - brownish green and α - water green. The extinction angle of the light brownish variety varies between 3 - 5 degrees while the other type give ZAC - 15 - 23 degrees. From this type of zonal arrangement it is not clear whether these changes are progressive due to the introduction of alumina, alkalies and iron or whether they are the retrogressive changes caused by the removal of these constituents.

The flaky <u>biotite</u> along the two sets of cleavages is dull brown green, and sometimes the biotite of one crystal is seen to be growing into another. In this way the biotite of one set appears to be making a sort of foliation, and sometimes two such foliations seem to converge in the same hornblende crystal. A similar flaky biotite also occurs bisecting the re-entrant angle of the cleavages. Whether all the three or any one or more of these biotite sets is original or due to later hydrothermal replacement of the amphibole or pyroxene is not clear from the larger crystals,

however, it appears that those along the cleavages must be due to later replacement. Again, the diopside (with ZAC = 35 - 41 degrees) and its nature of occurrence is also peculiar. In twelve out of 20 cases it appears to be a replacement of hornblende while in the other eight the reverse is the case.

The granophyric matrix of the rock consists of hornblende, biotite and diopside but the proportion of diopside is greater than in the prismatic crystals of hornblende. In the fine matrix, quartz is by far the dominant component maximum and this may be the result of the alumina from the acidic magma being used up in the formation of hornblende from diopside which seems to be altering to amphibole. The plagioclase is turbid and is an acid labradorite (Ab.55). In a section from the Summy area there is a fairly large (3 m.m.) elongated crystal of <u>calcite</u>, which may probably be secondary. The other accessories include epidote, zoisite, clinozoisite, sphene, apatite and ilmenite. These are either associated or occur as inclusions or grow interstitially in between the larger grains. Sometimes e.g. near Kiltooris in addition to the above minerals fresh microcline is also present and the larger biotite flakes or hornblende crystals are unzoned, lighter in colour and show a good amount of chloritisation. The presence of microcline

and the chloritisation of the dark minerals suggest that these rocks have also been attacked by the later potash bearing solutions.

Remarks:- The sequence of crystallisation of the different minerals is very complicated but as indicated by the intergrowth and the replacement phenomena, it appears that with the incoming of the tonalite or soda rich magma, the original limestones were attacked and skarns with diopside were formed. With the inflow of later potash rich granodioritic magma the pyroxene and the soda plagioclase were attacked by the potash rich solutions or emanations and the formation of hornblende, biotite, apatite and the minerals of epidote group took place. These reactions are better seen in the fine grained matrix of both the appinitic and tonalitic rocks.

(ii) Cross-cutting dykes or bosses.

Bodies of this type are very common in the South Kiltooris and Rosbeg areas. Though they occur in innumerable patches, all have almost the same strike and the more important ones are described below:-

(a) Appinitic bosses on east and west sides of Portnatrawbane - Rosbeg.

Immediately at the northern road side near the house on the eastern shores of Portnatrawbane is a hill slope made

up of a greenish grey coarse-grained appinitic amphibole. The mass has an irregular shape and outcrops of similar rock occur for about 3 furlongs northwards up to Kiltooris Hill. The country rocks are the Banded Semipelitic schists of the Rosbeg group which strike in WNW-ESE with a low southerly dip. The appinitic outcrops are roughly in a N-S to NE-SW strike. It should also be pointed out that the garnetiferous calc.-pelitic band exposed in the Kiltooris Hill is abruptly lost in the east or south of the hill.

South of the appinitic rock of Portnatrawbane a similar rock forms the sea cliffs at Pollachoor and lies exposed at the high coastal platform for about 100 yds. in a roughly N-S strike. It appears that this exposure of Pollachoor is a continuation of the Portnatrawbane - Kiltooris group.

In a hand specimen the appinitic amphibolite is a medium to coarse-grained rock with both acicular crystals and prismatic plates (up to 1" long) of hornblende embedded in an irregular matrix of pinkish white colour. The rock is light green to dirty brown in colour with elongated and vein like patches of felspathic material. In these felspathic portions dark green large elongated crystals of hornblende are common, while the rest of the rock (major

portion)

is comparatively smaller in grain size and made up of tremolitic amphibole. Relatively coarser veins of dark greenish black hornblende and the same minerals as in the finer variety are seen to cut across the finer-grained light coloured rock. In a thin section the light amphibolic rock is composed of fibrous tremolitic hornblende associated with subordinate acid plagioclase, quartz and very minor calcite. The accessories include sphene, pyrite and iron ore. In the felspathic patches the amphibole is colour-zoned and at junctions with the light coloured rock one variety is changed to the other. It also alters to a brownish green biotite and sometimes small flakes of biotite are found enclosed in the dark coloured hornblende. The felspathic portion of the rock, though very minor, is pinkish white in colour and is made up of sericitised oligoclase, minor potash felspar and quartz with inclusions of olive green to brown biotite and small grains of a pyroxene associated with epidote which is also distributed in irregular grains throughout the rock. The accessories include good euhedral crystals of apatite, pyrite, ilmenite, iron oxide and secondary chlorite. The amount of calcite, apatite, sphene and epidote is far greater in the small grained rock.

The country schists are exposed very close to the

appinitic rock. Up to a distance of a few feet fine streaks of amphibolite occur in the foliation planes of the rock and have given rise to a gneissose structure, in which small blebs and augen of quartz-felspar are present. This semi-pelitic gneiss is also rich in hornblende which is less than the larger flakes of olive green to brown biotite. On the weathered surface the rock is streaky compact and slightly harder than the semipelitic schists themselves.

Appinitic amphibolites similar to the one described above and with similar field relations, are found forming a wall like N-S ridge in the marshy and arable land about 250 yds. west of the western boundary of Portnatrawbane. The ridge is made up of several low elongated hillocks and a westerly sloping platform. At the eastern steep face of the platform and in mounds amphibole-rich rock crops out. The only difference between this rock and those of Portnatrawbane or Pollachoor is that the felspathic patches and the dark hornblende prisms are almost lacking. Along the same strike or slightly deviated are several other exposures in other ridges and seem to continue almost to the Rosbeg pier, where the amphibolite is lost against a calc-pelitic band and associated metadolerite near the road. It is possible, however, that the xenolithic lamprophyre described on pp.199-201 may be its northward continuation.

Another group of similar appinites with such north-south or slightly divergent trends is found in the fields and low-lands south and west of Lough Anure (a small lake about 300 yds. N.E. of Rosbeg P.O. and south of the main road). These laccolithic dykes are very irregular in shape and weather with a peculiar "scoraceous" surface. In the same strike and of the same form and type are a group of several more appinitic bosses in the eastern portion of Dawros peninsula. There the rock appears to cut through the metadolerite sheet which probably forms a low table-land, but unfortunately due to lack of good exposures the true relationship could not be established.

(b) Appinitic diorite near Rosbeg P.O. :- About 100 yds. south of Rosbeg P.O. the road is a gentle north facing slope. On the northern or N.eastern side of the road are exposed the dark, compact, massive and medium to fine grained metadolerite and by the south-western walls of the road runs a low ridge partially made up of the garnetiferous calc. pelitic band and the associated metadolerite. In a small cutting of the road and in the blocks of road used to construct the adjacent walls fresh rocks are very beautifully exposed. Almost every block used in the walls is a separate museum specimen in itself. A striking phenomenon is the occurrence of small angular to sub-angular or even

rounded xenoliths of a white quartzite (few) blocks of partly digested semipelitic and small rounded patches of bright green acicular hornblende (after calc-silicate rock). Another common characteristic is the presence of small segregations of cubic crystals of pyrite. These are all found embedded in a black to dark grey or sometimes greenish black rock. Occasionally patches of coarse pinkish white felspathic rock are also seen. Around each of the xenoliths are narrow dark coloured rims of hornblende and fine dirty green material and these are more marked in the case of partly digested enclaves. The size of these xenoliths may vary from a few millimeters to 10 centimeters. Amongst the xenoliths a single compact, massive, fine-grained and angular xenolith of metadolerite (1½ft x 1ft.x 2ft) is of great interest. It occurs in a small low mound about 50 yds. north of the slope. In general the appinitic diorite is not so rich in well-defined xenoliths.

(c) Petrography :- The appinitic rock is a dark grey to greenish-grey compact porphyritic rock with "phenocrysts" of dark hornblende up to 1 cm. in cross section scattered and segregated in the massive ground mass. Sometimes such dark crystals are also common in the subordinate patchy felspathic material but are less well developed. It has been noted that the edges of these inconspicuous felspathic portions are

a very variable in texture but generally the cores are coarse; towards the margins they are dirty greenish grey in colour and ultimately they grade into the massive compact rock. In thin section, the main rock is panidiomorphic in texture and is composed of predominant euhedral plates of amphibole, plagioclase, biotite, potash felspar, quartz, epidote, apatite, sphene and minor calcite. Iron ores are scattered throughout the rock. Occasionally the hornblende is associated with augite and is more abundant in the dark appinites. Textures of the rocks are very variable and range from that of the coarse appinitic hornblendite with columnar amphibole of Summy or Kiltooris Mass to dioritic or metadoleritic (subophitic) textures in which pyroxene and calcic plagioclase are most common. The relatively fine grained rocks are pale green in colour and are rather richer in sodic plagioclase, potash felspar and granophyric quartz, while the darker varieties are either monomineralic coarse panidiomorphic rocks or bear augite and calcic plagioclase in larger proportions. When the augite is more abundant the amphibole is lighter in colour. In all types the hornblende is colour-zoned, the dark green rims being up to 3 m.m. in width and the cores being brown. In these cores relict pyroxene may or may not be present.

The felspar-rich rock is coarse idiomorphic to granophyric in texture. The most important difference in this

variety is the absence of pyroxene and a preponderance of brown-green hornblende which is deeply colourzoned. The plagioclase is a sodic variety and occurs associated with granulated quartz and microperthite or microcline.

The mineralogical and petrographical characters of these rocks and their xenoliths are thus very similar to those of the xenolithic sill near Rosbeg pier (pp. 199-201.) and the writer believes that the appinitic rocks produced in this region are the result of the same phenomena.

3. Conclusion. In the writer's opinion much more work needs to be done on these appinitic rocks before a decision can be made on their origin. Two provisional suggestions can however be made. First, these appinites are connected in their origin with limestones, which have been transformed by granitic material and second, there may be a close genetic relationship with certain members grouped with the explosion breccias.

XII. ARDARA GRANITIC PLUTON.

1. Introduction.- The main Granitic mass within the Portnoo district is approximately circular in outcrop, with a diameter of some 5½ miles. It is composed of an outer tonalitic margin with a granodioritic core. The granite occurs within the eastern portion of the present area where it forms a wide outcrop with an arcuate contact against the schists. The main Narin - Ardara road (which is also the eastern limit of the area under discussion) crosses the granite area. A semi-circular ridge of low hills extends from Narin to the northwest of Sheskinmore Lough and marks the contact zone; They are composed of hornfelses resistant to weathering. It will be seen from the diagrammatic profile (Fig. ~~10~~ 14) that as one proceeds from Kilclooney Church in the east, the area made up of the grandioritic rocks rises slowly to the west giving place to the higher tonalitic tableland. Still further west and near Summy Lough, the Tonalites abut against a steep escarpment made up of the hornfelsed metasediments.

The structural relationship of the granites with the country-rocks is shown on the geological map (Pl. 1..). The border zones of the pluton are of foliated tonalitic

types; the amount of quartz and microcline increases towards the centre which is made up of a coarse and slightly foliated granodiorite. Foliation and planar structures parallel to the host rocks are very well developed in the Tonalites and in general all the rocks have a gneissic appearance.

The central granodiorite seems to occur as an independent "dome" in the centre of the Ardara Pluton. The contact between the two granitic rocks is rarely seen; in fact it is marked by an arcuate erosional depression (see profile referred to above), which is partly occupied by Lough Fad, Lough Martin and Mooney's Lough and the swamp with the river Birroge. As is evident from the geological map, the contacts and structures of the central and marginal portions dip inwards with a steep or vertical dip. From this interpretation of two separate parts of the granitic mass, it follows that the Ardara Pluton was not emplaced in one phase. It is also reported that in the centre of the pluton, another granite type similar to the older granite of the Gweebarra area is found to occur; contacts between these different types are clearly visible. From this evidence it seems that the intrusion of the Ardara

Pluton took place in more than one stage i.e. first a Tonalitic plase and then a later Granodioritic.

For most parts its exposed contact with the wall-rock is sharp and concordant and except for the limited areas of Sheshkinmore, Derryness and N.Renny Point the granites of the Ardara Pluton do not show any injection phenomena.

The metamorphic effects produced on the country rocks are typical of contact metamorphism. The most important of these are the recrystallisation and the production of minerals such as garnet, sillimanite, staurolite and andalusite in the pelitic and semi-pelitic hornfelses. The production of sphene diopside and epidotes in the limestone and other calcareous schists is well marked, but the effects on the metadolerites are very limited, though they include the alteration of hornblende to green biotite and a little uralitisation. A most important result of the contact metamorphism is the destruction of the 'new chlorite' porphyroblasts and the transformation of the retrograde chlorite, (formed after garnet), to biotite. This latter occurs as rounded, oval or irregular circular spots in the planes of schistosity.

The structure of the area indicates that the intrusion of the pluton must have taken place as a diapir, the different stages of the intrusion being closely connected. From evidence provided by the contact phenomena, it is suggested that the magma must here be plastic and viscous. Free movement in this magma was slight, otherwise the inclusions would have been deformed and mobilised (Cloos, 1937). Brecciated and mobilised wall rocks of the Summy and Sheshkinmore region indicate a forceful intrusion of the pluton. The invading pluton exerted a compressive force, perpendicular to the contacts, which has resulted either in brecciation of the country rocks, possibly due to drag, or in the development of the vertical lineation. Further, the curvature in the strike of the country rocks, the development of the horizontal tangential lineation (III & VERTICAL ivth. lineation pp. 80 and 81.) in the outer zone of the aureole, and the doming and buckling of the metasediments around the pluton suggest a slow and continuous swelling of the intrusive body which pushed aside the plastic country rocks. The elongated schlieren of the ferromagnesian minerals and the foliation of the tonalite may also be due to this flow of the magma.

2. General characters.- The mineral composition and texture of the granitic rocks of the Ardara pluton vary, and the rock types can be classified as : (i) the Foliated Tonalite of the marginal or border zones, (ii) the Medium Grained Granodiorite of the central parts, (iii) the Coarse Pink Granodiorite occurring irregularly between the first and second varieties and (iv) a series of Hybrid Dioritic rocks of local occurrence.

As has been pointed out earlier, the number of mineral species is small and these are common to all the rock-types. The first three types differ by variations of their modes, in grain size and in physical characters, on the basis of which these rocks have been divided. The fourth type is very much richer in hornblende and sphene, the products of the assimilation of metadolerites which have been attacked and partly incorporated in the granodioritic magma of the central type.

On weathered surfaces, the Foliated Tonalite appears as a white coarse-grained rock in which the schlieren or biotite streaks are very prominent. The central Medium Grained Granodiorite weathers to a dull pinkish grey. Its area is mostly covered with bogs, swamps and peat, but from the nature of the sporadic

exposures occurring all along the main Narin-Ardara road, it is evident that this non-foliated or partly foliated rock continues and extends towards the centre of the pluton. The Coarse Pink Granodiorite is distinctive due to the pink colour of the ground-mass contrasting with the pinkish white phenocrysts. On the weathered surfaces these phenocrysts of felspar stand out from the pink or dark spotted groundmass in which they are embedded.

These three different varieties of granodioritic rocks can easily be mapped on the basis of their colour or other properties, but contacts are hardly visible and gradation from one type to the other is common. The location and nature of these contacts could reasonably be made in the field by the marked arcuate and irregular depressions (now filled with alluvium, swamps and bogs) existing between the several types of granodiorites.

3. Distribution of Granitic rock types and their Relationship.- The disposition and distribution of the rocks of this limited portion of the granitic pluton permit of their sub-division into three sectors:- (i) the Northern area lying between Summy Lough in the west, Kilclooney church in the east and the Junction

of the Narin-Ardara and Glenties roads in the north; (ii) the Southern area between the eastern tip of Sheshkinmore Lough in the west, Kilclooney church in the north and Owenea Bridge in the south, and (iii) a smaller Middle area between the two. The first two main sectors are made up of the two chief types of granodiorites, i.e. the Foliated Tonalite and the Medium Grained Granodiorite and the third comprises the other two mixed varieties, i.e. the Coarse Pink Granodiorite and the series of Hybrid Diorite rocks.

Two-thirds of the Northern sector is made up of the foliated Tonalite and only the eastern portion of this sector is occupied by the Medium-grained Granodiorite of the central type. There is no definite boundary between the two, but it is assumed that the position of this is indicated by the difference in the level of the rock-types and the well-marked circular narrow gully extending from Lough Fad in the north to the swamp with Mooney's Lough (E. of Summy Lough). Further south, the boundary between the Foliated Tonalite and the Hybrid Diorites is marked either by sharp or gradational changes in the appearance of the Coarse Pink Granodiorite and in its porphyritic nature.

This pink variety can easily be treated as an intermediate type between the Foliated Tonalite and the basic Diorites forming the Hybrid rocks of the Middle sector.

The Southern sector is mostly made up of the medium-grained Granodiorite and only in a narrow (1 - 3 furlongs wide) belt along the lower south-western limb of the triangle are the Foliated Tonalites present.

Between the two Northern and Southern sectors, the rocks of the Hybrid series (iv. above) are best developed in Sheshkinmore - Lackaweer and Craig's Town (S.W. of Kilclooney) region forming a Middle sector. Here these mixed rocks constitute a series ranging from true amphibolites (really the metadolerites of the country rocks near Sheshkinmore Lough) to the true granodiorite of the central type. All the felspathic types of these hybrid rocks are gneissose in character. They are comparatively resistant to weathering (compared with the granodiorites) and form the low irregular hills just south of Summy Lough and the western higher fringe of Lackaweer plateau (E. of Sheshkinmore L.). Similar variable rocks also occur in the badly exposed regions of Deryness and Renny Points, and together with the

metadolerites, form the innumerable islands of the Owenea Estuary. As in the southern part of the Northern sector, the Coarse Pink Granodiorite of these areas is intimately associated with the hornblende-rich dioritic gneissose rocks. At all the localities the width over which these heterogenous and transitional rocks occur is very variable but does not exceed more than half a mile. The colour of these mixed rocks varies from dark grey to pinkish grey or pinkish white. The hornblende-rich varieties show irregular intercalations with the Tonalites of the Owenea side (in the area between the two Renny Points) and in the Northern sector the association of the two and their mutual relationship are not clear due to the lack of good exposures.

4. The Contact.-

As has already been noted the contacts of the granite against the country rocks are sharp and concordant and, except for the limited areas near the Sheshkinmore Lough, Derryness and N.Renny Point, injection is limited. This local lit-par-lit injection or migmatisation may have been influenced by the old structures of the wall rock which at places seems to have been more shattered. In this area as in the whole contact zone of the Pluton, the rock is highly foliated parallel to the contact and concordant with the schistosity. Abundant xenoliths show all degrees of reaction, many are angular with knife edge sharp contact, others are rounded with somewhat transitional margins and some show the growth of plagioclase porphyroblasts in a hornblende-rich matrix.

On the basis of structural features and the different rock types the exposed contact of the pluton can be classified as (i) Sharp smooth contacts with little injection and of a concordant or discordant nature; (ii) Contacts with brecciation and mobilisation of the country rocks; (iii) Gradational contact with a considerable assimilation of the country rocks.

These different types of contacts and their relationship are discussed below during the statements on the distribution of the different major rock groups.

(a) Contact relationship of the Northern and Southern Sectors- As stated above, the contacts of the granitic rocks with the country rocks in these two major sectors are linear, concordant and sharp. Discordant relationships of the outer part of the Pluton are very rarely seen, but this may be partly due to the lack of good exposures all along the contact. Neverthe-less, the contact maps as a linear boundary.

In front of the houses, about 200 yards north of Summy Lough, mobilised and partly injected metasediments are exposed in a hillock (150 yds. x 100 yds.). The meta-sediments and the meta-dolerites in contact with the Tonalite are similar in appearance and mineralogy to those in the hornfels exposed nearby. The amphiboles of the metadolerites are crushed and occur with still more granulated pyroxene, epidote and sphene. On the other hand, the metasediments exhibit all the mineralogical and textural characters of

of contact metamorphic rocks.

This discordant contact of the pluton at Summy Lough is actually the best representative of the 2nd. Contact type in which brecciation and mobilisation of the country rock has taken place. Amongst the xenoliths of the country rocks, the smaller ones are in line with the general contact, only the larger masses occurring in a discordant fashion, and mostly trending in NE - SW or E - W directions. The best example of such larger masses is the coarse hornblendic dyke-like rock of possible limestone parentage, which may have been connected with the limestone exposed in a quarry about ½ a mile S. or S.S.W. of Summy Lough. At the immediate contact or in the neighbourhood of the granite, this limestone is altered to a flesh coloured coarse garnet rock in which only a few grains of quartz and felspar can be made out (3/63). This garnet rock is exposed in a small outcrop of a thin band at the W. shores of Summy Lough. The structural relationship of this band is quite in conformity with the other country rocks.

The discordant relations of the larger brecciated fragments and agmatitic bodies observed only in this locality, suggest that this brecciation of the

country rock is due to some early movement, though this may have been a manifestation of the intrusive phenomena. It has already been suggested in chapter VI that this curvature in the strike of the hornfels may be due to such movements accompanying the intrusion of the pluton. Further it will be seen later that hornblendic xenoliths derived from metadolerites and calc-silicate rocks are prominent in the granites of the pluton well away from this Summy Lough area.

(b) Contact relation of the Middle Sector:- The type of gradational contact mentioned above (pp.141..) is best developed in the eastern region of the Sheshkinmore Lough and extends in a north-east direction from the centre of the east shore of the Sheshkinmore Lough up to Craig's Town (about ½ mile S.W. of the Kilclooney Church). In this region the dark grey gneissic rock of the Medium Grained Granodiorite and the pink granites of the Coarse Pink Granodiorite form two distinct rock types which are associated with the coarse dark green amphibolite. In fact over a width of between ¾ and one mile a series of all types of rocks varying from coarse amphibolite to the pink granite

are seen. In the gneissose transitional types foliation is well-marked, while in the Coarse Pink Granodioritic rocks this foliation is usually absent. The contact between the different types is seldom visible and often shows an irregular margin with the isolated patches of dark grey gneiss which are common in the pinkish Medium Grained Granodiorites or the Foliated Granitic types. Examples are best seen at localities about 3 furlongs E. of Summy Lough near the bridge and in the western part of Derryness island.

Considering the simple nature of the major portion of the contact, it is difficult to integrate this irregular and gradational phenomena as part of the same pluton. This probably results from the fact that the pluton was intruded in more than one phase.

Contacts of the various granitic rocks and the marginal amphibolites of the Mid.Sector are gradational and show evidences of recrystallisation and felspathisation. The Foliated Tonalites or Granodiorites are modified by an increase in hornblende or biotite and accessory minerals, while the amphibolite is enriched in felspar. Agmatites are rare and generally there is a transition of hornblendic streaks

set in a granodioritic matrix. Near the ridge, east of Summy Lough, felspathised metadolerite masses grade rapidly into normal amphibolite; this gradation is often sharp enough to be seen in a thin slice (11/7). Gradational contacts such as this might be construed as proving migmatisation of the metadolerites implying that the Coarse Pink Granodiorite and Hybrid Diorite Series are the result. On the basis of the field evidence and the petrological characters, an hypothesis of limited reaction and assimilation in an acidic magma is preferred. A closer examination of the whole contact (western part) of the pluton with its sharp contact and linear trend shows that this area of gradation is only a local phenomenon and that the majority of the evidence is clearly in favour of the intrusive character of the pluton.

5. Foliation:- In the border Tonalites the abundant dark ferromagnesian minerals have a distinct orientation producing a foliation parallel to the country-rocks and contact with the granite. In the Northern sector near the main Portnoo - Glenties road, this foliation is NNE-SSW, near Summy and Sheshkinmore regions it is approximately north - south, near N.Renny Point it is NW-SE. At the Owenea Bridge the

foliation, shown by the streaks (or schlieren) of the ferro-magnesian minerals, trends East - West. The plates of micas and the longer axes of the hornblende are poorly aligned in the foliation which forms a steep or vertical plane. When these minerals occur in clots, which generally end in streaks or schlieren, these also have the same orientation and thus form a very important and most prevalent planar structure with a dip between 75 degrees E. and vertical. Sometimes these streaks curve around the xenoliths so common in these rocks; these curved streaks suggest a type of flow structure. The foliation also produces a marked plane of fissility in the tonalitic rocks.

The central granodiorite, like the tonalites, is also foliated but the foliations are not nearly so well marked. Near Mooney's Lough and at the western fringe of the swamps, east of Summy Lough, the rock is very coarse grained with phenocrysts of pink microcline up to one cm. in cross-sections; the foliation is hardly visible but, whenever it is present, it is parallel to the main contact. Again in the Lackaweer plateau (east of Sheshkinmore L.) thin and thick irregular bands of hornblendic rock can be traced for more than ten yards, being parallel to the outer marginal foliation.

North of the Bridge (east of Summy Lough) the dark grey granite weathers to a 'morrum'* -like coarse grit made up of pink felspar. The rock is gneissose in character, and the foliation still follows the general trend of the circular contact. Similarly, in the region between Derrynes and North and South Renny Points, thin bands of alternating granodioritic rock and a more hornblendic type are seen to be parallel to the contact.

From the Kilclooney Church to the south, along the Ardara road as far as a point a little south of Beha Bridge, the granite is comparatively massive and any sign of foliations is seldom visible in it.

In summary, foliation in the Tonalite is readily recognisable inside the contact in a belt varying between 2 - 4 furlongs in width, and the planar structure appears to become weaker towards the centre of the massif. Due to lack of exposure along the mid-central ring-like depression (at the slopes of the road in front of the Parochial House at Kilclooney) it could not be directly established, whether in fact the foliation of the Tonalite does become weaker towards the centre of the pluton or

* "Morrum" is an Indian word used for a gritty soil produced due to the weathering of the gneissose rocks of Chota-Nagpur, i.e. The Bengal gneisses or as a covering soil of the laterite or bauxcite deposits. The soil is reddish in colour, gritty in nature and with very subordinate clayey material.

whether there is a more marked change in the intensity of this structure such as might be produced by a discordant inner granodiorite. From the nature of the erosional features at the probable contact, the variation in colour, grain-size, and mineral composition, it seems that the two major rock types, Tonalite and Granodiorite, are different stages in the history of the granite emplacement.

6. Xenoliths.- The nature, mineralogical composition and occurrence of the xenoliths show that they are: (i) fragments of the adjacent wall rock consisting of (a) Metasediments (b) Metadolerites and (c)? lamprophyres; (ii) inclusions such as quartzites from unknown horizons.

In the outer belt of Tonalite, xenoliths of different rocks are very abundant. Though metasediments predominate generally these are of small size; for most the average length is between 6 inches to 15 inches. There are some large slabs of Hornfels, metadolerites and quartzites at one locality. On the middle eastern shore of Sheshkinmore Lough large masses of the country-rocks lie in alignment with the smaller xenoliths of metadolerite or the platy structure of the Granodiorite.

The strike is almost N.-S. and with a steep easterly dip to vertical. Of these the biggest is a band of metadolerite exposed over an area 100 yards x 25 yards. associated with this are slabs of andalusite - garnet hornfels and of a white to pale brown quartzite. The junction is perfectly concordant and the fingers or apophyses of the granodiorite penetrate along the foliation or the bedding planes of the sediments. Vertical lineation of the ivth type is well developed.

Again, north and north-east of Summy Lough, at South Renny Point and at Derrynes, large xenoliths of the country-rocks lie in a very haphazard manner. The mobilised angular and brecciated hornfels or the metadolerite masses are cemented in a granitic matrix. The size of these xenoliths varies from large blocks to small rounded ball-like bodies.

As stated above, the smaller xenoliths are very common in the marginal tonalitic rock; these are generally aligned with the streaks of the micaceous minerals or the foliation of the granite mass. In most of the cases the xenoliths are elongated and their lengths are far greater than their breadths. Though enclaves with rounded edges are present, the most common have

thin angular forms up to 6 inches to one foot, also aligned parallel or subparallel to the general foliation of the rock (Fig.16A,B&C) and sometimes tapering into streaks of dark minerals. The xenoliths show well preserved primary features such as bedding, schistosity and lineation. The directions of bedding and the foliation of these inclusions may either be parallel to the general foliation of the granitic rocks or may lie in a discordant fashion. In others, the original structural characters are masked due to the re-crystallisation of the micaceous minerals. In a few small rounded and partly digested permeated xenoliths, phenocrysts of felspars up to 1.5 by 1 cm. are developed. At the eastern circular fringes of the tableland, east of Summy Lough at the junction of Granodiorite with the amphibolite, excellent occurrences of such felspathic porphyroblasts are well exposed. The presence of patchy elongated pools of hornblendic material is also common both in the outer marginal Tonalite and the middle Granodiorite. These are due to the complete re-crystallisation of the original minerals of the included metadolerites.

On the northern and north-eastern shores of Summy Lough and also east of the road, numerous dark

hornblende-rich xenoliths with rounded edges develop prismatic porphyroblasts of hornblende (up to one inch in cross section) and are slightly injected with pink granitic material. Here the rock weathers with a honeycomb structure; this is due to the weathering of the easily soluble and thin felspathic material in between the stout prisms of hornblende. Once the cementing material is removed the crystals of hornblende probably become loosened and separated, leaving again a fresh rock to face the action of the weathering agents. Stained, friable and broken pieces were seen in the loose thin soil of the vicinity. A coarse hornblendic rock with honeycombed outcrop 50 yards long and 30 - 40 ft. wide occurs about 20 ft. east of the road. It has a dyke-like form and is probably due to the complete metasomatism and recrystallisation of a 30 - 40ft. limestone band observed in a quarry just north of the road between Cromer House and Lough Doo (N.W. of Sheshkinmore Lough). Though this dyke-like hornblendite is exposed only for 50 to 75 yards, a deep gully of the same width and in the same strike suggests that this coarse hornblende-rich band continues below the thin alluvium. About 2 furlongs east of the above exposure, small rounded and angular xenoliths of coarse

hornblende-rich rock are found to occur in the Tonalite. Similar xenoliths of the same rock are met with in a belt about 100 yards wide and in the same strike, about 250 yards west of Kilclooney Church.

Another type of xenolith, found in outcrops on the hillock on the eastern shore of Summy Lough, is composed of a medium-grained whitish-grey granitic material, the mineralogical composition of which is very similar to the composition of the enclosing Tonalite, though the rock is finer in grain-size. These xenoliths are rounded in shape and 3 to 6 inches in diameter.

In summary, the enclaves or xenoliths can be classified as (i) Mobilised country-rocks, very near the contact, and with or without original structures;

(ii) Xenoliths with original structural characters, and lying parallel to the foliation or concordant with the planar structure;

(iii) Xenoliths with original characters but discordant with the planar structure of the host rock;

(iv) Xenoliths with recrystallised minerals;

(v) Xenoliths with porphyroblasts of felspar which ~~the latter~~ do not show any planar or linear structure;

(vi) Ghost xenoliths occurring as pools or patches of completely digested and recrystallised material, more commonly in the marginal tonalites.

With regard to the first three types of xenoliths, it may be mentioned that reaction zones are formed around some of these inclusions; the minerals of these zones are those found in the contact hornfelses viz. sillimanite, garnet, etc., If the inclusions are small, a completely homogeneous rock is formed, suggesting that an equilibrium between the xenolith and the intrusive is attained. In the case of larger xenoliths, generally with original structures, reaction is seen to be limited to the margin and from their angular to subangular nature it is evident that the intrusive magma was comparatively cool and less energetic. Like the walls of the main contact, only a limited soaking or permeation by granitic solutions has taken place.

In the last three types the recrystallisation is complete and homogeneous xenoliths are formed. This phenomenon is best exhibited by the coarse hornblendic rocks (8/12) and the porphyroblastic felspar-rich xenoliths. These recrystallised xenoliths are common in the Coarse Pink Granodiorite or at the contact of the

of the same with metadolerites. In this rock type, xenoliths other than metadolerites are fewer in number, and these are generally rounded. From these facts it is suggested that the granodioritic magma at the time of its intrusion was more energetic and at a higher temperature than the earlier tonalitic, and the enclaves remained in a liquid magma for a longer period. This magma not only permeated and soaked into the earlier rock but was also responsible for the complete recrystallisation of the enclaves, thus producing rock-types different from those occurring in tonalites of the contact zone of the pluton.

7. Schlieren.- These are long streaky belts (6 inches or even more in width) of darker bands which are sometimes wavy and produce a gneissose structure. They are characterised by aligned flakes and crystals of either biotite or hornblende or both together. The contacts of these schlieren are generally sharp but gradual contacts are also common. The schlieren are predominantly parallel to the contact, but some with random orientation are also present. This last type is locally common in the Tonalite near the contact and

in the Granodiorites of the Lackaweer plateau (east of SheshkinmoreLough).

The mineral composition and grain size are the same as those of the surrounding granite, the only difference being that the amount of dark minerals in the schlieren is increased.

In the Pink Granodiorite of the Lackaweer plateau and near Craig's Town, SW of Kilclooney Church, the schlieren are more common and are irregular in shape. They show a complete gradation into the main granitic rock and their biotite flakes are comparatively larger in size and hornblende occurs in prisms up to half cm. in length. The general alignment of these minerals is in line with the associated large xenoliths. From the nature and the quantity of dark biotite it appears that these schlieren are the relics of the meta-dolerites of the country-rocks, the inclusions of which are very common in this part of the area.

The question of the origin of the schlieren is a very difficult one, but from the nature of their occurrence, disposition and their mineral composition, it is suggested that in the main they are due to the complete digestion and recrystallisation of inclusions

of the country-rocks, usually metadolerites, which have taken the linear arrangement due to the flow of the later Granodiorite magma.

8. Mineralogy and Petrography.

(a) Introduction.- It has already been shown that the granitic rocks are very varied in their physical characters but they are all granodioritic in composition. The constituent minerals in all these different granodiorites are those normally present in such rocks. The essential minerals include quartz, oligoclase, microcline, microperthite, biotite, muscovite, hornblende and sometimes chlorite. The accessories are apatite, zircon, epidote, sphene, ilmenite, zoisite, and iron oxide. Generally orthoclase is lacking and the amount of quartz is also very subordinate in comparison to the plagioclase or microcline, either of which may predominate over the other (See Table .2.). On the basis of their mineral composition these different varieties are Tonalitic or granodioritic in nature and there are no true granites present in the whole of the "granite". The average Sp.gr. varies between 2.56 - 2.585.

The Tonalites of the border zone are definitely foliated medium to coarse grained and white to light grey rocks. Xenoliths are very common. Oligoclase is the chief constituent and forms the major portion of the rock. Potash felspars are either absent or when present are very subordinate, occurring in small granular crystals. Patches of biotite are aligned to give a gneissose appearence to the rock.

The Granodiorites of the central zone are characterised by their dirty pink colour and medium grain. The main constituents are the same as in the Tonalite but here microcline is the chief felspar. The amount of quartz is increased in comparison with that of the Tonalite, whilst the dark minerals are less conspicuous. Generally these rocks are non-foliated and do not show a well developed gneissose nature.

The Coarse pink Granodiorite is really a hybrid rock, produced by the assimilation of either or both the tonalite and the metadolerites (of the country rock) in the later granodioritic magma. It is characterised by its pink colour, the presence of porphyroblasts of felspar and almost equal amounts of both the Soda and Potash felspars with sphene, epidote and zoisite.

In short the plagioclase felspar, biotite and chlorite diminish in amount towards the later granodiorite. On the other hand microline and quartz increase in the later varieties. It is important to record that the accessories, particularly sphene, epidote and zoisite are generally very minor in both the earlier Tonalites or later granodiorites, while the total amount of these forms a high percentage in the mixed coarse pink granodiorite.

(b) Petrography of Tonalites.- The common type of the foliated tonalite is a medium to coarse grained rock with a gneissose appearance. Its colour varies from white to light grey and a mineral alignment is always apparent. Though the grain size may vary, the composition (mode) is comparatively uniform. The essential minerals are plagioclase, microcline, microperthite, biotite and quartz, with lesser amounts of muscovite, apatite, ironoxides (ilmenite and haematite) and rare tourmaline are accessory. The over-riding importance of plagioclase and biotite is well shown by the modal analysis given in the Table (2.) below. From a comparison of the different 'modes' of the different rock types, it is evident that there is a slight gradational variation in the mineral composition of the granitic rocks.

TABLE No. 2.

Specimen No.	8/19	8/23	8/31	11/15	Average
Plagioclase	41.79	49.92	41.12	43.36	44.05
Microcline	21.16	17.07	13.01	16.47	16.24
Quartz	16.9	18.13	18.16	16.56	17.43
Biotite	16.92	10.23	19.17	17.7	16.00
Muscovite	rare	0.03	rare	0.05	rare
Hornblende	0.54	rare	2.4	1.25	1.04
Epidote	1.8	3.3	2.9	1.9	2.2
Sphene	1.1	0.03	2.1	1.4	1.20
Apatite	0.72	0.35	1.4	1.12	0.9
Total	99.78	99.03	99.36	100.26	99.62

The texture of the Tonalite tends towards equigranular with the biotite flakes forming aggregates, aligned in a parallel arrangement. The subhedral to enhedral plagioclase crystals are equigranular and produce a hypidiomorphic to idiomorphic texture. Microcline or microperthite when present ~~are~~ is moulded by the plagioclase. Very subordinate granulated quartz when present occurs in the intersitial spaces.

The descriptions of the "felsic" and "~~Carpensic~~ Cafemic" minerals are given below in the order of their abundance.

Felspars - <u>Plagioclase</u> occurs as enhedral to subhedral grains, sometimes with irregular margins. The size of the crystals varies from 2 m.m. to 1 c.m. in greatest length. The crystals show an oscillatory zoning even under ordinary light; the different degrees of alteration of the various bands are well manifest. Usually the central and peripheral zones are fresh and unaffected; while a single band or several bands are rendered turbid by sericite. The degree of sericitization varies from crystal to crystal in the same slice. Sometimes, as in Sp. and slice No. 11/15 in the plagioclase carlsbad twinning is also present, which does not affect zoning; the reverse is as common.

Lamellar twinning in one half of the carlsbad twin is often well developed, while in others it is feebly shown. In a few cases pericline twinning is also present and passes through the crystal zones. In other cases the albite twin is displaced and the extinction angle is low, varying between 3 - 8 degrees. In comparatively more altered crystals the twinning is hardly visible. On the basis of such a low extinction the average composition of the plagioclase is between Ab.70 An.30 - Ab.85 An.15. though the Ab.85 An.15 variety of acid oligoclase is most common.

The small subhedral grains of plagioclase enclosed in the microcline or in association with quartz are usually unaltered and are probably more sodic in composition.

Well away from microcline but associated with the plagioclase irregular saussurite is also very common.

In almost 90 out of 100 cases the potash felspar is microcline-microperthite occurring either with or without any microcline in its association. It occurs in small grains though in some slices large plates of microcline or "quartz-like" microperthite enclose the biotite and plagioclase crystals. From the nature of the occurrence of the two it seems that the biotite and

plagioclase are the early formed minerals, which have been enclosed by later microcline. In a few cases, cross-cutting boundaries between the plagioclase and microcline suggest that the shape of the microcline is moulded by the plagioclase. Sometimes a little myrmakite is also associated with the grain margins of microcline, plagioclase and quartz.

Quartz.- In most of the slices quartz is very subordinate. When present, it occurs in ill formed patches varying from less than 1 m.m. to even 7 m.m. in length and 3 - 5 m.m. in width. The grains are irregular and show an undulose extinction or are even granulated. In larger grains some colourless inclusions probably of muscovite or even of a liquid are present.

Biotite.- Dark mica occurs in medium sized flakes, which are between 2 m.m. to 5 m.m. in size. Generally it forms patches and streaks in a sub-parallel orientation and in most of the rocks and their slices produces a gneissose pattern. The biotite is mostly brown to dark brown in colour, and has a pleochroism. x - pale yellow, y -z - greenish brown or dark brown. A few of the flakes show a bent cleavage, showing that after their crystallisation

the rock had suffered some movement. In most of the slices, the biotite flakes are associated with dusty iron oxide and a dark reddish brown non-pleochroic material which may be an alteration product of the original brown biotite. The larger flakes are sometimes altered to a dark green chlorite (penninite).

Muscovite.- White mica occurs as thin flakes along the cracks or cleavages of the plagioclase; the flakes exhibit an arrangement in two directions. Another muscovite associated with biotite is also present in irregular patches, possibly as an alteration product of biotite.

Sericite.- Fine aggregates of sericite replacing the plagioclase and actually giving a turbid appearance to the felspar are very common and mark the zoning. These fine concentrations are usually present in the middle or the inner zones of the larger crystals, although such alterations are also seen elsewhere. Sometimes the aggregates of larger sericite flakes seem to be forming the muscovite.

Saussurite.- Fine dusty segregations are associated with the plagioclase but microcline is always pelucid. These irregular patches seem to be

formed of a mixture of zoisite, fine chlorite and probably felspar.

Apatite.- Colourless subrounded and sometimes long prismatic crystals of apatite are commonly associated with the felspars and are characterised by their mode of occurrence.

Tourmaline.- Elongated brown prismatic or subtriangular crystals of Tourmaline are common, particularly in the Tonalites near their contact with the hornfels or the quartzites.

As would appear from Table II, the proportion of the dark minerals is very constant, but it varies in the different portions of the slice. In association with a biotite clot or xenolith, it is always increased, and this biotitic knot tapers into a thin streak. Of all the dark minerals, biotite is the chief member, whilst hornblende and chlorite are very rare.

Though the ferromagnesian minerals give the rock its gneissose texture the relationship between the felsic minerals can be best described an monzonitic in which the quartz and microcline are moulded by the early formed sieved plagioclase; the quartz and microcline occur interstially between the plagioclase.

Before actually passing on to the petrography of the other rock types, the nature and origin of the well developed foliation is considered.

(c) Origin of Foliation.- As has already been shown in the general characters of the granitic rocks (p.p. 254-257..) the foliations of the Tonalites are actually due to the (i) Streaky tail-like endings of the pelitic or pelitic xenoliths (2)Schlieren of basic mineral and (3) the parallel alignment of the biotite clots or flakes. All these are parallel to the general contact of the pluton and thus follow the trend of the country-rocks around the granite massif; the foliation becomes weaker towards the central portion of the pluton. It is seen to curve round the xenoliths. These platy elements have a steep or vertical dip and the schlieren may be discontinuous in depth.

In the Hybrid rocks of the Middle Sector, a foliation produced by the biotitic or hornblendic streaks is common, the aligned growth of the plagioclase porphyroblasts also suggests that their direction of growth was controlled or that they were drawn into alignment during flow. Balk discussing such instances of linear parallelism of elongated

crystals, writes "Linear parallelism of this kind is best developed in pipe-like or steep walled, stock-like igneous bodies", (1948 - p.9). Linear arrangements of a similar character have been observed by Adams (1903, pp.239 - 282), H. and E. Cloos (1927 pp.33-40, 1927 pp.93-95), E.Cloos (1932 pp.289-304), J.E.Richey (1930 p.69. Mem.Geol. Surv.Scot.).

The streaks, schlieren and the spindle shaped knots of micaceous minerals such as are present in this area are supposed to be due to the magmatic flow. Irrespective of their origin, Balk (p.12) and others including Buddington (1927 pp.224-246 & 1929 p.232) are of the opinion that these clots must have been in a plastic flow for some time and that their thin or spindle form suggests the degree and direction of their elongation. Their long axes are drawn out either at right angles to the direction of flow or parallel to the flow. In this case of the Sheshkinmore Hybrid rocks, it has already been seen that the streaks are horizontal and parallel to the longer axes of the felspar phenocrysts. We may consider that flow has occurred here, but it is further advanced that the medium was plastic and not very fluid.

This foliation could be interpreted as due, or to represent, ~~that it may be~~ a residual structure of former sediments. A full consideration of the nature of the Tonalites, with their angular and little altered xenoliths and the sharp contact relations with lit-par-lit injection of the country rocks does not in any way support a hypothesis of in-situ replacement.

(d) The Medium Grained Granodiorites of the Central Zone.- As described earlier, these form the central portion of the granite mass. They are pinkish grey to whitish grey rocks of variable character, but generally of medium grain. Unlike the Tonalites of the border zone the common rock is slightly richer in potash felspar and quartz, and poor in biotite (Table 3). Xenoliths of country rock are a constant feature of the Tonalites and are also far less in number and smaller in size. All present seem to be of metadoleritic origin and nowhere is any other kind of xenolith found.

These metadolerite xenoliths are elongated, lenticular or rounded pebble-like bodies. They lie with a dip of 65 degrees E. to vertical and trend

parallel to the faint streaky structure of the rock, which agrees with that in the outer Tonalites. Xenoliths with discordant relations to the streaks are rare. When such a case is found, their form is irregular e.g. S. of the Craig's Town or about two furlongs east of N. Deryness Point.

The contact with the Tonalite is never seen, being marked by a low depression in the topography of the area. The two rocks are distinguished by their colour, grain size, degree of foliation and presence or absence of one or more minerals such as epidote, sphene, etc., In the Summy and Deryness areas these contacts are well-marked by the presence of tongue-like apophyses, the occurrence of intercalations of Coarse Pink Granodiorite and thin veins rich in epidote. In these two areas the admixture of the two Granodioritic magmas and the country rocks is a more marked phenomenon than in the Northern sector.

Around and near this complicated contact, the streaks or smaller xenoliths are slightly deviated from the general direction, indicating a forceful intrusion of the granodioritic magma.

This view is further strengthened by the occurrence of what appears to be a zone of minute fractures now filled by ramifying veins cutting and cross-cutting the altered plagioclase, biotite flakes or hornblende crystals of the Tonalites. Examples occur at the margins of tableland east of Summy Lough and eastern portion of Derryness Island. These particular veins consist only of fine grained quartz and microcline. Other similar veins are light green in colour and are rich in green epidote. The Foliated Tonalites at these places are richer in epidote and much of this mineral could be correlated with the late intrusion of the central granodiorite.

(e) Petrography of the Medium Grained Granodiorite.-

In thin section a typical specimen is a medium grained, equigranular allotriomorphic or hypidiomorphic rock in which the minerals are evenly distributed. The important constituents are quartz, plagioclase, microcline, hornblende, biotite, secondary chlorite, and the accessories in small amounts are epidote, apatite, ilmenite, sphene and iron ore.

TABLE No.3.

Specimen No.	8/1	8/26*	10/3	10/5	15/3	16/1	Average
Plagioclase	44.52	40.98	39.82	46.33	38.29	41.58	41.92
Microcline	27.58	24.07	27.69	21.67	22.74	24.89	24.80
Quartz	23.21	22.72	24.81	20.36	32.14	26.58	24.97
Biotite	1.67	5.61	3.03	7.0	5.37	5.31	4.68
Muscovite	0.03	rare	0.58	rare	0.61	rare	0.20
Hornblende	1.43	1.52	nil	0.94	nil	rare	0.65
Chlorite	0.91	1.26	2.65	1.25	0.02	0.03	1.20
Epidote	rare	3.03	0.87	1.66	0.04	1.04	1.00
Apatite	0.03	0.04	0.38	0.73	0.02	0.3	0.19
Sphene	rare	0.53	rare	N.D.	0.18	nil	rare
Iron Ore	rare	rare	N.D.	rare	0.2	rare	rare
Total	99.38	99.86	99.83	99.94	99.79	99.73	100.49

8/1 - Massive pink Medium Grained Granodiorite (non foliated) about one furlong W. of Kilclooney Church.

8/26- Foliated Sheared Granodiorite from the quarry near Kilclooney Parochial House.
* Epidote rich (Specimen by the side of a metadolerite xenolith).

10/3- Sheared Granodiorite from the quarry South ofCraig's Town, about ½ mile S.W. of Kilclooney Church.

10/5- Foliated Granodiorite from the Lackaweer Plateau.

15/3- MassiveCoarse Granodiorite, near Beha Bridge.

16/1- Massive Non-foliated Granodiorite from the western island of Derryness.

A comparison of the model analysis (Table No. 3 ...) of the granodiorites from the various parts of the pluton shows that the mineral distribution in these rocks is moderately uniform. As will be seen by comparing with Table No.II the modes of Foliated Tonalites and the Medium Grained Granodiorites significantly differ in proportion of felsic and femic constituents.

The textures of the somewhat sheared rocks on both sides of the depression forming the apparent contact are similar to the massive varieties between the Foliated Tonalites and the central Medium Grained Granodiorite. Mineralogically, except for the fact that the quartz is more granulated, the felspars are inequigranular and turbid and the amount of chlorite is comparatively increased (Sp.10/3).

Immediately at the contacts either with Tonalites or the Coarse Pink Granodiorites, the Medium Grained Granodiorites exhibit a well developed foliated and gneissose structure in which the biotite or hornblende clots and streaks are aligned.

(f) Mineralogy.- The Plagioclase is a soda oligoclase (Ab 85-75) in composition. The crystals are generally subhedral and like those of the Foliated Tonalites. They exhibit a well-marked zoning of which the marginal zones are clear, broad and more sodic in composition than those of the Foliated Tonalites. Sometimes the cleavage and twin lamellae are very contorted. Sericitisation of the middle zone is common and cores of saussurite occur. The potash felspar is entirely Microcline or Microperthitic microcline, and one or both occur in irregular patches. They occur interstitially between the plagioclase crystals. Generally large plates of microcline enclose small zoned or scricitised irregular patches of the Soda plagioclase, biotite, chlorite or muscovite. These enclosed crystals are often rounded or embayed.

Quartz.- As would appear from the table given above the quartz is very evenly distributed throughout the granodioritic area. It always contains minute lines of very fine dusty inclusions and generally displays a strained extinction. As in the case of felspar, inclusions of plagioclase and muscovite are not uncommon.

Biotite:- is also less in amount in comparison to the Tonalites and may occur in clots. The distribution of the mineral in uniform. It is present in its maximum proportions in the foliated types close to the apparent contact with the Tonalites. The non-foliated coarse granodiorites are poor in biotite or amphibole (compare modes of 10/5 and 8/1). The mica flakes are green to bluish green in colour with x = pale yellow, y = z = deep green to greenish or brownish black. It is often associated with irregular grains of iron ore, rounded or sub-rounded apatite and alters to epidote or chlorite. In most of the cases the cleavages of biotite are bent.

Muscovite and Sericite.- Almost all the plagioclases are turbid due to the incomplete scricitisation of the mineral. This Sericite may sometimes form stouter thin irregular flakes of Muscovite along the cleavages of the felspar. In this way two sets of muscovite are clearly seen in one plagioclase plate. A small amount of muscovite, cross-cutting the biotite flakes is often present associated with iron ores.

Amphibole.- The amphibole is a green coloured hornblende with α = pale green, γ = dark green.

It always occurs in small irregular patches or tiny euhedral to subhedral crystals enclosed in microcline. ~~green.~~ The irregular patches are seen to be replaced by brownish green biotite or sometimes by chlorite. Occasionally it is associated with irregular grains of Sphene (10/11). The Amphibole is usually present in those areas where the Xenoliths of Metadolerites are common.

The Accessory Minerals are not very abundant. Of these the most important is epidote, which occurs in small irregular or subhedral colourless or pale green grains and appears to be an alteration of biotite or hornblende or even the plagioclase. The pale green variety is zoisite and occasionally encloses reddish brown orthite. Another accessory mineral is apatite occurring in enhedral or subhedral or rounded grains in association with biotite and iron ore. Dark brown pleochroic Sphene is rarely present. It occurs in association with ~~of~~ the biotite, amphibole or as inclusions with chlorite and iron ore in plagioclase. Iron ore is present throughout the plagioclase and identifiable grains of ilmenite are rare ~~to occur~~. All those present occur with chlorite, which is itself an alteration product of biotite and hornblende.

(g) A comment on the Potash Felspar and Quartz.-

As it would appear from the Petrography of the Foliated Tonalite and the Medium Grained Granodiorite, essential minerals are the same, but a difference in their relative proportion is marked. In the same way it has been observed in these rocks that whenever the Quartz is unstrained or does not give a marked undulose extinction the Microcline is fresh and good in its form and with a typical chess-board structure. It is generally always the case that with highly strained or granulated quartz the potash felspar is either perthitic or microperthitic. With only undulant quartz perthite may or may not be present, but it seems to be a rule that with granulated and crushed quartz there is a smaller amount of microcline and microperthite or perthite is best developed. To be more precise, where the granites (either of the two major types) are sheared and show signs of movement, the development of perthite is common. Similarly myrmekite is generally absent from the two major rock types, but in the rocks at or near their contacts or in the hybrid rock series, faint and minor myrmekite is seen growing or replacing at the junction of the potash felspar with the soda-rich

outer zone of the plagioclase and thus requiring an influx of the soda-rich material, suggesting an alternate introduction of potash and soda solutions.

From these two facts it seems likely that the intrusion of the granodiorite magma was accompanied by movement and this view is further supported by (i) the dusty aligned inclusions in the quartz of the granodiorite in comparison to the quartz of the Tonalites; (ii) the presence of minute quartz-felspar veins cutting through the plagioclase and merging in the microcline; (iii) light green microcline-epidote veins, cutting through the felspars and the foliations of the rocks and (iv) the inclusion of altered and sericitised plagioclase in microcline. These observations suggest (1) that the Potash felspar is late and denteric in origin, and (2) that the plagioclase crystals of the earlier Tonalites have probably acted as nuclei for the growth of the later large plagioclase crystals of any of the two rock types particularly worked in the Coarse Pink Granodiorites.

(h) Petrography of the Normal Xenoliths (Excluding the Middle Sector);-

Introduction:- The general mode of occurrence and the different types of Xenoliths have been dealt with in an earlier section (p.p.269:275) of this thesis. There they are classified into six different classes, which can be grouped into two major types (I) Xenoliths with original characters (II) Xenoliths with new structures due to complete recrystallisation. Of these two major groups, the maximum number observed in the area are those of the first group and these are generally of metadoleritic origin, which rarely recrystallised in the Foliated Tonalites. Though enclaves of pelitic, semi-pelitic and rarely calc-pelitic schist are common, their number is far less than that of the metadolerites; they generally show original characters. They are associated with a streakiness in the host rock, e.g. in the Foliated Tonalites N.E. of Summy Lough and South of the Curagh Lough as far as Owenea Bridge. As reported earlier there are only two xenoliths of quartzite, though there is another block at the western fringe of Medium Grained Granodiorite, East of

Sheshkinmore Lough; their stratigraphical horizon is unknown. The rounded xenoliths often weather out and leave oval cavities in the surface ofthe Tonalites (N.E. of Summy Lough); these easily weathered types may be of Lamprophyric origin. The unique mass of (appinitic) coarse amphibolite just N.E. of Summy Lough is probably of limestone parentage.

(1) Metadolerite Xenoliths:- These xenoliths are found to occur as small and rarely larger lenticular bodies with sharp contacts. They weather as raised elongated lumps. Nearly always they are elongated parallel to the schlieren or the streaks in the Foliated Tonalite and have a dip varying between 75 - 90 degrees. Their length and breadth are very variable. The large unoriented examples are only seen near the contacts, but the smaller xenoliths occur throughout the Tonalite. They are mineralogically similar to the metadolerites at the contact with the Foliated Tonalites. The increase in percentage of felspar and granular quartz and the rare growth of larger phenocrysts of plagioclase at the contact of the xenolith are the only marked changes observed. In comparison to the normal rock,

the enclosing Tonalite shows its darker minerals to be larger in size and brownish green in colour, the amount of biotite and hornblende is increased for a short distance from the contact.

In a typical thin section, the minerals present are green and brownish green hornblende sometimes changing to green biotite together with plagioclase (oligoclase-Andesine) and ilmenite, sphene, epidote and apatite as accessories.

In thin sections number 8/27 and 8/31 the amphibole is optically similar to that of the meta-dolerite and the tonalite. The larger irregularly bounded plates are always sieved and intimate inter-growths with greenish biotite are common. This greenish biotite is generally subordinate to hornblende and is essentially similar to that of the Tonalite. A deep brownish biotite replaces the hornblende near the contacts of the xenolith with the tonalite rock. The plagioclase forms euhedral to subhedral grains, which are always zoned, the cores being turbid. In these central zones, stout flakes of muscovite are sometimes seen developing along the two sets of cleavages of the felspar. In xenoliths from the outer

marginal zones of the Foliated Tonalite microcline is absent but towards the centre of the pluton it is present in small subhedral grains associated with biotite and somewhat granular quartz. Ilmenite occurs as small grains and sometimes forms an irregular rim around the hornblende. In some specimens it is surrounded by granular sphene which may also exist as independent patches and crystals. The irregular or rounded, pale or colourless epidote occurs generally associated with biotite and sphene, which clearly indicates that this is a late deuteric alteration product of biotite. Crystals or minute granules of apatite are present throughout the slices especially near the margins of plagioclase, showing that this mineral is an alteration product of the plagioclase along its margins due to late metasomatic effects.

From the study of these xenoliths of metadolerite, the following changes are found to be general - the alteration of amphibole to brown biotite, formation of sphene from ilmenite, association of epidote or zoisite with biotite and the presence of colourless soda-rich rims (sometimes with apatite) around the plagioclase.

These phenomena are similar to those observed at the contacts of the metadolerites with the Foliated Tonalite (p.p. 361.).

(2) Pelitic and Semi-pelitic Xenoliths are less abundant than those of metadolerites and are confined to the Foliated Tonalites of the Northern and Southern Sectors and are especially common near the contacts. Streaks or dark patches of ferromagnesian minerals are always associated with these enclaves (Fig. 16..). Their contact with the Tonalite appears to be sharp but under the microscope it is not a 'knife edge' contact as the crystals of the dark minerals and the felspars grow as continuous units from one rock to the other. This fact may partly explain their relatively smaller number; they are presumably more easily assimilated in the magma than those of metadolerites. The chief constituents are oligoclase, microcline, granular quartz, muscovite, brown and brownish green biotite. The accessories include iron oxide, apatite, epidote and zircon. In the xenoliths very close to the contact with the hornfelses, minerals such as sillimanite, garnet and even the late 'New biotite' (8/45) are developed. This late biotite is the mineral which is

after chlorite, which is itself after garnet and is referred to above in the country metasediments as "chlorite after garnet".

In a specimen of a particular xenolith (8/15) which was collected from the tableland half way between Summy Lough and Kilclooney Church, the main mass of the recrystallised xenolith consists of shreds and flakes of muscovite. The original schistosity and foliations of the schist are preserved and these planes are marked by the growth of new quartz and felspar. The size of the grains of these two minerals increases towards the edge of the xenolith. In the central portion of the schistose rock the micas are larger. Under high power, each of the muscovite flakes shows a central brownish core. In the muscovite flakes are also included fine needles of sillimanite which are probably the relicts of the sillimanite, now broken down to white mica. The biotite of the core is presumably that which originally formed the central mass of the fibrolite found occurring so commonly in the contact hornfels.

Epidote and zoisite occur in elongated but irregular patches and are associated with the large

biotite flakes of the reaction rims of the xenolith. The cleavages of some of these flakes of biotite may be bent. The larger flakes are aligned parallel to the streaks of the Tonalite, and are arranged at low angles to the foliation planes of the schists.

Near the contacts, plagioclase and quartz are granular but at the immediate contact, these fine quartz grains are welded and thus form larger grains. Away from the contact the plagioclases(Ab.75) are larger in size and exhibit a zoned structure.

The slice 8/75 is taken from a xenolith discordant to the general foliation and lying very close to the main contact of the semi-pelitics. This enclave is made up largely of equigranular irregular grains (2 - 3 m.m. in diam) of quartz and plagioclase (Ab.60-75), which are filled with dusty ore granules and enclose small flakes of muscovite and biotite. Aluminium silicate minerals are absent from this xenolith of pelitic schist. Quartz is strained and the plagioclase is fresh. Flakes of brown biotite occur in thin streaks and mark the planes of schistosity. In these biotitic streaks occur irregular rounded knots or clusters of biotite. Present in some of these knots are the pink

rhombododecahedral crystals of garnet enclosing quartz granules or biotite. This peculiar combination of biotite and garnet is probably the result of the thermal metamorphism of the retrograde chlorite which is itself after regional garnet. A similar phenomena is observed in the hornfelses immediately at or near the contact with the granite pluton (described on p.p. 338-48).

(3) Calc-pelitic Xenoliths are much rarer and are very few in number. A specimen 8/11 collected just east of Summy Lough is lenticular in shape and forms a raised surface above the enclosing Tonalite. The medium-grained rock is brownish grey in colour and consists of whitish felspar, brownish green biotite and hornblende. In slice 8/11 the xenolith is seen to consist of equigranular intergrowths of three irregular layers of plagioclase, of biotite and hornblende. These are angular or subhedral grains of a fresh plagioclase (Ab.55) associated with another sieved felspar (Ab.75-80) which exhibit the typical zonal structure like that of the Tonalites. The thin peripheral zones of this later plagioclase are associated with small granules of apatite. The

darker minerals include a bluish green hornblende, which is sometimes colour zoned and may even be colourless in its outer rim. It appears to change to a green biotite. The cores of the larger plates of the amphibole are filled with a pale to colourless pyroxene (diopside). Dark green or brownish green irregular flakes of biotite are always associated with epidote, clino-zoisite and a little sphene with apatite. Enclosed in the larger flakes of biotite or in close proximity to these are rounded, oval or sub-rounded crystals of pyrite, which are always mantled with a thin layer of red haematite staining the associated quartz or the felspar.

(4) An Appinitic Xenolith similar in mineral composition, texture and appearance to the rock types in the Kiltoorish area (described on p.p. 235-7...) occurs 100 yrds. N.E. of Summy Lough and continues on the eastern side of the road. The rock appears to be little changed by its enclosure in the Foliated Tonalites. The Tonalite does, however, show minor modifications, viz; small grains of diopsidic pyroxene are enclosed in a rather basic felspar (Calcic andesine) which occurs with the normal oligoclase and microcline.

Large plates of hornblende also enclose pyroxene and are changing to biotite (8/13).

(5) Quartzite Xenoliths:- Only two enclaves of quartzite, one a small piece about 18" x 10" and another 15ft. x 4 ft. in size were found in the Tonalites, E. of the road and about 200-250 yards east of Summy Lough. These xenoliths are pale white to buff in colour and show good primary characters of foliation, bedding etc., Their direction of elongation subtends a slight angle to the foliation of the Tonalite. A block 70 yds. x 30 yds. occurs at the approximate contact associated with the country schists and metadolerites. It is located just on the mid eastern shore of Sheshkinmore Lough. On the granitic side the quartzite forms a compact rock but it retains its fissility away from the granite contact. It shows good current bedding. The quartzite block possesses the same dip and strike as the foliations of the granite; that is it has a N - S strike and a steep dip of 85 degrees to the east. The contacts both of the block and the xenolith are sharp but, at their margins, long radiating crystals of Tourmaline are seen growing

both in granite and in xenoliths.

In thin section (8/16) the quartzite is medium grained and somewhat heterogeneous in appearance due to the streaky or patchy nature of the biotite. The rock has a granoblastic texture. The recrystallised grains of quartz and felspar are comparatively large being up to 5 m.m. in diameter, they are elongated and show a sub-parallel arrangement with the streaks of biotite. The predominant mineral is quartz with subordinate plagioclase (soda oligoclase), microcline, brown biotite and less abundant sphene associated with iron oxide. Inclusions of biotite and muscovite are common in quartz. Sometimes the quartz grains are strained and all show an undulose extinction. Near the contacts the grains are larger in size.

The Foliated Tonalite at the contact is a pale coloured medium grained rock with a lesser amount of biotite and an increased amount of quartz (11/10).

No quartzite is found occurring as an immediate country rock to the pluton, and thus the presence of the quartzite xenoliths in the pluton is of special

interest. This occurrence can be explained in three ways; firstly the huge block, east of Sheshkinmore Lough, may be a part of the country rocks which lie unexposed beneatn the Lough, the Sand-dunes and bogs of the great gap without any rock exposures. Secondly, the xenoliths might have been brought from below by the granitic magma or thirdly these may be the stoped masses of the covering rocks of the pluton. This question can be solved only by a wider survey than the present.

(6) Xenoliths of ? Lamprophyre:- In the whole of the area covered by the Tonalites rounded or oval patches often weathering into cavities of a fine-grained greyish granitic rock are commonly seen. These cavities or patches may have 1" - 3" wide irregular rims of leached reddish brown oxide of iron (Fig. 16D.). The number of cavities is far greater than the patches, and their origin is puzzling. As an example, in a hillock at the eastern shore of Summy Lough a few very rounded xenoliths, about 6" in diam., are found. In all cases the contact is sharp and reaction does not appear to have taken place. Under the microscope the rock composing one xenolith (Sp. and slice No.8/9), of the type mentioned above,

is a microdiorite in which green hornblende in the form of irregular plates makes up more than 50% of the rock. Its edges are irregular and the amphibole is intergrown with a Zoned plagioclase. A few of these hornblende crystals associated with dark brown biotite and iron oxide, and it appears that the amphibole is altering to biotite and ilmenite. This latter mineral is transformed to sphene. The hornblende has a pleochroism, y = olive green, B = yellowish green and L = green and the few enhedral crystals show two good cleavages and show ZAC =Ca: 20 degrees. The zoned plagioclase (Ab.75) has acomposition and is similar to that of the Tonalites except that the difference in Zonal composition is not so well marked. Almost all the crystals are sericitised. Lath shaped flakes of muscovite are formed both at right angles and along the cleavages of the felspar. When both biotite and the amphibole occur together, the pinkish brown sphene is always present. Small granules of Apatite are associated with the plagioclase and biotite.

The narrow zone of this apparent contact, which is not perceptible in the hand specimen is composed of dark green unidentified aggregates which seem to

be much alterated. The resultant rock can be compared with the grey or whitish grey lamprophyres (Spessartites) of the first group found well exposed both in the Portnoo ~~Lough Specimen~~ limestone and Rosbeg Pelitic and Semi-pelitic rock groups.

(i) Coarse Pink Granodiorite and Hybrid Diorite Rock Series :- These rocks and their associates mainly occupy the Middle Sector between Sheshkinmore Lough and Craig's Town and are poorly exposed in the region between Derryness and Renny Points. As would appear from their distribution and mutual relationship, they are very intimately connected with each other and to the two major granitic rock types i.e. (Foliated Tonalites and Medium Grained Granodiorite). Except for their mineral proportions, they are modally very similar to the Tonalite and Granodiorite on the one hand and to the country rocks on the other. Thus the two rock types classified in the field as Coarse Pink Granodiorite and the Hybrid Diorite Series form only one unit of mixed rocks produced by the mixing of the country rocks and the tonalitic or granodioritic magma.

(a) General Characters:- The Coarse Pink Granodiorite is rosy pink to pinkish white or without a gneissose structure, but a coarse porphyritic appearance is not uncommon. The rocks of the Hybrid Diorite Series vary from dark grey to pinkish grey or white and display a gneissic character. In both these rock types the felspar porphyroblasts, as large as 2 cm. by 1 cm., are arranged parallel to the foliation of the rock; they are embedded in a pinkish white felspathic or dirty green hornblendic matrix. The irregular streaks of the darker minerals are sometimes half a cm. or more in width and can be traced for more than 1 ft. The gneissose nature of the Coarse Pink Granodiorite is actually due to the schlieren, which sometimes curve round a xenolith and even a porphyroblast (in a thin section). On the weathered surfaces the prismatic faces of the felspar and amphibole are clearly visible, and generally thin epidote-rich veins are seen cutting through the felspar and the green matrix. In places, these veins seem to be faulted and displaced and in thin sections they are found displaced by a few millimeters.

(b) Petrography and Mineralogy:- The Hybrid Diorites are coarse grained and exhibit a Panidiomorphic to hypodiomorphic texture. Abundant, patchy aggregates and euhedral crystals of amphibole and biotite lie in a matrix of plagioclase (oligo - andesine) with microcline-microperthite and quartz. The order of perfection of crystal shape is plagioclase, biotite, hornblende, quartz and microcline. Important accessories are sphene, apatite, ilmenite, and zircon. The secondary minerals include muscovite, sericite, epidote, zoisite, chlorite and leucoxcene. In some slices of hybrid types irregular grains of a pale greenish pyroxene and small grains of colourless amphibole are also present. In thin sections the typical Coarse Pink Granodiorite is a hyidiomorphic inequigranular rock.

The well formed plates of plagioclase consists of a central turbid core of andesine (Ab.65-70) surrounded by a zone of oligoclase (Ab.75-80) and by a clear wider outer zone of more sodic composition (Ab.80-85). The central core encloses plates of brown biotite and granules of iron oxide. Along the two sets of cleavages muscovite is seen to form in

thin flakes. The albite and carlsbad twins of the crystals are generally bent. Fresh microcline - microperthite, rarely forms large plates, and encloses altered plagioclase. It moulds the other minerals of the rock. Sometimes two separated crystals of microcline are seen joined by fine quartz-felspar stringers. These stringers are never seen cutting through the microcline - an indication that microcline is later than plagioclase. In most of the cases in the clear perthite associated with microcline fine thin parallel streaky stringers of quartz are present. In a single crystal or grain, these quartz stringers never cross each other. Sometimes these are connected by a quartz grain which is generally interstitial in nature. Both the microcline and quartz are subordinate. The former is cracked and granulated and is lined with tiny ~~or~~ dusty inclusions.

The bending of the lamellas of the plagioclase inclusions in microcline requires explanation. The platy nature of the development of the microperthite in the microcline host suggests that this is due to strain as indicated by the work of Chayes (1952).

The bending of the twin lamellas may be the result of this same strain effect; another possibility is that the plagioclase suffered deformation previous to the growth of the microcline.

Biotite and hornblende occur as patches or schlieren. If the patch is small and does not exceed more than 5 m.m. or so, it is made up of green or brownish green biotite, A larger patch or schlieren is composed of both biotite and hornblende. Biotite is always associated with sphene and pleochroic haloes around zircon are often common. The dark irregular mica flakes are aligned or subaligned parallel to the general foliation of the rock. This biotite is strongly pleochroic, x= pale yellow, y = z = deep green to olive green or rarely brownish black. Sometimes flakes of pale brownish grey biotite are also found as inclusions in the plagioclase (11/19). These flakes are always surrounded by dusty iron ore and leucoxcene. Hornblende is deep bluish-green to brownish green and sometimes has a definite core. The junction between amphibole and felspar is complex; the felspar seems to invade the hornblende. The

latter occurs as small irregular grains or euhedral crystals in the felspar matrix and is associated with biotite and sphene. Like the biotite, the hornblende is also strongly pleochroic with x = pale green, y = pale yellowish green and z = bluish green to deep bluish green and ZAC = 21 - 23 degrees. Some of the hornblende crystals or patches are associated with brown pleochroic sphene and biotite. In fact, in a patch of hornblende all stages of its alteration to biotite and sphene can be studied (10/13). Accessory minerals include Apatite which occurs in euhedral or subrounded grains either as inclusions in the felspars or in association with biotite. Ilmenite associated with sphene and rutile is common in these rocks. These generally alter to leucoxene. Of the secondary minerals pale green or greenish yellow epidote (pistachite) occurs replacing the hornblende or biotite and as inclusions in the plagioclase. The larger subhedral or euhedral crystals of pistachite always have a core of allanite. The other epidotic mineral zoisite is common as prismatic crystals with its characteristic anomalous blue colours and a few crystals are seen growing in the cleavages of the felspars.

The dioritic rocks (Slice 11/7) from the cliffs immediately at the northern shore of Sheshkinmore Lough, exhibit a gradational contact with the metadolerite. Here the major western portion of the cliffs is made up of an amphibolite while towards the east the rock rapidly grades into a dioritic type and this grading is seen even in a slice of one and a half inch length (11/7). The mineral constituents of the rock are the same as described above for the whole series, but the amount of green hornblende in the amphibolite and in its gradation is far in excess. At the contact with the felspar the amphibole is again broken and the larger grains of this granulated amphibole are re-crystallised. The crystals are seen growing into the plagioclase, which is an oligoclase (Ab.65). This is zoned, sieved and full of inclusions of chlorite, muscovite, and epidote. Associated with hornblende and sometimes included in the larger plates of amphibole are irregular patches of a colourless to pale greenish pyroxene (ZAC = 40). Sometimes this granulated pyroxene is also present at the junction of the felspar and the amphibole and it is not clear,

whether the pyroxene is altering to amphibole or vice-versa. Subordinate quantities of biotite are present in association with the amphibole and sphene or as inclusions in the felspar. The larger flakes enclose brownish green hornblende and all stages of its change to biotite can be made out. Microcline is totally absent and fractured quartz is very subordinate, exhibiting undulose extinction.

The nature of the mineral contents and their mutual relationship in the rock suggests that this is an example of assimilation of the early meta-dolerites.

In another slice (10/12) from the isolated patches of granite or contaminated rocks exposed in the swamp about 200 yards S.W. of Mooney's Lough, large phenocrysts of pinkish white plagioclase (Ab.60) 2 cm. by 1 cm. are embedded in a matrix of hornblende and biotite. The pyroxene observed above is absent and quartz is very subordinate.

In still another outcrop south of the above and by the north side of the road, half way between Summy Lough and the Bridge in a similar rock (10/15) the phenocrysts of microcline and plagioclase

(Ab.60) occur side by side and it is sometimes difficult to make out whether the plagioclase encloses the microcline or is enclosed in it. Here in this slice the amount of fractured quartz is relatively increased (compare 10/12 or 11/7). Again in another locality about 300 yards east of Summy Lough the large subhedral crystals of quartz are much fractured and have inclusions of Sphene, apatite, biotite and iron ores in their angular fragments.

There are, however, all gradations of dioritic rocks between quite felsic granodiorites and dark amphibolites, As an example a coarse grained type is made up of equigranular dark or grey minerals in similar proportions. In thin sections (11/25, 11/48, 11/13, etc.) they are seen to contain felsic and mafic minerals in almost equal proportions. Zoned plagioclase varying between AB.55 to Ab.70 is seen penetrating the larger plates or grains of brownish amphibole or biotite. The smaller grains of hornblende are irregular and broken, but when enclosed in the felspar they form enhedral crystals. Thus the plagioclase and rare microcline-microperthite are poikiloblastic in texture, with inclusions of biotite, hornblende, sphene, etc.,

The larger plates of hornblende are also sieved with common inclusions of quartz and felspar. They show all gradations of change to biotite; the associated sphene occurs with ilmenite or rutile or both. The larger crystals of hornblende sometimes include angular patches of colourless or pale pyroxene with ZAC = 36 degrees.

(j) Petrography of Xenoliths in the Middle Sector.

The xenoliths are most numerous in this sector. They are variable in their shape and size. As has been described earlier, these xenoliths are generally metadoleritic in composition and actually there is not much difference in their petrography from the general petrography and mineralogy of the Coarse Pink Granodiorite or the Hybrid Diorite series.

As an example a xenolith of metadolerite observed in the midst of the Medium Coarse Granodiorite at about a distance of 300 yards W. of Kilclooney Bridge, exhibits partial injection and recrystallisation at its margins. Crystals of dark minerals are partially aligned, more particularly in association with the pink crystals of felspar; in general they grow along the foliation.

In thin section (10/7) the rock consists of zoned plagioclase surrounded by a matrix of fresh microcline and microperthite and strained and fractured quartz. Hornblende occurs in euhedral crystals and irregular plates. The crystals of granulated amphibole are brown and occur completely surrounded by microcline or by plagioclase and quartz. Some of these crystals show a twinning and schiller structure and are associated with brown pleochroic sphene and ilmenite or dusty and irregular patches of iron ore. Needles of zoisite, subhedral crystals of apatite and epidote with a little allanite are also common penetrating the granulated patches of hornblende or the felspar. Green biotite is subordinate and occurs intergrown with the irregular plates of green hornblende.

Another slice (8/6) comes from a group of xenoliths about 200 yds. W. of Kilclooney Church. This locality is the northern-most extension of the Hybrid rocks in the present area. Here the irregular elongated xenoliths are angular or sub-angular. Around each of these xenoliths are very thin dark blackish rims. Dark brown flakes of biotite stand

out prominently in a matrix of dark and greenish hornblende. These rims seem to be due to the introduction of potash around a (?) Calc-silicate xenolith. Such a reaction on a minor scale has already been reported in the "brecciated" xenolithic rock found in the Doon Lough region.

9. Summary of observations and significance of the Hybrid Rocks.

The passage of the metadolerites (country-rocks) to the central Medium Grained Granodiorite is gradational and best developed in the Sheshkinmore region. The mixing of these rocks has produced dioritic hybrids with abundant dark rounded patches and ghost xenoliths. Limited felspathisation of the country rocks has occurred and the dioritic Hybrids grade into the Foliated Tonalite of the North and Southern Sectors on the one hand and the Medium Grained Granodiorite of the central zone on the other. The resultant changes undergone by the constituent minerals as a result of the inter-action between the granitic magma and the country rocks in this section are:-

(i) Zoned plagioclase felspars nearly Ab.60 - An.40 (compare with metadolerites) common in the Foliated Tonalites, have a wide clear outer sodic zone of Ab.80-85 (in the plagioclase of Hybrid dioritic rocks).

(ii) Microcline and quartz, though minor in amount, are moulded by the early minerals.

(iii) Microcline and quartz enclose "relict" patches of plagioclase and biotite and replacement textures are simulated.

(iv) At the junction between green hornblende and invading felspar the former appears to be granulated and when the granules are enclosed by the felspar, some of these are recrystallised and become of enhedral shape and brownish in colour.

(v) The apparent change of hornblende to biotite is very common and the brownish or deep brown core of hornblende is frequent.

(vi) The formation of sphene from ilmenite is very common and the occurrence of the later as cores to the former is not uncommon.

(vii) Ilmenite with rare rutile and sphene are commonly associated with hornblende.

(viii) Undeterminable relationship of pyroxene and amphibole, the inclusions of the later are present both in the felspars and sometimes in one other.

The field relationship of the various grades of rocks of this mixed and hybrid group and the changes in the mineralogical composition revealed by thin sections lead to the conclusion that these rocks have been formed by the progressive digestion of the country rocks (metadolerites) and consequent contamination of the advancing magma. The rocks show the following characters;

(i) The rock types met with are varying between light coloured Medium Grained Granodiorite to dark coloured diorite or the amphibolite;- blending of rock types is common.

(ii) The xenoliths and the schlieren display intricate contacts.

(iii) Lit-par-lit injection is local and is very limited.

(iv) Only some xenoliths show reaction rims.

(v) Formation of minerals such as sphene, zoisite, epidote, apatite, brown hornblende, biotite and sodic oligoclase.

The "porphyroblastic" textures of the microcline - microperthite and quartz suggest a late influx of K and Si rich solutions.

The Medium grained granodiorite may also be responsible for the pink or red colouration of the third coarse variety (i.e. the Coarse Pink Granodiorite). As will be shown later, the amount of microcline and quartz increases towards the centre of the pluton; the second type (the Medium Grained Granodiorite) is richer in microcline than the outer Tonalite and the pink colouration is a reflection of this enrichment in potash felspar. It may be that the pink potassic felspars, found in large numbers both in the matrix and as porphyroblasts, are the result of introduced material, a potash metasomatism being envisaged. It is conceivable that with the inflow of more and more granodioritic magma, the latent heat coupled with the earlier residual heat of the Tonalitic magma, energised the country rocks and the earlier

Tonalites, preserving a high temperature for a longer time and thus producing the coarser crystallisation of the Coarse Pink Granodiorite.

The inter-relationship between the Foliated Tonalites of the outer zone and the inner Medium Grained Granodiorites is difficult to decipher. It is more so because the coarse Pink Granodiorite occupies a very peculiar position i.e. it seems to wedge in between the two major granitic rocks on the one hand and actually grade into the amphibolites of the country meta-dolerite on the other. This difficulty is further enhanced by the lack of exposures in the circular depression, which itself might be due to the weathering along the weak contact of the tonalitic and granodioritic rocks or might be a result of the circular or ring joints. But it is certain that in this peculiar Middle Sector the rigid division of the outer Foliated Tonalite and the inner Medium Grained Granodiorite can not be made out. The latter grades into the former (as east of Summy Lough) and although partly unexposed these rock types also seem to grade into the Medium Grained Granodiorite of the centre.

Whether this hybridisation is to be associated only with the Foliated Tonalites or with the inner Granodiorite is one which can not be decisively answered from the evidence available.

(a) Discussion:- Nowhere along the major portion of the pluton contact is there any marked evidence of stoping from the country rocks and all that is present is of very local nature. It is now apparent that in the Sheshkinmore region there is a remarkable difference both in the nature of the contact and changes in the country rocks. In this area, the granodioritic rocks are reacting with the metadolerites and even with the Tonalites, resulting in the formation of complex rocks with characterstically heterogeneous composition and peculiar textures. In this connection reference may be made to the formation of "contaminated rocks" in the Arnage district of Aberdeenshire (Read, 1923 p.128). The argument advanced in support of his idea is that "the rocks of the younger igneous masses have absorbed either partially or completely material of the sedimentary origin so that a magma of abnormal composition has been formed". This relates to the "reciprocal reaction" (Read, 1923, p.p.446-486, Q.J.G.S.Vol.79)

between a gabbroid magma and argillaceous sediments. Further, according to him the contamination process depends upon the "reciprocal reaction". The relation and the principles laid down for the production of these "contaminated" rocks in Scotland is directly applicable in this region of Donegal.

These ideas have been developed by Nockolds on the study of Garabal Hill complex, by Brammall and Harwood on Dartmoor Granite, by Thomas and Smith on the igneous complex of Trigastal Ploumanach Granite, Tyrell on "Geology of Arran" and many others, where the Xenoliths of basic rocks are seen to contaminate the granitic masses and normal looking rocks have been formed. On the basis of such examples Nockolds (1934, p.33) writes very emphatically that, "We must admit, therefore, that the intermediate rock types, diorite tonalite, and granodiorite, may arise from the interaction of an acid quartzo-felspathic magma with solid basic igneous material.

As in many cases cited above or in the literature, the xenoliths and the country rocks of the Sheshkinmore area or the Mid.Sector of the "Portnoo District" are mainly metadolerites. The hybrids produced are

mineralogically similar to the tonalite rocks present in many of these cases. The resultant minerals both in the Xenoliths and the country metadolerites are similar and have similar textural features. Likewise the same minerals, (in smaller or larger proportions) are present in the more acidic and widespread granodiorites as in the Foliated Tonalites.

The flooding of the granitic rocks with newly crystallised biotite and hornblende, the increase in accessories e.g. apatite, sphene, and the zoning of the plagioclase, suggest that the magma has been enriched in the constituents of the xenoliths. The xenoliths also show changes in composition although these are not so very well marked. It is probable that reciprocal exchanges have occurred between the Xenolith and the magma, but it is thought that chemical reaction was limited to the immediate contact zones, whereby material was recrystallised and partly mechanically added to the magma.

(b) Conclusion.

The rocks of the pluton are mostly granodioritic in composition but the rocks of this (Sheshkinmore) area

tend to be more dioritic with obvious addition of country rock material. The same minerals in smaller or larger proportion and with similar textural features are present in the more acidic and widespread granodiorites. Although the process of hybridisation is not clear in the rocks of the major portion of the pluton, it is strongly suspected that these rocks are similarly the result of such additions. As at Sheshkinmore dioritic rocks are produced at or nearly the present level, it is reasonable to surmise that the production of the older granodioritic type may be the result of such processes at depth.

The variation from granodioritic to more granitic rock types in the pluton is a possible indication of the original granitic composition of the intrusive magma. The added material is seen in the Mid.Sector or better in the Sheshkinmore area to be of metadoleritic origin; never-the-less, numerous small xenoliths of pelitic material are found, some of which, at least, must have been incorporated.

With regard to the origin of the tonalites, granodiorites and their associate hybrids two alternative hypotheses can be put forward: they may be the product

of assimilation and contamination or a direct derivation by magmatic differentiation.

As regards the first hypothesis; it is well known that basic and acid rocks can mix and produce a hybrid intermediate product. In the present case it has already been seen that the hybrids of the Sheshkinmore area have been produced by an inter-mixture and digestion of the country metadolerites. Bowen (1928, p.p. 199-201) on the basis of his experimental studies has shown that such an assimilation is possible, if the invaded and dissolved rock is of the same reaction series though this process may be of little importance.

We can however see contamination as an active process. The basic rocks are of very much earlier date - differentiation from a basic magma (if any) must be a process occurring at depth - of which we have no evidence and it is most probable that the granitic rocks of this pluton are not a product of crystallisation differentiation of a pure basaltic magma.

10. Relationship of the Outer Foliated Tonalite and the Central Granodiorite:-

Again a comparison of the normal Medium Granodiorite of the central zone and the marginal Foliated Tonalite shows that the granodiorite differs from the tonalite mainly in :-

(a) slight excess of quartz and potash felspar.
(b) decrease of plagioclase.
(c) decrease of biotite and hornblende.
(d) absence of pyroxene.
(e) presence of inclusions of iron-oxide confined to the central zones of the plagioclase.
(f) decrease in apatite, sphene, ilmenite and epidote.
(g) lack of prominent foliation and a marked equigranular texture, and
(h) lack of muscovite.

Moreover the cleavages of the dark mica or the felspars, so commonly bent in the Foliated Tonalite are less commonly deformed in the granodiorites of the central zone. This may be due to the pushing aside of the semi-solid or pasty early tonalite by the subsequent magma. Further, the distribution of microcline in the tonalitic rocks is not uniform but

increases towards the centre. Whether all these differences are but the intermixing of two rock types or gradational from contact to the centre of the pluton is not certain from the present work, though there are indications that there is a definite change localised in the circular depression already noted in the field. The myrmekite texture common in the mixed rocks is subordinate in the central granodiorite.

From these facts it seems likely that the intrusion of the pluton was not one single phase but a series of intrusions i.e. several up-wellings of magma. The magma intruded in the first stage (forming Tonalites) cooled and partly crystallised, and the intrusinn of the more acidic magma seems to have produced changes in the Tonalites. For example the outer sodic zone of the plagioclase may owe its origin to a new influs of soda. Introduced material plus mechanical deformation may have led to the production of the abundant microperthite. Further, such mechanical movements also seem to have been the cause of fracturing and veining (fine epidote or epidote, microd ine and quartz veins cutting through the plagioclase crystals but never the microcline) of the tonalites.

A comparison is given below in Table No.4. of the descriptions of the normal Tonalites in association with their various xenoliths. In the case where pelitic xenoliths are involved there does not appear to be any appreciable change in mineralogical composition except that the biotite is now represented by a brown "hornfels" variety in somewhat increased proportions, and amphibole and sphene are totally absent.

In contact with quartzite there is an increase in the quartz content and a fall in biotite, hornblende, sphene and epidote. When in contact with amphibolitic (metadolerite) rocks the tonalites show appreciable changes in composition. Hornblende becomes the important ferromagnesian mineral and is increased in quantity. The accessories, sphene, apatite and ores appear in abundance.

The Tonalitic rocks associated with appinitic and calc-pelitic material show the most marked changes. The ferromagnesian minerals form distinctive clots, brown and green amphiboles occur together often associated with a diopsidic pyroxene. Sphene, epidote, apatite, and ores become important and pyrite is much increased.

Summary of Mineralogy and Petrography

Chart showing the relative abundance of essential and accessory minerals in the Foliated Tonalites, Hybrids and the Granodiorite types of the Ardara pluton.

Table No. 4.

	TONALITES							MIXED	GRANODIORITE	
	Nor.	Pel.	Dol.	Appi.	Calc.	Lam.	Qt.	*Hybrid	Nor.	Cont.
Quartz	A	A	A	A	A	A	A	A	A	A
Microcline-microperthite	A	F	A	A	V.R.	C	F	A	A	A
Plagioclase (Ab>70	A	A	A	A	A	A	F	A	A	A
Plagioclase (Ab<70	-	-	-	A	A	-	-	F	-	V.R.
Sodic Mantle	-	-	-	A	A	F	-	A	-	V.R.
Biotite (Brown	A	A	-	V.R.	F	V.R.	A	A	V.R.	F
Biotite (Green	F	V.R.	A	F	A	A	-	A	V.R.	F
Hornblende (Brown	-	-	V.R.	F	A	A	-	A	V.R.	F
Hornblende (Green	F	-	A	A	A	A	-	A	V.R.	A
Pyroxene	-	-	-	C	V.R.	-	-	F	-	-
	ACCESSORY MINERALS									
Ilmenite	A	A	A	A	A	A	A	A	A	A
Iron ores	A	A	A	F	F	F	A	C	A	A
Sphene	V.R.	-	A	F	C	V.R.	R	A	V.R.	A
Apatite	F	R	F	A	A	??	V.R.	A	V.R.	F
Zircon	F	F	V.R.	??	C	-	F	V.R.	V.R.	F
Epidote	C	F	R	A	C	A	-	A	F	C
Pyrite	-	-	-	-	A	-	-	-	-	-
Chlorite	F	F	A	V.R.	F	F	V.R.	A	F	A

A - Abundant
C - Common
F - Frequent
R - Rare
V.R.- Very rare

* In one thin section a small grain of a colourless amphibole with bluish violet and azure blue pleochroism and $z \wedge c$ - Ca 1-2 is associated with amphibole and pyroxene (Slice No. 10/12).

In associati on with a (?) lamprophyre xenolith there does not appear to be any appreciable change and only sometimes dark rings of reddish or brown colour are present around a xenolith or xenolith patch. From this it is likely that in such cases only an enrichment of iron-oxide has taken place.

11. Possible reasons for the zoned nature of the Pluton.

It has been shown abov e that there is a transition from an outer Tonalitic margin to a Granodiorite core. Although it is thought that the inner mass is possibly a slightly later separate intrusion there is no doubt that there is a marked gradation from one rock type to the other; that is the probable contact marked by the arcuate depression does not provide a very pronounced change in the rock. At least two explanations are possible for this "differentiation". There may have been some type of differentiation of a magma at depth; or it is a case of assimilation by addition of the country rocks to the granitic magma, the most hybrid and earliest up-wellings of which form the outer tonalites, and the later comparatively

pure has given rise to the granodiorites of the central core of the pluton.

Differentiation at the present level by any of the well known proposed processes is discounted as there is no field evidence available for it. Local assimilation in the tonalite is very probable but if such a process is invoked for the production of the tonalite magma such must have operated in depth.

A. - ... The Contact Metamorphic Effects.

1. Introduction:- The metamorphic effects of the Ardara Pluton are well marked in an aureole, about ¾ of a mile in width, in which are developed contact minerals such as sillimanite, staurolite, garnet, andalusite and biotite in pelitic and semi-pelitic rocks. Sphene, epidote and diopside, garnet, etc. appear in calc-schists. The re-crystallisation of hornblende and the development of porphyroblastic plagioclase are thermal effects produced in the metadolerites.

It has already been shown that the metasediments and the associated metadolerites have suffered at least two distinct regional metamorphisms. The most important regional metamorphism, presumably broadly contemporaneous with the folding, was followed by a retrogressive phase. The metamorphic grade of the country-rocks was therefore low at the time of the granite emplacement except where the intrusion of the different lamprophyres had produced minor and generally very local contact effects. Contact metamorphism by the granite was superimposed upon these low grade metamorphosed rocks. This timing has been proved by the

growth of the andalusite crystals and their relation to the ivth lineation (p.p. 80-81, Fig. 8.. and plate 4. of pt. vi.), by the growth of andalusites across the folded and faulted bands and cleavages (Fig . 15.) and by the change of both the rounded chlorite after garnet and new porphyroblastic chlorite to biotite.

(a) Aureole of the Ardara Pluton:- As described earlier, the country rocks around the granitic pluton form a semi-circular ridge of low hills. In the area dealt with in this Thesis these hills extend from Narin to the northern shores of Sheshkinmore Lough. Except for narrow gaps, the height of the hills varies between 207 ft. to 320 ft; of these gaps, the most important runs from the S.W. shore of Summy Lough to Terrylagh where the average height is about 200 ft. and the hornfelsed country-rocks make a wide table-land studded with low hillocks and swamps. The trend of these ridges and hillocks agrees with the local strike of the rocks, which seems to have been disturbed locally by an E - W fault.
The otner two gaps (with road) are very minor and

appear to be due to differential weathering. They are located North-West of the group of houses, near the tortuous road bend (road joining the main Portnoo-Rosbeg Road and the Narin-Ardara Road), and north of the Cromar Houses (at the northern cliffs of Sheshkinmore Lough); they do not appear to be located on any fault zones. In the area south of Sheshkinmore Lough, the rocks are badly exposed, being mostly covered by alluviam, sand or bog, but a small rock outcrop in the midst of the sand-dunes shows that the hornfelsed metasediments are present beneath the sand. Further south or south-east towards the Owenea estuary and thence to the Owenea Bridge via Derryness and Renny Points exposures of meta-sediments or metadolerite of the aureole are extremely poor, but these rocks seem to make the innumerable islands in the Owenea estuary. The height of this region does not rise to 50 ft. The story of the aureole is therefore mainly confined to an account of the contact metamorphic effects observed north of Sheshkinmore Lough.

(b) Structural features of the Aureole rocks:-

The better exposed rocks of the northern region display many of the characters that are to be expected around any granitic pluton, and the few exposures of hornfels in the southern region are in accord. In dealing with the "Tectonics and Structure" of the Portnoo District in general, it has already been shown that the strike of these hornfels or schists curves round the pluton. The bedding dips (marked by the banded nature of the sediments), the schistosity and the cleavage are all commonly coincident as noticed in the other regions of the district. The dip varies between 70 degrees to vertical and is generally towards the interior of the pluton. Away from the contact the dip flattens and the strike takes a turn to the S.W. and ultimately conforms with the general strike of the country rocks (i.e. E-W and WNW-ESE) near Kiltooris or W. of L.Birroge. It has been noted that the dips are steeper in the north towards Narin Hill or the main Glenties road junction.

Sometimes the planes of cleavages are seen to make an angle of 8 - 10 degrees with the direction of strike and dip of the bedding. This feature is

most notable when the thinly banded hornfels*es* are contorted or slightly dislocated e.g. S.E. of Narin Hill or east of Doon Lough. In the hillocks immediately N.W. of Sheshkinmore Lough, the dip of the hornfels is again very steep to vertical but the cleavage is not so well marked. This may be due to the fact that the metasediments of this region are more siliceous in composition.

The phyllites and mica schists showing numerous structural features form the bulk of the country rocks outside the aureole. In a zone 200-250 yards wide from the contact of the pluton these rocks are represented by dense compact and micaceous hornfelses of bronze colour and completely devoid of any structural character. About a furlong or 200 yds. away from the contact the hornfelses are cleaved, fissile, and cremulated and show at least two linear structures, the ivth and vth lineations (p.p. 80-81). Three hundred and fifty yards away from the contact the ivth lineation due to the crinkles appears in force and runs parallel to the circular trend of the contact or the cleavage of the hornfels. This ivth lineation is probably the result of the same phenomenon as

the cleavage around the pluton i.e. the intrusion of the granitic pluton. Again it will not be out of place to remark here that this ivth lineation appears to die out away from the granite, e.g. W. of Doon Lough or W. of Terrylagh. It is clear that, as a result of the intrusion of the granitic magma, the rocks of the aureole were rendered plastic, and in the outer zones this semi-solid material was thrown into undulations, the crests of which form the ivth lineation. The upward pushing of the magma in the form of a cylindrical diapir also produced the vth vertical lineation. During the last cooling stages of the pluton cleavage and jointing were produced.

(c) Physical & Mineralogical characters of the hornfels. As the granitic body is approached the first evidence of the contact effects observable in the phyllitic schists is an induration, the rocks becoming slate-like in character. This is followed by the development of small spots and spindle shaped marks on the cleavages e.g. W. of Doon Lough, E. of Pound Lough, near Terrylagh and at the E. portion of

Carrickalagh. Slightly closer to the granite contact, the spots become larger and recognisable crystals of andalusite are present e.g. S. of Doon Lough, S. of Terrylagh and in the isolated outcrop among the sand-dunes. Nearer the contact, in the higher portions of the arcuate hills, a cleavage is developed and 2" - 3" long andalusite crystals occur abundantly; this belt of large andalusites is more than 300 yds. wide. Below the high ground of the hornfels ridge towards the interior of the pluton, the cleavage is gradually lost and the rock becomes massive.

Immediately at or near the contact the predominantly pelitic hornfelses are massive, compact and with typical hornfels structure. They are grey or coppery grey in colour.

These massive hornfels close to the contact exhibit the characteristic minerals of thermal (contact) metamorphism; sillimanite, garnet, staurolite, andalusite appear in the pelitic and semi-pelitic rock groups; green - brown or bluish green hornblende, andesine and epidote together with a little green biotite and much iron oxide constitute the metadolerites. The calcareous

rocks are not well represented in the aureole. In two small outcrops West and South of Summy Lough calcareous rocks are represented by a flesh-coloured garnet-rich rock and a peculiar hornblende-biotite schist.

The sketch map (Fig. 17.) shows the distribution of the different metamorphic minerals as studied in numerous thin sections. Except for andalusite or the shimmer aggregates after andalusite, all the thermal metamorphic minerals lie in a belt about ¾ mile in width; the inner and narrower portion of this belt is made of compact and massive rocks. The distribution of these minerals shows that they are not strictly confined to zones, though sillimanite is locally more common at the immediate contacts. Good mineral specimens may be collected at many localities. Pink garnet and sillimanite are best seen near the road junction E. of Narrin Hill and andalusite crystals as 5" -6" in length and 1 inch in cross section are found in exposures about 400 yds. N.W. of Summy Lough.

Andalusite is the most abundant mineral of the aureole. The crystals are very irregularly distributed both on cleavage planes and bedding surfaces of the hornfelses or schists. Though there does not seem to be any arrangement in the growth of the andalusite, the number and size of these crystals on the cleavage planes is far greater than on the bedding surfaces. The growth is at random though mainly within the cleavage planes. Commonly, however, crystals are seen to cross cut these planes and have even developed across minor fault planes (fig. 15. .. ~~and plate~~ ..). From this larger number of better developed crystals on cleavage planes it is likely that their growth has taken advantage of the early developed cleavage and that they are mimetic in character. Sometimes quartz veins or knots of quartz are present in the cleavage planes and very often these quartz-knots enclose minerals of the hornfelses, especially andalusite.

The width of the aureole is at a maximum near and around Narin Hill. High temperature and so called "Stress" minerals, sillimanite, staurolite

and garnet occur together with "Antistress" andalusite. Inspection of the main geological map will show that at this locality the country rocks seem to be bending; they are in fact converging due to the push from the granitic intrusion. This abnormal width of the aureole at this locality (i.e. in between Narin and Cashel Hills) is due to the influence of the explosion breccia already described. Again at the southern foot of Narin Hill, the schists or hornfelses are very contorted, crumpled and sheared and appear to be partly in a granitic matrix, a circumstance which might have also influenced the width of the aureole.

Similarly, the occurrence of Shimmer and Andalusite well away from any visible granitic activity e.g. near the Dunmore Hole in the schists of Portnoo L.St. group, or in the Dawros peninsula may also be due to granitic intrusions at depth. Local growth of andalusite is probably everywhere due to concealed granitic offshoots, associated with the main intrusion of the pluton.

2. Rock types and Petrography of Metasediments.

The rocks of the aureole are mostly pelitic or semi-pelitic in composition and are associated with metadolerites sills and very subordinate (?) calc-pelitic bands. These lithological types vary from a typical hornfels to schist or green schist and rare crystalline limestone.

The pelitic or semipelitic andalusite schists of the Portnoo L.St. group E. of Narin Church and N.E. of Dunmore Hole or E. of Dunmore Hill respond to contact metamorphism in an exactly similar way as the main pelitic rocks of the Rosbeg group. The only difference in the composition of these rocks is that they are rich in carbonaceous matter which is sometimes found enclosed in the andalusite crystals.

(a) Pelitic and semipelitic Rock Assemblages.

As has been noted, the width of the contact metamorphosed rocks in the Narin-Cashal Hills region is abnormal for a typical contact aureole, and is complicated and ~~indexed~~ widened by the intrusion of "explosion breccias". The different rock assemblages of this area do not show progressive phenomena. The contact metamorphic rocks of the southern region are better

representatives and the low grade rocks of the west gradually change to those of high grade towards the east.

In thin sections, typical of the outer aureole, the andalusite-biotite-muscovite schists (11/34 and 11/35) from the isolated patch in the sand-dunes and S.W. of Summy Lough, /3/13 and 3/20) collected immediately east of Pound Lough and north-east of Lough Birroge, and (8/51 and 8/52) from the southern slopes of Narin Hill), show that their schistosity is produced by the abundant original micas and associated subordinate grains of quartz and plagioclase; iron oxide is scattered throughout; a few large shimmer aggregates after andalusite occur and seem to distort the foliation planes (8/51). Iron oxide also occurs in irregular patches and is associated with a little biotite around which the foliation planes seem to be deflected. These spots of iron oxide are probably after the chlorite which is itself after garnet. In other sections the same mineral assemblage is accompanied by small pink garnets (8/138), brownish staurolite (8/123) and sillimanite needles or prisms (8/50, 8/40, 8/129 and 8/139)

all of which are common. In these rocks skeletal iron oxide is collected into small aggregates (with or without any biotite or chlorite) or appears concentrated in the shimmer aggregates after andalusite or occasionally after staurolite.

In rocks also typical of the outer aureole and collected from the schists of the western portions of the aureole nearly 2 furlongs N.E. of Doon Lough, the fine grained rock is formed of thin laths of micas associated with needles of fibrolite, grains of quartz, minor amounts of plagioclase and iron oxide. Oval or rounded patches of chlorite after garnet (which may sometimes show a skeletal structure) are common. Some of the spots are mere segregations of the granules of ore. Sometimes the rock has a typical herring-bone pattern due to the secondary cleavage structures and is very similar to the low-grade schists of the Rosbeg or Dawros areas. The lath-shaped flakes of the New Chlorite, occurring commonly in the crinkles at 30 - 50 degrees, in the areas west of Pound, Doon or Kiltooris Loughs is absent, but appears immediately outside the aureole just W. of Doon Lough. From this fact it is evident

that the formation of New Chlorite is earlier than the granitic intrusion which has actually destroyed this earlier manifestation of retrogressive metamorphism. A similar destruction of the New Chlorite has taken place in localities where there is no visible granitic activity e.g. near Dunmore Hill or Hole; where the andalusite or its shimmer is very well developed.

Near the crest of Narin Hill or the crest of the arcuate hills, in the central part of the aureole, the cleavage is very well developed and appears to be at a maximum. The shimmers or the andalusite crystals attain their maximum development. The schistosity is interrupted and broken up against large porphyroblasts of white mica. This sudden breaking of the foliation planes appears to be due to a rotation effect of the andalusites (8/128, 3/58 and 11/35). In the shimmer aggregate or in mica plates, thin colourless needles of sillimanite are sometimes present and it is likely that these porphyroblasts of muscovite are due to the late hydrothermal alteration of sillimanite. The spots of iron oxide are not so well marked but patches or irregular spots of dusty scattered ore are commonly associated with the biotite flakes.

In a slice(8/134) of a sillimanite - staurolite - andalusite hornfels from the western side of the upper road near the road junction (Ardara - Narin and Portnoo - Glenties roads) and typical of the inner portion of the aureole the rock is much sheared, it is coarser in texture and the foliation is seen to curve round the andalusite shimmers. The white micas replace the alumino-silicate and always appear to cross cut the biotite. Relics of andalusite are common in the abundant shimmer aggregates. Of frequent occurrence are rounded and comparatively large porphyroblasts of a pale brown biotite associated with iron oxide dust.

Further west towards Narin Hill the hornfelses are traversed by a few granitic dikelets and the country rocks are very similar to those described above. But a further stage of contact metamorphism is exemplified in the massive, hard, compact coppery grey sillimanite - garnet - staurolite - biotite hornfelses (8/126, 8/127, 8/128). In these rocks the schistosity is lost. The andalusite crystals (or their replacing shimmer aggregates) are completely absent and pink garnet with sillimanite can be made out

with a hand lens. Pale coloured shimmer aggregates associated with some biotite and iron oxide and even with relict staurolite are common. The quartz and plagioclase are recrystallised forming aggregates; bands of the granular minerals preserve the original foliations. Elongated poikiloblastic flakes of muscovite and biotite are formed. Some of the pink garnets are aligned and enclose biotite or quartz grains. These elongated biotites and garnets with included biotite or quartz are believed to have been formed from the original garnet or rounded chlorites after garnet which have recrystallised as a New biotite from the chlorite. Rocks with similar characters but slightly richer in recrystallised quartz are also common west of Summy Lough (3/51, 3/53 and 3/60). In slice 8/59 all the biotite forming the foliations is being converted to sillimanite; the relics of the biotite are altering to chlorite. The pink garnet present in the rock is formed from the new biotite (after rounded chlorite).

The final stage of contact metamorphism of the pelitic or semipelitic metasediments in the innermost parts of the aureole is seen immediately at the contact

with the granitic pluton. It is best exposed in two small quarries, one on each side of the branch road (connecting the two main Portnoo - Rosbeg Road and Narin - Ardara road). The metasediments are thoroughly crystallised, very fine grained, dark coppery or bronze coloured hornfelses. Similar rocks are partially exposed on the craggy slopes to the north and south of this branch road. ~~At~~ *In* this section (8/70) of these hornfelses from one of the two quarries along with others (8/47, 8/48, and 11.D/1) from such exposures show a matrix of small shreds of reddish brown 'hornfels' biotite, rare laths of muscovite and some quartz and plagioclase grains. The biotite is changing to felts of sillimanite, in the cores of which a light brown pleochroic biotite, sometimes with pleochroic haloes, is common. Embedded in these shreds of biotite and fibrolite are small enhedral crystals of pink garnet. These garnets seem to be of two types. One occurs in clusters of grains and another as sporadic single crystals which cross cut the schistosity. This latter type is always associated with or encloses quartz or biotite and thus seems to be a new phase

of the original garnet and rounded chlorite as already observed in the previous paragraph. It may again be noted that a very few garnets of the same type have been noted earlier (on p.p.302-5) as occurring in the pelitic xenoliths of the Foliated Tonalites. In slice 8/70 large colourless shimmer aggregates are not present but medium sized shimmers of pale yellow colour, associated with brown biotite and iron ore, occur. It seems likely that these shimmers are after staurolite, irregular relics of which, surrounded by pale brown biotite, sometimes occur in similar rocks (8/47) as 'augen' or 'eye shaped' structures.

All the slices both of the hornfelses and the schists from throughout the aureole show well developed shear cracks generally at an angle of 5 - 10 degrees with the planes of foliation. The schistosity and the usual lineations of the schists are less well developed in the hornfelses and this may be due to the recrystallisation of the meta-sediments. It seems that solutions have utilised the shears mentioned above and impregnated the rocks. When such shears cut through a biotite flake

(either of the schistosity or otherwise), iron oxide in irregular grains is segregated along it; in the siliceous or muscovite-rich bands sillimanite is formed. From these facts it is probable that the shears are probably simultaneous with the hornfelsing action i.e. with some stage of the granitic intrusion.

On the basis of their mineralogical composition and the textural relations, the different rocks of the pelitic or semipelitic metasediments can be grouped as:-

(1) Sillimanite - garnet - biotite	hornfelses close to the contact.
(2) Sillimanite - staurolite - andalusite	
(3) Garnet - biotite - chlorite	
(4) Sillimanite-biotite-muscovite (sheared)	Sheared assemblages in the outer zone of the aureole.
(5) Garnet-staurolite-andalusite-muscovite	
(6) Garnet-andalusite (Shimmer aggregates)-biotite-muscovite	
(7) Andalusite - biotite - muscovite	
(8) Muscovite - biotite - chlorite schists	

(b)- <u>Calc. or Calc. - pelitic assemblages:</u>-

It has already been stated (p.p. 38-43) that the limestones or definite calc - pelitic schists are never seen in contact with the granitic rocks of the pluton. However, a small, 30 ft. thick, vertical band of grey

to whitish - grey crystalline limestone is found in a quarry by the roadside noth of Cromer Houses (N. of Sheshkinmore Lough). If the supposed contact inferred in the bed of Sheshkinmore Lough is correct then this Limestone outcrop is the nearest exposure to the main pluton contact, and thus represents the highest grade of calcareous rocks affected by the granitic intrusion. A similar band is partially exposed in another small outcrop about 300 yds. W. of Lough Doo (N.W. of Sheshkinmore Lough).

The limestone from the quarry mentioned above exhibits a banded nature and occurs intercalated with pyritiferous schists of dark grey or yellowish grey colour. In hand specimen, the crystalline limestone is white to grey; sometimes thin pale brownish grey veins run parallel to the bedding. In the white portion of the rock, enhedral octagonal crystals of flesh coloured garnets (up to ½ inch) are visible. In thin sections 11/62, the granular rock is a crystalloblastic mosaic of calcite, in which subhedral grains of diopside, plates of clinozoisite and zoisite, enhedral garnet, cubes of pyrite and small amounts of interstitial

quartz and plagioclase are present. The veinlets are made up of quartz and subordinate plagioclase. Along these veins skarns similar to those described by Pitcher (1951) are developed on a very minor scale. The large subhedral crystals of pale yellow diopside are cracked and stained at their margins. Apatite occurs in small rounded grains. In another slice 11/29, in addition to the above minerals, a light green actinolitic hornblende occurs associated with ilmenite and subordinate flakes of biotite and enhedral crystals of pyrite.*

Another specimen 11/30 collected from the ridge immediately at the road bend about 100 yds. east of the above quarry is brownish in colour and is composed of alternating thin bands of a calcareous and arenaceous nature. In thin section, the rock is seen

* In this section pyrite is breaking down to dusty iron oxide; when in association with diopside, it is clear that the stained nature of the pyroxene is actually due to this alteration of pyrite, but in the case of the first slice no pyrite or dusty iron oxide is visible in association with the pyroxene.

to be a mosaic of calcite, filled with dusty inclusions, zoned amphibole changing to tremolite, a pale stained pyroxene and clinozoisite - zoisite, together with lesser amounts of brown pleochroic sphene, apatite and epidote. The sphene is always associated with the hornblende and ilmenite.

Another exposure immediately south of Summy Lough is made up of a dull brown micaceous schist. On the weathered surfaces euhedral or subrounded or oval crystals of hornblende are prominent. When fresh the rock is lustrous and reddish brown in colour. Across and in the planes of foliation pale green eye-shaped crystals of amphibole are set between the folia, which seem to have been pushed aside by their growth. In thin section (3/65) the rock has a schistose texture in which aggregates of hornblende form augen, surrounded by a brown felt of biotite. The quartz and very subordinate plagioclase are probably original. A uniformly distributed iron oxide is the main accessory mineral; it follows the foliation planes and also occurs at the peripheries of the augen. These augen are made up of actinolitic hornblende, which exhibits a zoned appearance, the core being generally bluish and towards

the margins dark bluish brown; augen with a reverse colour order are not uncommon. The formation of these composite augen is certainly later than the prismatic hornblende occurring in the planes of schistosity produced by the alignment of the brown biotite. This prismatic hornblende is light green to bluish in colour and sometimes seems to cross cut the foliation planes. Like the biotite, it curves round the 'augen'.

A flesh coloured garnetiferous rock occurs on the western shore of Summy Lough. It is thought that this rock may be a continuation of the crystalline limestone exposed in the quarry (near Cromer Houses). In thin section (3/63) the rock is made up of large enhedral crystals of grossular which are partly sieved and poikiloblastic in nature. The other minerals are very subordinate. A few grains of recrystallised quartz occur interstitially along with a scanty iron oxide, sphene and minor diopside. A few flakes of brown biotite and apatite complete the mineral components.

On the basis of their mineral association, these rocks are grouped together and the different assemblages of the few occurrences are :-

(i) Garnet rock.

(ii) Calcite - diopside - epidote)
(iii) Pyroxene - amphibole - epidote) assemblage

(iv) Amphibole - biotite schist probably equivalent to the calc - pelitic schists of the Rosbeg group.

3. Metadolerites at the Granitic Contact.

(a) Introduction :- Around the granitic pluton the meta-dolerites are very subordinate in comparison to the meta-sediments, and unlike these pelitic or semipelitic hornfels show very little reaction. Except for the Sheshkinmore region already described (p.p. 311-14) under the heading of contaminated rocks, the contacts are sharp and do not exhibit very marked agmatitic effects or metamorphic changes. The Mineralogical or other characteristic features, observed in the western margins of the dioritic or amphibolic complex of the Middle Sector, are not seen anywhere else, but the minor reactions that have taken place along these sharp contacts are similar to those exhibited by the hybrid rocks.

In the partially exposed border areas between Derryness and S.Renny Point, the contact is somewhat irregular and the pale-coloured tonalitic rock makes a network [Fig.....] in the country-rocks and it appears that migmatisation of the metadolerites has taken place. These irregular veins of granitic material are found to ramify in it and to be intercalated with the metadolerite sheet. This alteration of metadolerite by minor lit-par-lit injection at its contacts is usually completed within a few feet and the mixed zone never exceeds 10 feet, e.g. at the W.Coastline of the Derryness island or in the several islands near North Renny Point. On the whole, the permeation does not appear to be very extensive. Ordinarily, the thin veins make a sharp contact and it is possible that the granitic magma has been intruded in a shattered or sheared zone.

North and N.W. of West of Summy Lough thin sheets of metadolerites are found intercalated with the hornfels of the metasediments. Like the sedimentary rocks, these also have a steep dip and follow the strike of the country hornfels. These metadolerites are rather dark greenish in colour and have a massive

or dense to foliated appearence. The foliation is parallel to the cleavage present in the metasediments. These metadolerites, immediately at the contacts with the massive Foliated Tonalites, give a coarse to medium grained amphibolites which form for example part of the ridge and the narrow range of hillocks running parallel to Summy Lough. These amphibolitic rocks exhibit a patchy and variegated or spotted appearence of pale felspars in a dark green or green matrix. These felspathic spots are elongated or streaky and lie parallel to the foliation of cleavage of the metasediments. At the immediate contacts with the felspathic knots, the green colour of the matrix is changed to a slightly brownish shade.

The minerals present in these coarse to fine grained amphibolites are the same species as those present in the metadolerites dealt with earlier (in section viii p.p. 314:29). The metadoleritic rocks of the contact aureole are characterised by certain minerals ******** such as the abundance of brown-green hornblende, sphene, iron ore, biotite, oligoclase or andesine, little quartz and rare microcline and apatite.

(b) Petrography:- Under the microscope the fine grained rocks show a typical ophitic texture with plates of green hornblende studded with plagioclase. The amphibole is associated with patches and grains of brown iron ore probably ilmenite. The andesine is very subordinate, partly turbid and sericitised and sometimes inclusions of epidote or saussurite are common. The other important mineral is the granular, patchy or enhedral prismatic crystals of brown pleochroic sphene. It occurs both in independent crystals or in association with iron ore, leucoxcene and rutile generally close to the amphibole. Rounded or oval-shaped grains of apatite and rare flakes of dark brown biotite with pale green epidote are the chief accessory minerals.

The coarse grained rock close to the granitic contact looses its ophitic texture and in addition to the above minerals is rich in sericitised porphyroblasts of andesine (Ab.55-60) and minor quartz. Both these minerals are generally in association and show sutured margins. The bluish green hornblende occurs both as large plates and slender prismatic crystals. Almost all the plates have a darker or

brownish green core and the crystals are sometimes arranged in a radiating or criss-cross pattern. Associated with the crystals and sometimes at the irregular bluish green margins of the platy amphibole, granular or enhedral sphene and iron ore are developed. At the junction with the plagioclase or the quartz the amphibole is pale brown and the development of six-sided crystals out of the broken or irregular grains of hornblende is a common phenomena. These crystals have very well developed cleavages and their formation suggests resorption. A similar phenomenon has been observed in the hybrid dioritic rocks of the Middle Sector. Pale green epidote (pistachite) enclosed in the plagioclase is more abundant than in the fine grained rock and is seen to replace the andesine. Microcline and myrmekite are very rare.

At the junctions with the elongated patches of felspar and quartz, only little reaction seems to have taken place, but sometimes at such junctions thin streaky brown biotite is intergrown with hornblende in sheaths of few millimeter thickness, thus

producing a sort of foliation with the hornblende, which is also partly chloritised along its cleavages. Sometimes, foliation is very well developed as is the production of biotite e.g. immediately west of Summy Lough. Well formed garnets are never seen in these rocks, but sometimes the biotite is sieved by and closely associated with a peculiar skeletal clotty mineral of pale brownish colour which is always isotropic under crossed nicols; this mineral may be garnet.

The rare thin granitic veins cutting through the metadolerites and also lying in the joint planes have a well developed brownish hornblende and chlorite. These veins themselves are composed of oligoclase and andesine and very minor quartz and little ilmenite. This hornblende is obviously due to the contamination of the granitic material by the ferromagnesian contents of the metadolerite. It should be remarked that such examples are very rare in this area and only a few minor thin veins have been located around the granitic margin of the pluton.

A thin section of a granitised basic rock from

the western coast of Derryness island has a diffused nature and the rock is seen to be made up of irregular whitish felspathic patches in which the bluish green hornblende, sometimes altering to chlorite occuring as pseudomorphs is less predominant. The amphibole occurs in rounded, subrounded or irregular grains with idioblastic large crystals of a pale brownish colour. The bluish green variety also sometimes has a brownish core and gives ZAC = Ca 18 - 20 degrees. The amphibole is penetrated by unzoned andesine (Ab.50). The brown enhedral hornblende crystals have the prismatic cleavages very well developed. In the felspathic patches the amphibole is almost completely absent and all that is present has a very hazy outline. Quartz is minor in amount and moulds its shape around the plagioclase. Sometimes, when in greater proportion, the grains are fairly large and have a sutured junction with the felspar. Epidote occurs both in the felspathic patches or streaks and also in the green amphibolic matrix of the rock. When in association with hornblende it seems to replace the amphibole or biotite, and iron ore is released along with the formation of sphene. Scarce brown biotite forms clots or sheaths

and is always associated with plagioclase or amphibole. Small rounded grains of apatite are present both in the metadoleritic portion and in the felspathic patches. These grains are irregularly distributed both in the plagioclase and hornblende, occur at the peripheries of biotite flakes, or in association with the patches of sphene or enclosed in the iron ore.

The most notable physical character developed in the metadolerites during the contact metamorphism is foliation and cleavage similar to that produced in the metasediments and the partial obliteration of the ophitic texture as observed in the coarse hornblendic rock close to the granitic contact. Mineralogically, the changes are characteristic, being the formation of brown-green hornblende, acidic andesine, dark brown hornfelsic biotite and epidote.

Though at certain places, e.g. about two furlongs N. of Summy Lough, striations similar to the vth lineation of the hornfels seem to be present in the metadolerites, these are not so definite. In the same way, immediately close to the contact, the development of the counterpart of the ivth lineation is difficult

to establish. Throughout the metadolerites up to the western side of Kiltooris Lough, a N - S foliation produced by the alignment of the felspathic streaks is common in the basic sheets. This structure is best developed in the Narin and Kiltooris sheets. The trend is in 210 - 235 degrees. Unfortunately due to the occurrence of "Explosion breccias" in the region between Narin Hill and S. of Doon Lough, the metadolerites are very crumpled and no regular foliation can be detected there.

Again, in the area S. of Kiltooris Lough no important metadolerites are present. But the weak foliations and streaks, in the very narrow and poor exposures of the aureole rocks (mostly metadolerites) between Derryness and S.Renny Point are remarkably parallel to the granite contact and across the strike of the country rocks. From this fact it is evident that the foliations in the metadolerites of the latter area are related to the granitic intrusion.

The permeation and injection by granitic material in this area of Derryness and N.Renny Point may be a localised phenomena along cracked or shattered zones.

(c) Summary of Metadolerite Contacts:- For the most part, these rocks are unaffected, but in close proximity or immediately at the contacts, migmatisation by the Foliated Tonalites has taken place on a small scale and rock types of medium to coarse dioritic or amphibolitic composition are formed. Slightly away from the contact, the metadolerites are rich in lineated and elongated felspathic clots or patches up to 3 cm. long and the matrix of the rock is darkened. The formation of these amphibole-rich diorites or amphibolites suggests a mutual exchange of material between the granitic magma and the metadolerites on a limited scale.

The granitised metadolerites are of minor occurrence. In these rocks acid plagioclase, microcline and a little quartz are developed. Hornblende alters to chlorite and the basic rock is rich in epidote presumably due to the breakdown of the amphibole.

Large flakes of brown biotite, with abundance of sphene and apatite both in the granitic and the metadoleritic rocks, formation of amphibolites and

the contemporaneous development of the felspathic streaks or clots all suggest that felspathisation and basification were simultaneous but depended on variations in local conditions at the time of contact metamorphism.

4. Summary of Contact Metamorphism.

A. - State of rocks previous to contact metamorphism.

It is difficult to determine the exact metamorphic conditions of the rocks just before the intrusion of the Ardara Pluton and other associated bodies. The country rocks had suffered various types of movements and metamorphisms before the emplacement of the granitic rocks. Of these the most important were the orogenic movements followed by a regional phyllonitisation and the development of New Chlorite. The intensity of the movements (if any) connected with this retrogression was low and the mechanical planes such as cleavages and schistosity developed during the main orogeny were retained by the country-rocks. The rocks affected by the granitic activity include recrystallised limestones, pelitic and semipelitic rocks with associated basic igneous rocks and the late lamprophyric dykes and sheets.

Of these the latter were most probably fresh and thus do not provide material for a metamorphic study. The various metamorphosed country rocks, best represented in the Dawros and Rosbeg areas, are on the whole the muscovite - biotite - chlorite (after garnet) - quartz - plagioclase assemblages.

B. - Contact effects.

The contact between the granites and the country rocks makes a semicircular arc. It is sharp and the rocks in the apparently wide aureole display only broadly defined metamorphic zones. Immediately at the main contact of the pluton or around the "Explosion Breccias" rocks of the highest metamorphic grade were produced with the formation of contact minerals such as garnet, sillimanite, andalusite etc., in the pelitic or semipelitic rocks; brown-green hornblende, epidote, sphene and iron ore were produced in the metadolerites; diopside, garnet, sphene, apatite and a little plagioclase were formed in the limestones. An outer belt of thermally altered rocks is characterised by the development of andalusite - schists in pelitic facies.

C. - Timing of the Contact Metamorphism.

That the contact metamorphism is later than all other activities can easily be ascertained by the following structural, mineralogical and other characters observed in the country-rocks affected.

(a) Structural

(i) The regional strike in the area is east-west or NW-SE. An abrupt deflection and curvature in this regional strike is seen in the aureole, due it is suggested to the intrusion of the granitic pluton.

(ii) The production on the bedding and cleavage planes of the IIIrd lineation in the outer zone and of the IVth lineation in the inner zone. Both these structures become weaker and weaker till they disappear in the major regional rocks or even in the outer belt of the aureole. These structures have been shown to be superimposed on the earlier structures;

(iii) Destruction of the Schistosity and other early structural characters such as drag folds in the hornfels at the immediate contact of the pluton.

(b) Mineralogical

(i) The granite intrusion has resulted in the production of hornfelses from the regionally metamorphosed country-rocks; granular rocks are formed from schistose. This textural change is accompanied by the appearance

(b) Mineralogical (Cont'd). of contact minerals such as sillimanite, andalusite, staurolite, garnet, etc.

(ii) Destruction of the New Chlorite formed during the regional retrogression in the rocks of the aureole both in the inner hornfelses and the outer andalusite schists.

(iii) Re-formation of biotite or crystallisation of garnet from the rounded chlorite with garnet relicts, so common in the regional rocks.

(iv) Formation of andalusite along the cleavages or across the minor fault or bedding planes.

(c) Others

(i) Presence of xenoliths of all other rock types including undeformed lamprophyres both in the main granite and in the other minor bodies.

(ii) Local occurrences of andalusite or their shimmers and simultaneous absence of New Chlorite porphyroblasts, well away from any visible igneous activity, indicate once again that thermal effects are superimposed on the regional retrogressive metamorphism.

(iii) Cross-cutting relations of the granitic dykes to lamprophyres confirms the age relations deduced from the xenoliths.

B. - Emplacement of the Pluton

(a) Granite Tectonics and the effect of doming on the country rocks.

It must be emphasized at the very outset, that the question in which we are interested here is not the cause of doming but its effect on the roof rocks. The country rocks are obviously domed and as can be seen from the map, the pluton is almost a circular body. The question therefore of 'space' or 'room' for accommodating the pluton is one of great importance. An apportunity is thus given of studying the way in which such circular masses are emplaced or accommodate themselves to the crustal pattern.

We may with advantage summarise the relevant data. The country rocks are a series of semipleitic schists, minor limestones and basic metadolerites. The granitic mass, in its central or interior portion is made up of almost structureless granodiorite and all foliations present in the sector are in conformity with the well marked and distinct foliations of the outer foliated tonalites. This structure is dominantly in conformity with the schistosity, cleavages and indeed the contact of the country rocks. This foliation is therefore interpreted as a result of flow and the granitic mass as an intruded body. In the northern portion the dip of the planes of foliation is almost vertical and this steep inclination

is maintained in the whole northern sector between 75 - 90 degrees, the inclinations being mostly towards the centre of the massif. In the western portion north of Summy Lough and east or south of Sheshkinmore Lough the foliation is almost north-south and has an easterly steep dip to vertical. Near Ranny Points or immediately north of Owenea Bridge it runs almost in an E - W. direction and has a constantly vertical dip. Likewise the schistosity or the bedding, cleavage around the pluton are very steep in attitude and vary between 70 degrees to vertical towards the interior of the Pluton. At the eastern contacts near Maas (Iyengar,1949) and north of Ardara (Cole, 1902 p.205 and Cheesman 1951) the dip of the country rocks and the foliations in the foliated tonalite (granite) is away from the granite contact into the country rocks. These characters, of the different behaviour by the contact and foliations, would suggest a certain amount of stretching of the covering rocks and the intrusion not as a vertical diapir but as an inclined cylindrical body. The 'room' was provided by forcing aside the country rocks.

From the above, it is now clear that the strike and dip of the country rocks and the foliations in the granite mass are sympathetic, and therefore must be due to the same cause — the intrusion or emplacement of the pluton. The

hornfelsic rocks surrounding the pluton, at least in the northern half of the area, give a continuous outcrop. In this portion the curvature of the regional strike corresponds with the curvature of the foliations of the granite. The steep or vertical lineation (ivth) corresponds with the inclination of the streaks or schlieren of the foliated tonalite, and the tangential (iii rd) lineation of the country schists is the result of tight isoclinal folds due to waves set up in incompetent beds due to the flow of the magma.

Now considering the granitic pluton alone, the foliations of tonalite in particular indicate the direction of greatest flow. According to Balk (1937) the mechanism is that: "the friction of a magma along relatively stationary walls results in layers parallel to that wall, whereby the first stimulus is given by the unequal composition of different portions of the magma". Again he states, "linear parallelism wherever it appears may be taken as a reliable reproduction of the direction of greatest lengthening in the exposed rock during the period when structure developed".

(b) Nature of the Tonalitic Magma:-

The mode and texture of the tonalites, especially the abundant occurrence of minerals such as apatite, sphene, epidote and ilmenite suggest that these rocks are of an abnormal character. On the basis of the similar minerals

present in increased amounts in the tonalite rock, more particularly at the immediate contact of xenoliths and the nature of the hybrid rock types of the Middle Sector, it is apparent that the tonalitic mass is a product of a contaminated magma, in which at some level or other, assimilation of the country rocks has taken place. To some extent evidences of such an assimilation are visible at the present level.

It has already been seen that there is little or no difference in the mineral compositions of the tonalite and the xenoliths of pelitic or semipelitic rocks; their composition is that of an acid magma. This is due to the fact that an acidic magma has become completely mixed with such material. In the case of a contamination due to calcareous xenoliths the changes produced are more marked, the plagioclase is more basic and the formation of a pyroxene with apatite, epidote and pyrite has taken place. In the same way, the changes produced in the tonalite by the quartzite or metadolerite xenoliths are also very characteristic; richness in quartz content and poverty in biotite are due to quartzite and an abundance of hornblende, sphene, epidote and paucity of biotite to metadolerite. In short the entry of material from a xenolith into the magma or vice-versa (in each case) has given rise to the same type of minerals, though in different proportions. Such a production of rock types with similar mineral composition must be due to exchange of material

or reciprocal reaction.

The incorporation of solid rock bodies in the magma is the result of mechanical disintegration, due to which the individual minerals of a xenolith were set free. The possibilities in such an incorporation, as set out by Nockolds (1933, p.562-589) are:-

1. the invaded rocks or xenoliths are not in equilibrium with the magma (this is a result of an early cooling history of a magma),
2. they are more or less in equilibrium,
3. the magmic material is injected en masse into the xenoliths or the country-rocks.

In the present case, characters indicating all three above mentioned possibilities concerning the incorporation of the solid rocks are likely in some degree or other. Further, the occurrence of pyrite, abundance of apatite and large flakes of hornfelsic biotite suggest that the volatiles were also active during the crystallisation of the magma.

From the description of the different rock types of the pluton, their mineral composition and the points discussed in the above paragraphs it is clear that the magma producing these tonalites was contaminated, dioritic or granodioritic in nature.

It is an admitted fact (Nockolds, 1933, 1934a, 1934b)

that normal-looking rock types can be produced by contamination of an acidic magma due to additions of basic rocks. The most important question which therefore confronts the writer is not the origin of a tonalitic magma but (a) the emplacement of the tonalitic mass or the intrusion of the pluton and (b) whether the two marginal tonalites and the central granodiorite are two variations of the same magma intruded at different stages.

(c) Origin of Tonalite Mass:-

In view of the nature of the material emplaced in the formation of the tonalites one has to consider:

(1) Whether these were intrusives as magma or (2) whether they are replacement rocks.

In this regard it will not be out of place to mention, that this particular question has attracted the attention of all Donegal geologists for about a century and their works have been summarised in the earlier pages of this thesis (see pp. 8 - 21). Their opinions can easily be divided: the rocks of the pluton are either intrusive or replacive in nature. On the basis of the detailed study of the granitic rocks and the aureole of the writer's area, he prefers to regard them as of intrusive nature.

The rocks of the pluton consist of the two main rock types (a) the Foliated Tonalites of the outer marginal

zone and (b) the Medium Grained Granodiorite of the central zone and a minor but important third series of the hybrid rocks. The characters of the outer tonalites are such that they give an impression that they may be of either of the origins suggested above.

1. The points in favour of a magmatic intrusive character are:-

Evidence of flow planes and the contact.

(i) The contact is sharp, linear, circular and the effects of forceful intrusion are clear, with the production of a general curvature in the strike of the country rocks.

(ii) The general trend of the foliations of the femic minerals is concordant to the general structures of the surrounding country rocks. At localities where it is discordant the relation of the country rocks with the tonalite does not give an idea of the replacive character.

(iii) Xenoliths of country rocks are generally concordant to the contact and do not show much agmatisation or mobilisation.

(iv) The sharp contacts of xenoliths lying parallel to the streaks or schlieren or foliations in the tonalite suggest a comparatively cool and pasty magma, in which the xenoliths were aligned and

made parallel due to flow in a magma.

(v) Direct contact effects by the tonalites are very marked and there is a wide aureole.

Evidence of petrographical characters.

(i) Streaks of flaky minerals of the tonalite are deviated and curved around a xenolith.

(ii) In the contact rocks and the xenoliths, felspathisation is very minor in degree (and limited to the borders of the xenoliths; on the other hand, the tonalite appears to chill against xenoliths.

(iii) The parallel alignment of the felspars and the biotitic clots or the femic flaky minerals parallel to the general foliation suggest an original structure due to flow.

(iv) Sharp and transitional microscopic characters between the different type of xenolith and the enclosing tonalite. Pelitic types usually have a migmatitic or granitised contact while the quartzite, lamprophyres or some of the metadolerite xenoliths show an absolutely sharp contact.

(v) The foliations of the tonalites are primary.

Evidence of the country rocks.

(i) Rare quartz, pegmatite or granite veins, stringers or dykes cutting through the hornfels.

(ii) Total absence of a cortége of cross-cutting acidic veins (even within short distances) in the country rocks, so common a phenomena observed at the contacts of the granites of replacive character.

(iii) Nowhere is an orientation of platy minerals marked in the hornfelses or even at the immediate contact. On the other hand, they are fine-grained and less developed and are altered to staurolite, sillimanite, garnet etc. showing the thermal effects of a hot magma.

(iv) The development of tangential lineation or flow lines (iiird lineation) gradually dying out in the country schists away from the contact.

(v) Destruction of schistosity and other early formed structures in the aureole.

(vi) Production of cleavage planes parallel to the contact and the impression of a vertical (ivth) lineation of these cleavages and the hornfelses.

(vii) Destruction of New Chlorite in the hornfelses and the reformation of biotite or garnet out of the rounded chlorite (after garnet).

Other evidences.

(i) The oval or somewhat subrounded xenoliths of lamprophyres (now mostly represented by cavities) and the reddish brown belt around the same suggest a hot magma. It should be noted that the longer axes of these xenoliths are generally parallel to subparallel with the general foliations of the tonalite.

(ii) The smaller discordant xenoliths though rare occur only in certain local areas. It seems these have been disturbed and rotated by the frictional drag of the flow. The disoriented smaller xenoliths of Sheshkinmore area appear to have taken up their present position as the result of the double mobilisation i.e. first by the tonalitic and later by the granodioritic magma.

(iii) Presence of xenoliths from unknown horizons suggest a magmatic intrusion.

(iv) The body of appinite enclosed in the tonalite near Summy Lough has its long dimension oblique to the foliation of the tonalite, suggesting movement and rotation by flow.

2. Evidence for replacement nature.

As regards the metamorphic origin of the tonalites by granitisation of the country-rock, points in favour are:-

(i) Their highly foliated nature and the trend of these foliations which are generally parallel to the contacts.

(ii) The orientation of the linear and platy structures, more particularly in the xenoliths of pelitic nature, is the same as the trend of such features in the country rocks.

(iii) The unmoved or little mobilised relict masses of the country rock show slight and very local signs of movement from their original place.

(iv) Granitisation of metadolerite in the Sheshkinmore area, where the lenticular blocks of country-rock lie in conformity with the schists and metadolerites in the aureole.

(v) The general tonalitic rock is similar in composition to the modified pelitic xenoliths and can therefore be considered as result of granitisation.

(vi) Similar type of biotite both in the country-rocks and in the foliated tonalite.

(vii) Growth of plagioclase phenocrysts in the xenoliths, identical to those in the enclosing foliated tonalite; (Michel-Levy's Dents-de-Cheval)

3. Remarks.

When the writer compares the points that seem to support one or other of the two views, he is forced to conclude that the tonalite has been intruded as a viscous body, a condition agreeing with some geologists' concept of magma. The fine grain of the tonalite margin, the absence of apophyses and the production of standard hornfelses are evidences for fluid magma; the structural phenomena of the aureole rocks are evidences of forceful intrusion of viscous or quasi-solid material. The tonalite itself may well be of contaminated or migmatitic origin, as prepeatedly mentioned previously, but theme processes operated at a much deeper level than the present erosion surface; this point is discussed in a later page.

(d) Mode of Emplacement:-

As a result of orogeny and large-scale folding, there were developed many weak zones such as the cross and strike joints in the country rocks. The employment of these for the intrusion of dykes and sheets, so numerous in the whole

area, has already been noted. At the later stages, due to the constant forceful intrusion there were developed many more weak zones through which it seems the acidic magma forced its way and formed what we have called the explosion breccias. Apparently these weak local spots were many in number but limited in their total size. With the uprise of more and more magma through these channels or weak zones, the surrounding rocks, mainly the metasediments, were stretched and rendered plastic. Due to this stretching and plasticity their resistance became weaker and weaker and finally the granitic magma pushed its way and widened out rapidly (Fig.18). At localities where the competent beds were thicker and covered a wider region or where the magma could reach the higher levels at a late stage, this action was less effective and probably formed the 'explosion breccias'. At places where the widening and dilatation or the intrusion of the magma was more easily accomplished, the soft plastic country-rocks were compressed into tight isoclinal folds ; and the same process, it seems, fractured and deformed the more competent rocks such as the metadolerite sheets. The comparatively smaller fragments of these became mobilised and gave rise to the hybrid rocks.

Through such a vertical or slightly inclined cylindrical channel or conduit, upwelling or upthrusting of magma emplaced

the Ardara pluton. During its early stages of intrusion the viscous soda rich magma exerted a vertical push coupled with a pressure at right angles to the steep walls of the funnel. This pressure was imparted as circumferential waves in the country-rocks, and ultimately this has given rise to the tight isoclinal folds and the iiird tangential and ivth vertical lineations in the country metasediments (Fig.18).

At the time of intrusion, stoping of the wall rocks has also taken place and thus the broken rock fragments were constantly added to the invading magma. Due to the heat and later engulfment in the magma, the plastic xenoliths of the country-rocks (particularly those of metasediments) were readily digested and incorporated -- changing the composition and increasing the volume of the magma. The larger xenoliths of basic metadolerite and the limestone were only slightly modified but it seems, that the smaller ones were much affected and were ultimately incorporated to provide the considerable amount of hornblende to the tonalites and the contaminated hybrids.

A little later, in continuation of the earlier intrusion of the tonalitic magma, the second phase, emplacement of potash rich magma took place. As in the first stage, this intrusion also exerted an outward circular push on the partially unconsolidated tonalitic mass. Due to the later

intrusion, the plastic xenoliths of the country-rocks or the solid rock material (quartzite) forcefully brought from deeper levels by the earlier magma, were pushed along with the semi-solid magma and thus were aligned and made parallel to the contact. With these later expansions or dilatations of the magma and consequent thrusting aside of the xenoliths, the country-rocks and the partially solidified tonalite, the biotite or hornblende crystals of the streaks or xenoliths were damaged. It would be worth noting again that inclusions of twisted cleavage biotite flakes and plagioclase with bent twin lamillae are commonly found in the microcline phenocrysts of the hybrid rock series.

Thus with the fresh uprise of magma, the inflation of the pluton went on, distending the foliations of the tonalite and the semiplastic country-rocks. The direct and immediate consequences of this are recorded in the country rocks by the impression of the 'IIIrd.' and 'IVth.' lineations.

The present nature of the country-rocks around the pluton is the result of the conditions in these rocks prevailing at the time of the granite emplacement, and can be compared to those of the rocks farther away from the contact. These changes are best exhibited by the formation of new minerals and structures in the pelitic or semipelitic metasediments which come to show a hornfelsed and recrystallised texture.

Criteria for two phase intrusion of the pluton:-

(i) Presence of a sharp contact between the foliated tonalite and the Medium grained Granodiorite marked by an arcuate depression between the two types of rocks.

(ii) Presence of a well developed foliation in the tonalite throughout, unlike the Medium grained Granodiorite, which is feebly foliated even at its outer margins.

(iii) A higher proportion of the darker constituents in the tonalite than in the central granodiorite which is rich in these constituents only at or near the contact with the metadolerite xenoliths or generally rich in microcline, microperthite and quartz.

(iv) Presence of rounded or subrounded, turbid and sericitised plagioclase in the fresh microcline of the granodiorite.

(v) Presence of microscopic thin veins of microcline and quartz rich veins cutting through the sericitised plagioclase inclusions of microcline or sometimes through the plagioclase of tonalite, as for example near Summy Lough. In the hybrid rock series such veins

are also rich in epidote and generally they are seen merging in the microcline on either side.

(vi) Presence of light green epidote veins cutting atbright angles through the foliations of the tonalite immediately east of Summy Lough, in Derryness Island and North Ranny Point.

(viii) Cross cutting relations of coarse pink-coloured microcline rich veins in the tonalites, near the houses north of Mooney's Lough.

(e). Summary and Discussion:-

For nearly a century, Donegal granites have attracted the attention of several geologists. Various theories have been put forward by them with regard to their origin, some advocating that they are metamorphic, others igneous and still others that they are both igneous and metamorphic in character. These different views have been summarised by the writer in pp.8-21.

Cole in 1902 designated certain types of granitic rocks as 'composite gneisses' (1902, pp.203-230). On the basis of his field study of the country rocks in general and the granites in particular he came to the conclusion that similar composite gneisses constitute the 'Ardara Dome'. He

also added that it was in the nature of a laccolith and stated: "the igneous rock has come up laccolitically along one of these surfaces, forming a low granite dome north of Ardara" (1902, p.205).

Recent structural study of the eastern portion of the country rocks and granite (Iyengar 1949; Read and Pitcher 1951 and 1952) and the western portion by the writer has led the author to believe that the 'Aradara Dome' may be considered as a 'diapir' (Wegman 1935) or a 'pluton' (Cloos 1936). Gindy (1950 and 1952) following Read (1948) advocated a'Unity of Plutonism' (Read 1948 p.196) for the Donegal granites. According to Read (1948A and 1948B) the granitic rocks of the Ardara Pluton form the end member of the 'Granite Series' in which the "younger parts are richer in potash due to the differential mobilisation" (1949, p.149).

E. Cloos (1936) consequent on his detailed observations in Yosenite region of California advanced the idea that the Sierra Nevada batholith has resulted from successive outbursts of magma which now constitute a series of plutons placed within a major structure. Applying this, Mayo (1941 pp.1001-1084) has demonstrated that such forceful intrusions of magma gives rise to a chain of plutons and build up the large batholiths.

Considering the various points enumerated before in subsection (d) (pp.386-390) and the large space occupied by

the Ardara pluton consisting of two distinct rock types, it may be concluded that the emplacement of the granite body is the result of the operation of forceful mechanism during two stages of the uprise of acidic magma.

XIII Latest Retrogressive Metamorphism and Dislocation.

From the descriptions of the contact metamorphosed country schists and of the different types of granitic rocks given in the preceding sections of this Thesis, it appears that these rocks have undergone some kind of retrograde metamorphism which can be related in many cases to a very late episode of dislocation. Such dislocations are exemplified by the E - W fault affecting the granitic rocks south of Craig's Town (S.W. of Kilclooney Church) and extending up to the west side of Summy Lough. Petrographically, this event is marked by a wide range of phenomena. These include the alteration of sillimanite to muscovite in the sedimentary xenoliths enclosed in the Foliated Tonalites, and in the hornfelses of the aureole. In the granite and country rocks affected by these dislocations, biotite is converted into chlorite. Other results are the sericitisation of plagioclase felspars, in many rocks e.g. hybrid granodiorites, the formation of epidote in the metadolerites.

The granulation of quartz and the formation of perthitic microcline in the coarse pink or the medium

grained granodiorites of the Middle Sector assigned to this phase.

Textural and structural evidence is provided by such phenomena as the formation of shear zones mainly in the granite e.g. near the Kilclooney Parachdad House and Mooney's Lough; similar zones are found in the country schists and hornfelses north of Doon Lough and S.E. of Narin Hill. Bending of twin lamellae in the felspars and of cleavages in the micas of the tonalites, or similar features found in the plagioclases of the hybrid diorites or of the country schists as near Aghros Hill, Rosbeg P.O. etc. belong also to this episode.

The very latest event appears to be the rising of boron-vapours up the fracture-zones with the formation of tourmaline in the broken up granites and the country rocks alike e.g. the occurrence of prismatic crystals of tourmaline up to 1 inch in length in the Foliated Tonalites east of Summy Lough. Tourmaline in similar settings is found around the xenoliths of quartzite, at the contacts of the metasediments and the pluton, in the semipelitic rocks near Terrylagh and in schists between Doon and Birroge Loughs.

This late episode is perhaps most widely recorded by the vth lineation present both in the granites and the country rocks e.g. near Craig's Town, at Narin Hill or in the brecciated rocks of Narin Hill. An account of this lineation has been given in the description of the tectonics of the area.

XIV. Conclusion.

From the foregoing, it is apparent that for a final demonstration of the very complex geological history of the Portnoo region much more detailed petrographical and chemical work is required. The writer considers that the main outlines of this history are established. More detailed work is however necessary for certain episodes; this is particularly the case in connection with the regional retrogressive metamorphism, the classification of the lamprophyres and the relation (if any) between the explosion-breccias, appinites and granites. This Thesis is put forward as a contribution to the study of what is possibly the most interesting of the Donegal Granite, the Ardara Pluton.

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	B.	Preliminary report on the Caledonian orogeny in Christian X's Land (N.E.Greenland) Med.om.Groland, 103,No.3.
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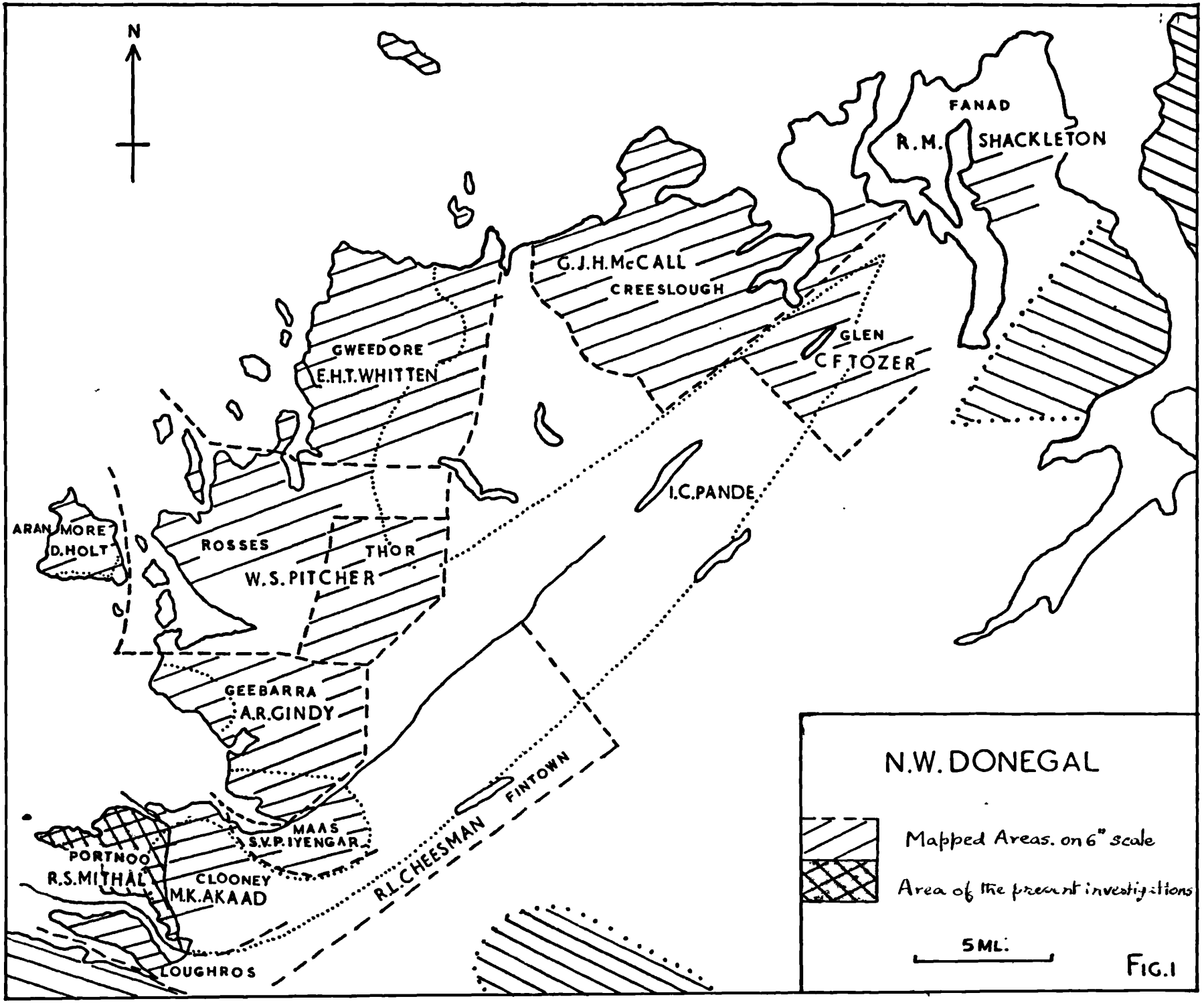

N
FANAD
R.M. SHACKLETON
G.J.H.McCALL
CREESLOUGH
GLEN
C.F.TOZER
GWEEDORE
E.H.T.WHITTEN
I.C.PANDE
ARAN MORE
D.HOLT
ROSSES
THOR
W.S.PITCHER
GEEBARRA
A.R.GINDY
MAAS
S.V.P.IYENGAR
PORTNOO
R.S.MITHAL
CLOONEY
M.K.AKAAD
R.L.CHEESMAN
FINTOWN
LOUGHROS
N.W. DONEGAL
Mapped Areas. on 6" scale
Area of the present investigations
5 ML.

FIG.1

Fig. 2A & B. Drag folds and crenulations in the Portnoo Limestone.

2C & D. Pencils of quartz (knots) in graphitic bands of the Portnoo Limestone

2E Sigmoidal cleavage in siliceous and graphitic bands at Portnoo Harbour.

2F Graded bedding in Portnoo Limestone shown by garnet crystals, Dunmore Cliffs

FIG. 2

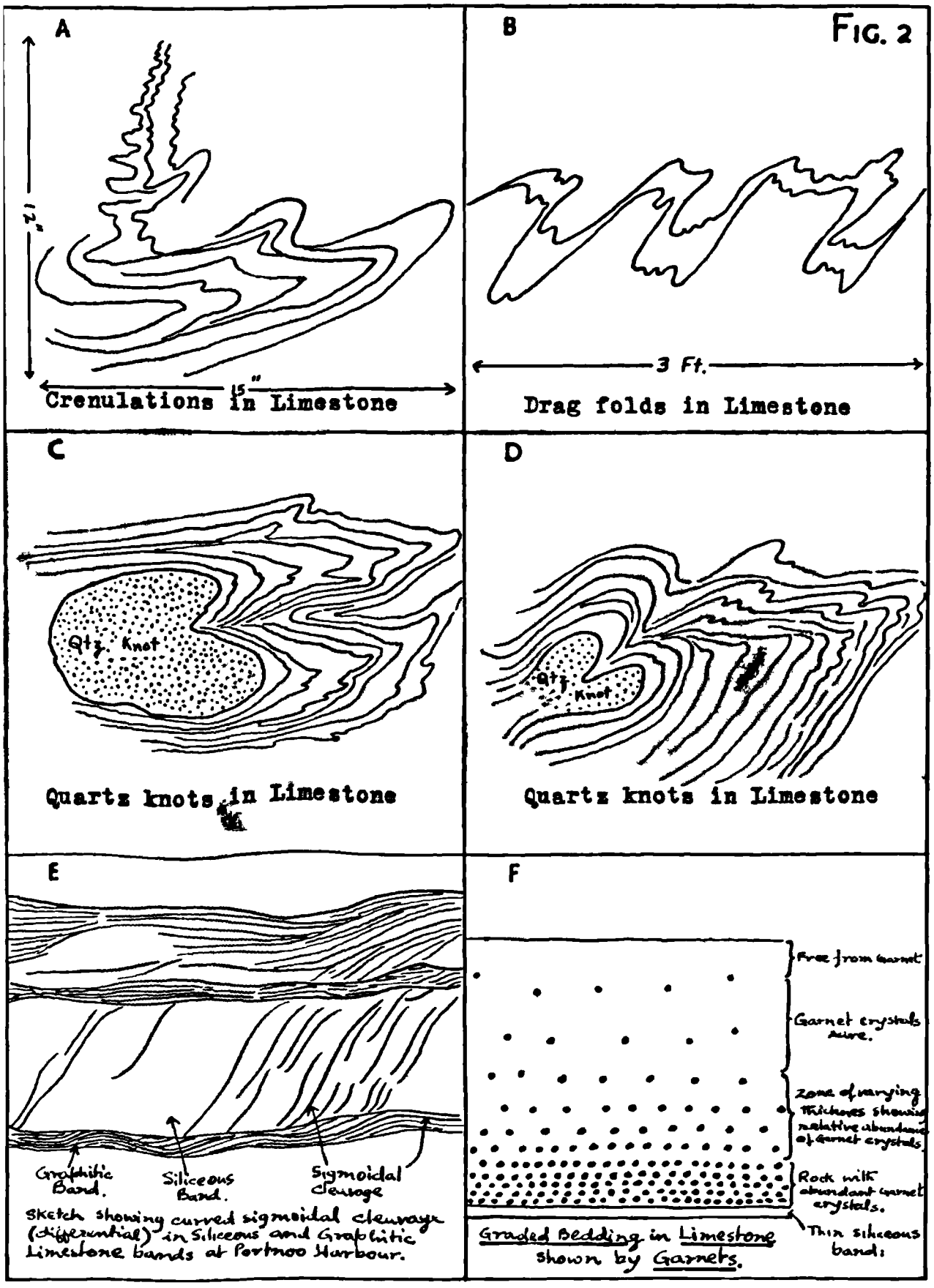

A
12"
15"
Crenulations in Limestone
B
3 Ft.
Drag folds in Limestone
C
Qtz. Knot
Quartz knots in Limestone
D
Qtz. Knot
Quartz knots in Limestone
E
Graphitic Band.
Siliceous Band.
Sigmoidal cleavage
Sketch showing curved sigmoidal cleavage (differential) in Siliceous and Graphitic Limestone bands at Portnoo Harbour.
F
Free from garnet
Garnet crystals scarce.
Zone of varying thickness showing relative abundance of garnet crystals.
Rock with abundant garnet crystals.
Thin siliceous bands
Graded Bedding in Limestone shown by Garnets.

Fig. 3A Curved and irregular quartz veins cutting through deformed current bedding near Portnoo P.O. (in Portnoo Limestone).

3B Inverted and distended current bedding in Portnoo Limestone at Dunmore Cliffs.

3C Folded and deformed current bedding in siliceous limestone band, Portnoo Harbour.

FIG. 3

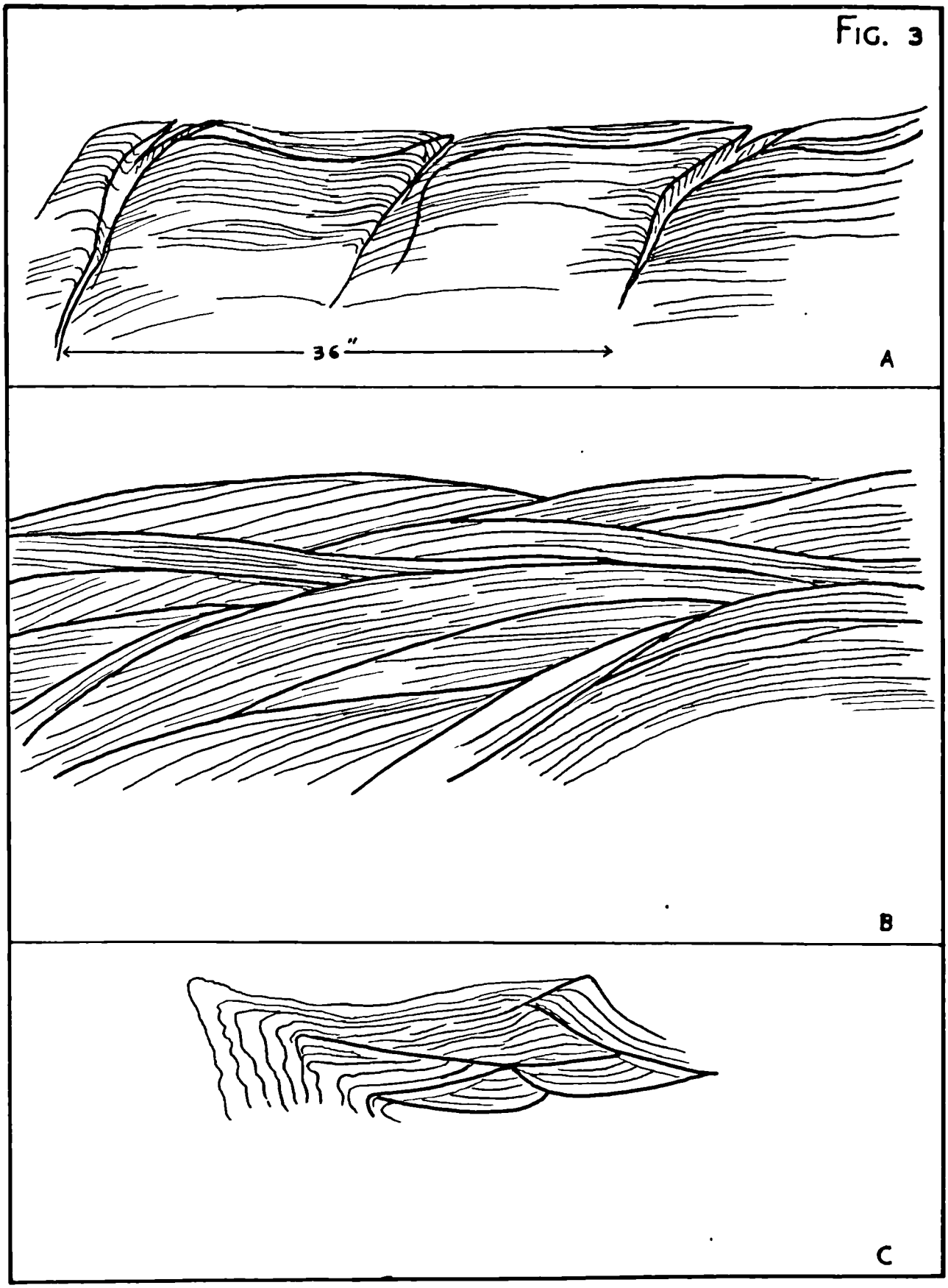
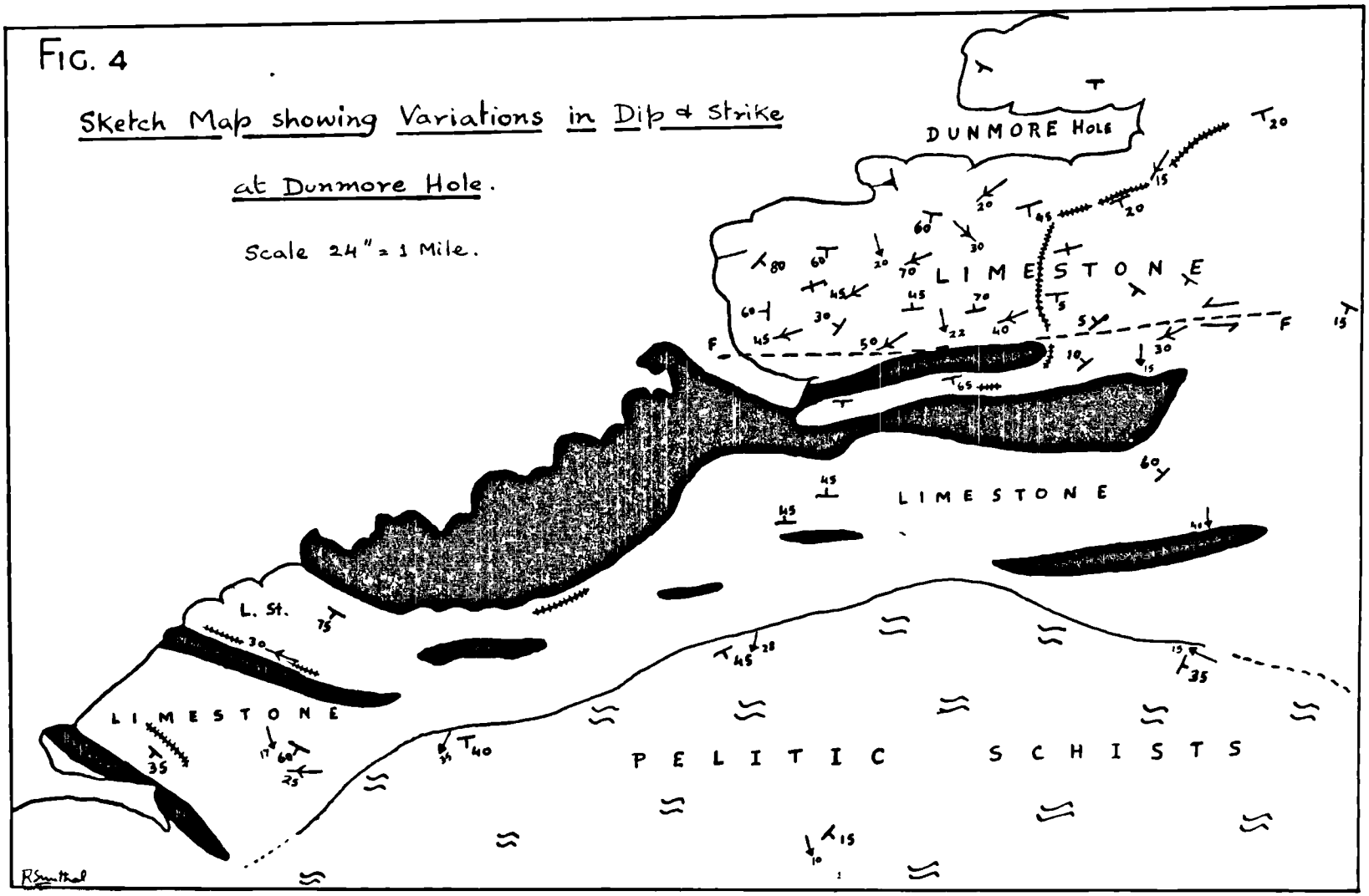
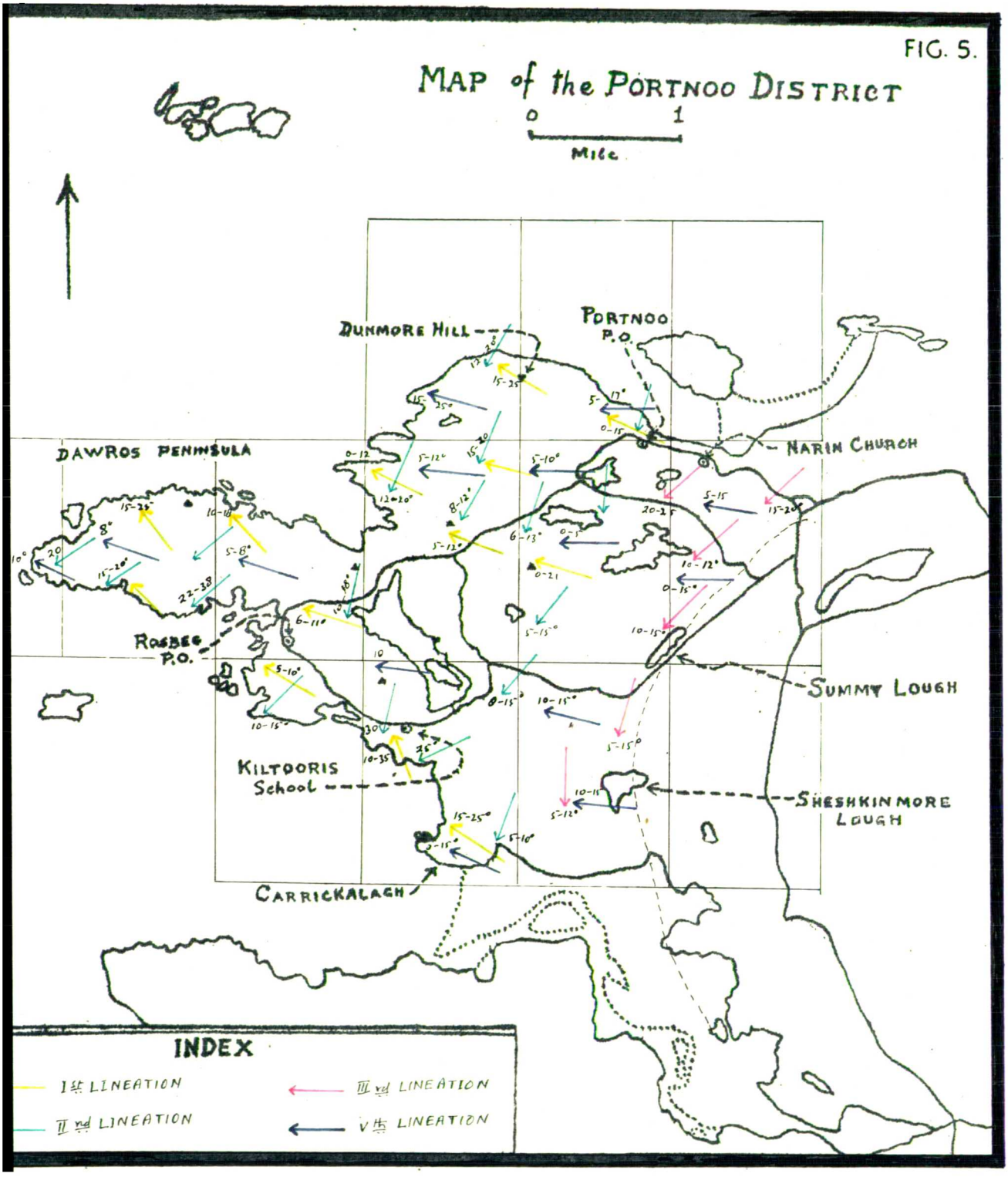


FIG. 4

Sketch Map showing Variations in Dip & Strike at Dunmore Hole.

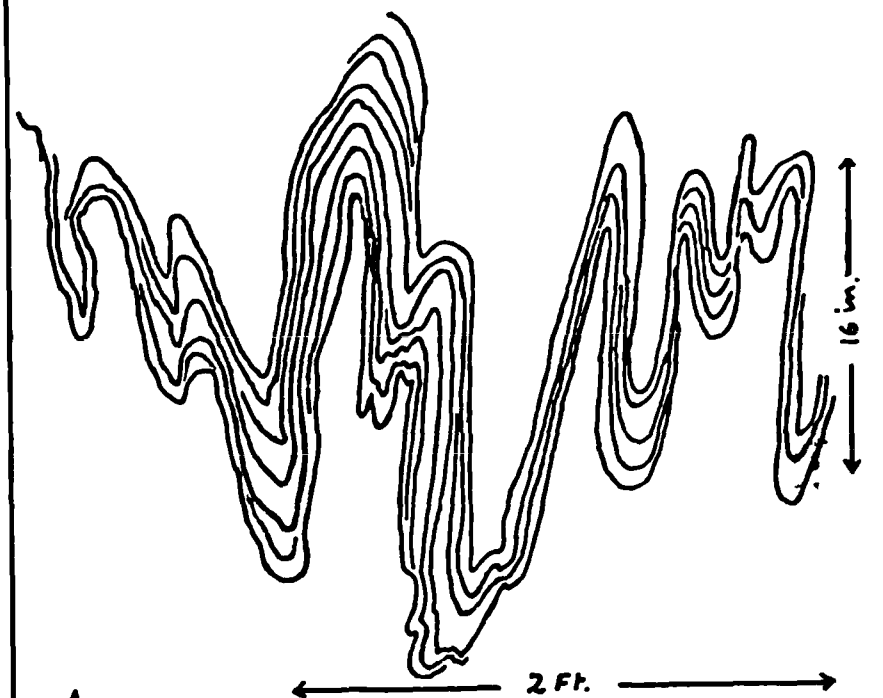
Scale 24" = 1 Mile.





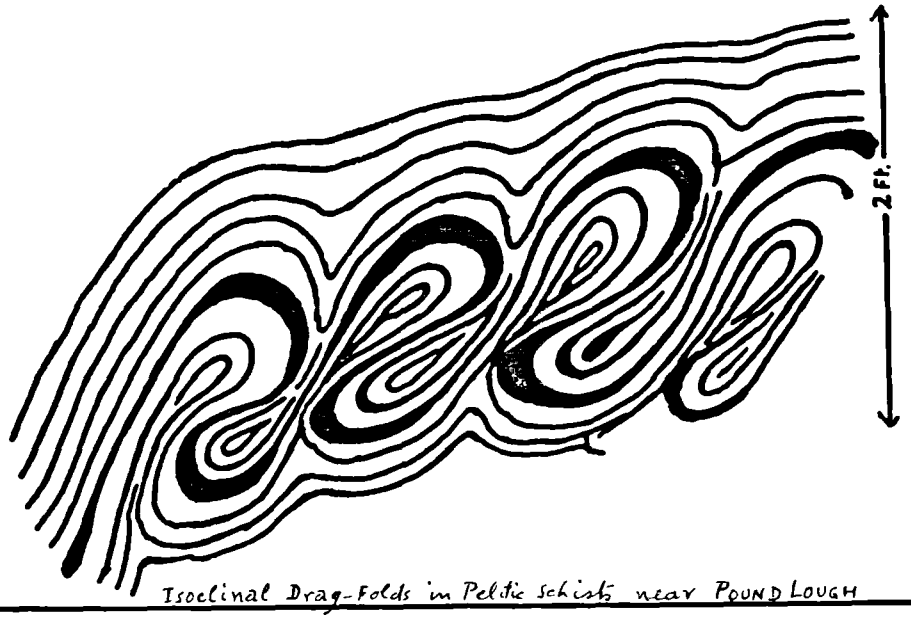
Sketch map showing the trend of different lineations.

FIG. 6



A

Drag-Folds in Semi-Pelitic Schists, Pollmurry



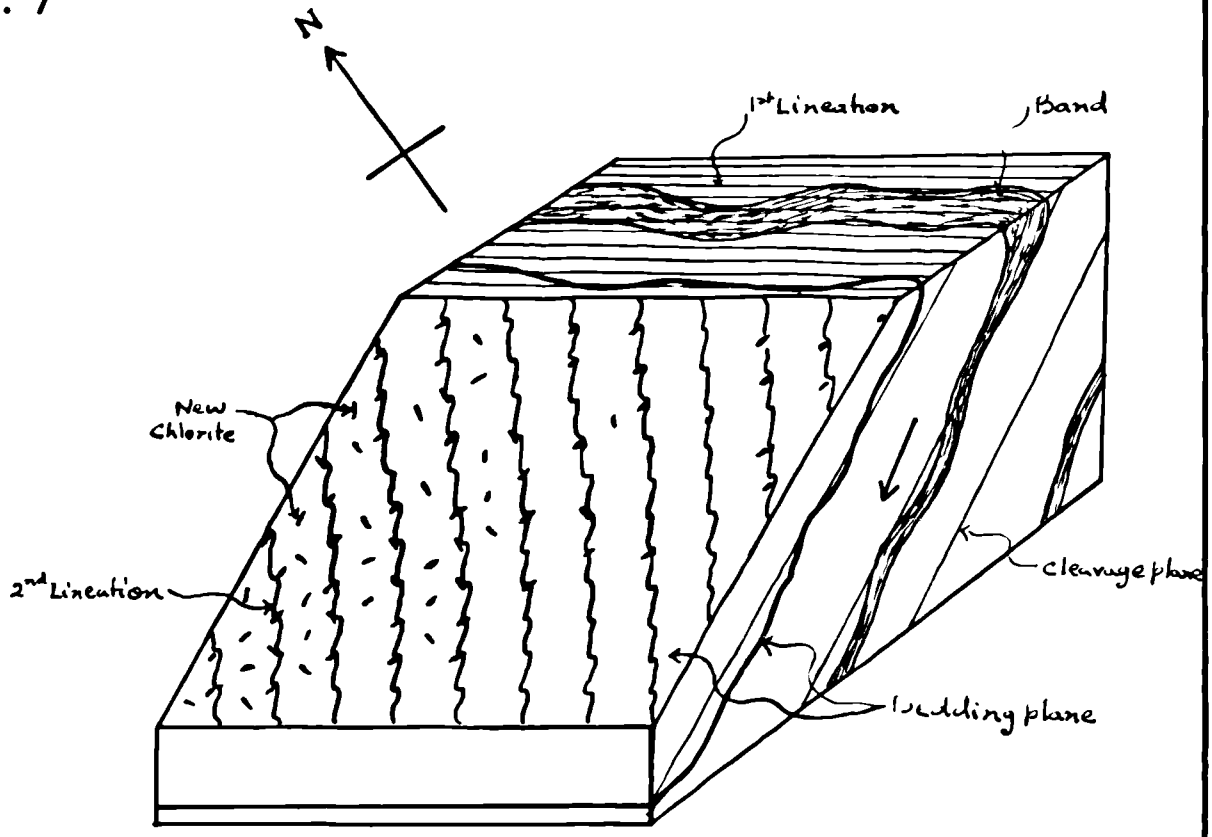
B

Isoclinal Drag-Folds in Pelitic schists near POUND LOUGH

Fig. 7 Block diagram showing relationship of Bedding, banding, Foliation, ist. iind. lineations and the New chlorite in the Rosbeg semipelitic schists.

Fig. 8. Field sketch showing the pushing of vth. lineation by the growth of Andalusite crystals in the semipelitic schists of the outer margin of the aureole, near Doon Lough. (see also Pl.IV)

FIG. 7



Block Diagram showing the relationship of Bedding, Banding, Foliation, 1st & 2nd Lineations and the New Chlorite.

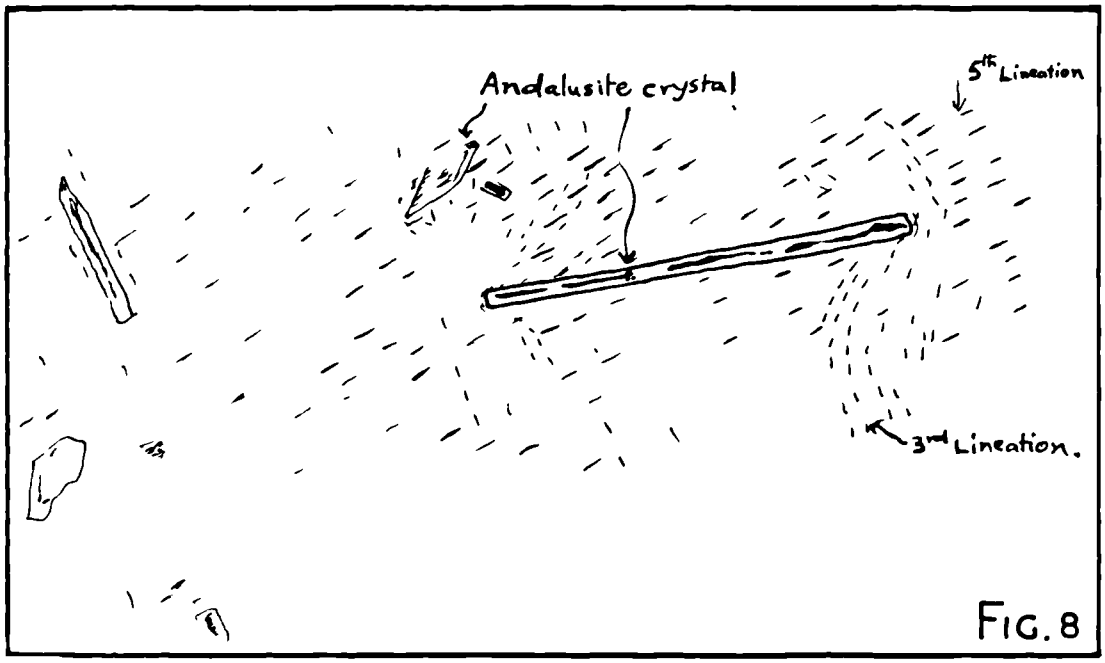


FIG. 8

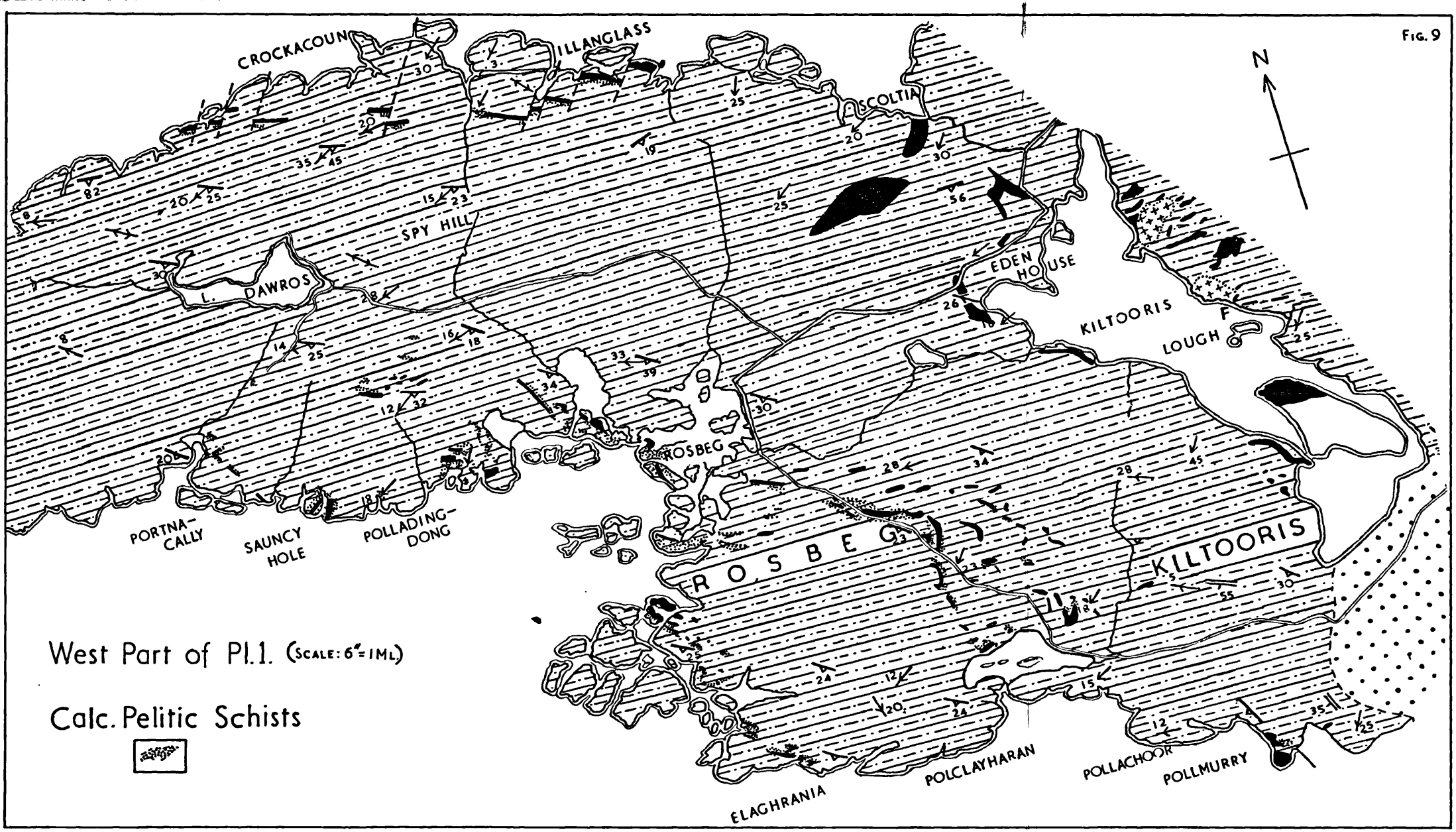

Fig. 9
N
CROCKACOUN
ILLANGLASS
SCOLTIA
SPY HILL
L. DAWROS
EDEN HOUSE
KILTOORIS
LOUGH F
ROSBEG
PORTNA-CALLY
SAUNCY HOLE
POLLADING-DONG
ROSBEG
KILLTOORIS
ELAGHRANIA
POLCLAYHARAN
POLLACHOOR
POLLMURRY
West Part of Pl.1. (Scale: 6"=1ML)
Calc. Pelitic Schists

FIG. 10

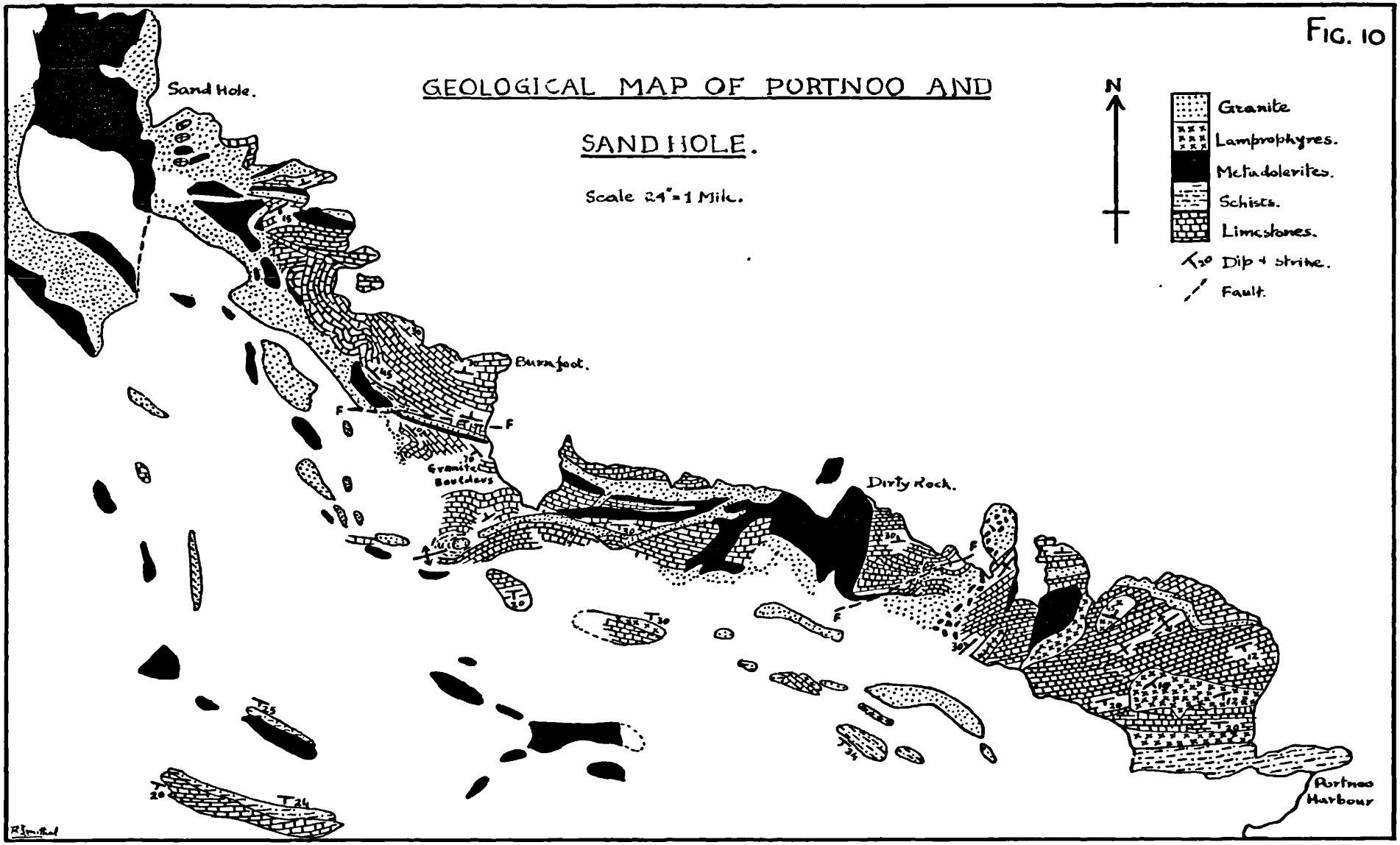

GEOLOGICAL MAP OF PORTNOO AND SANDHOLE.
Scale 24"=1 Mile.
N
Granite
Lamprophyres.
Metadolerites.
Schists.
Limestones.
Dip & strike.
Fault.
Sand Hole.
Burnfoot.
Granite Boulders
Dirty Rock.
Portnoo Harbour

Fig. 11A Offsets in felsite dyke near Pollateda

B Blebs of lamprophyric material at the eastern coast of Portawand.

C Screens of country schists and Fingers or apophyses of felsitic material at Pollateda.

D Offsets, Stringers, blebs and fraying of a pink felsite dyke W. of Crocakuna, (N. Daros coast line).

E Screen of country schist and stringers of grey lamprophyre west of Illanglass.

F Fraying of a grey lamprophyre in country schi south of Portntrawbane.

FIG. 11

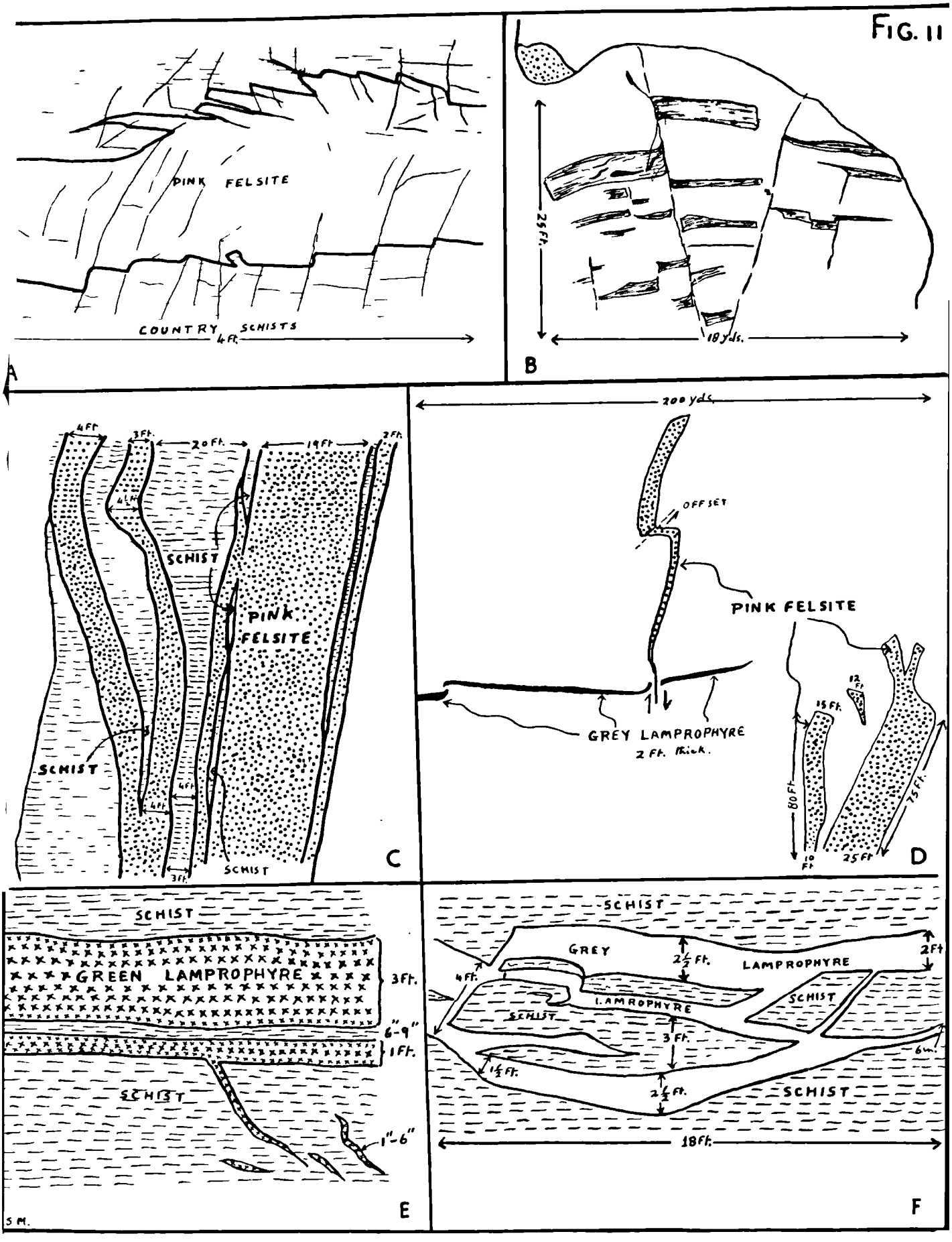

PINK FELSITE
COUNTRY SCHISTS
4 Ft.
A
25 Ft.
18 yds.
B
4 Ft.
3 Ft.
20 Ft.
19 Ft.
2 Ft.
4 Ft.
SCHIST
PINK FELSITE
SCHIST
4 Ft.
4 Ft.
3 Ft.
SCHIST
C
200 yds.
OFFSET
PINK FELSITE
GREY LAMPROPHYRE
2 Ft. thick.
12 Ft.
15 Ft.
80 Ft.
10 Ft.
25 Ft.
75 Ft.
D
SCHIST
GREEN LAMPROPHYRE
3 Ft.
6"-9"
1 Ft.
SCHIST
1"-6"
E
SCHIST
GREY
2½ Ft.
LAMPROPHYRE
2 Ft.
4 Ft.
LAMPROPHYRE
SCHIST
SCHIST
3 Ft.
1½ Ft.
2½ Ft.
SCHIST
18 Ft.
F

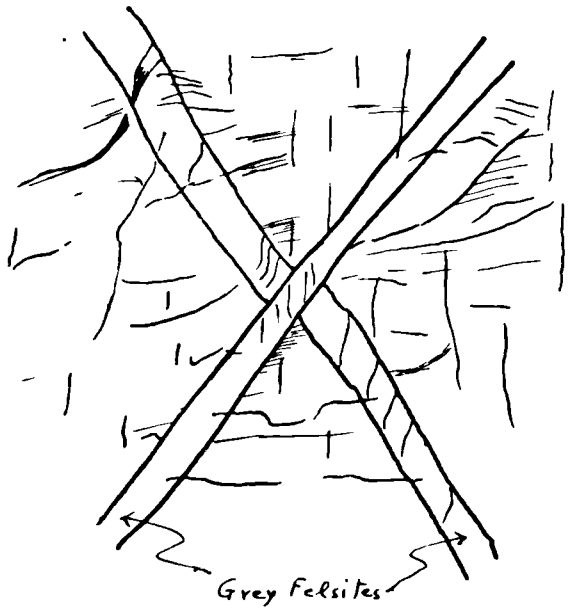
Fig. 12A Cross-cutting relationship of grey felsites at Carrickacuna.

B Cross-cutting relationship of a grey felsite and a xenolithic dyke south-east of Portnacally.

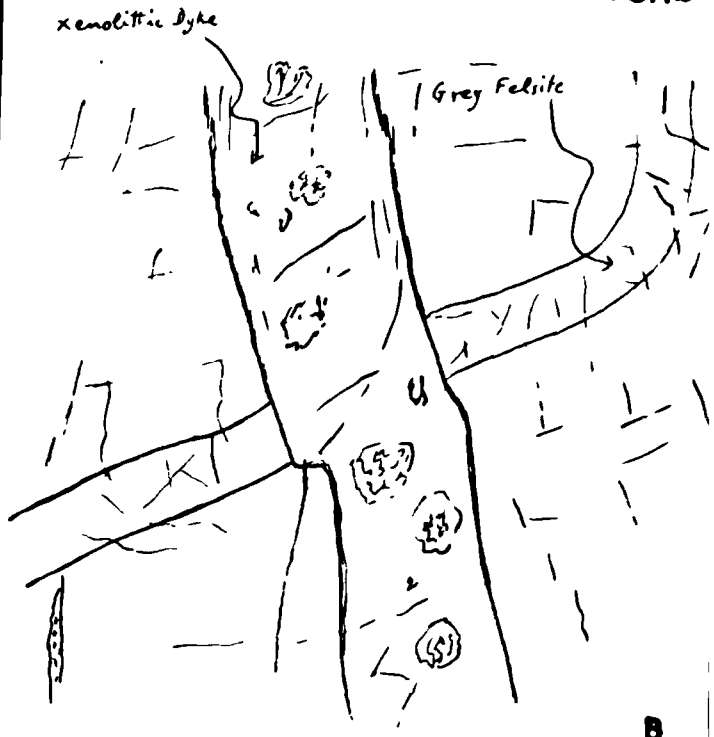
C Cross-cutting relationship of a grey felsite and Late felsite near Carrickacuna.

D Cross-cutting relationship of grey lamprophyre, spherulitic felsite, green xenolithic lamprophyre and quartz veins, south of Aghros Point.

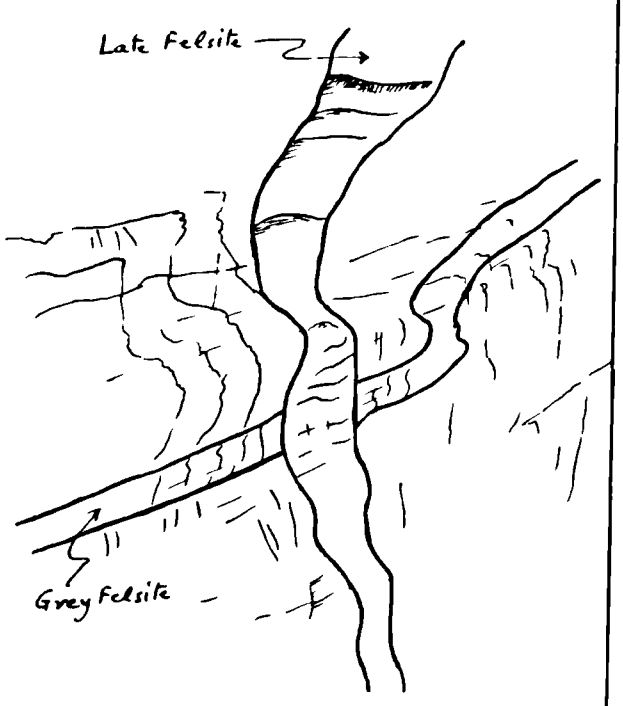
FIG. 12


Grey Felsites

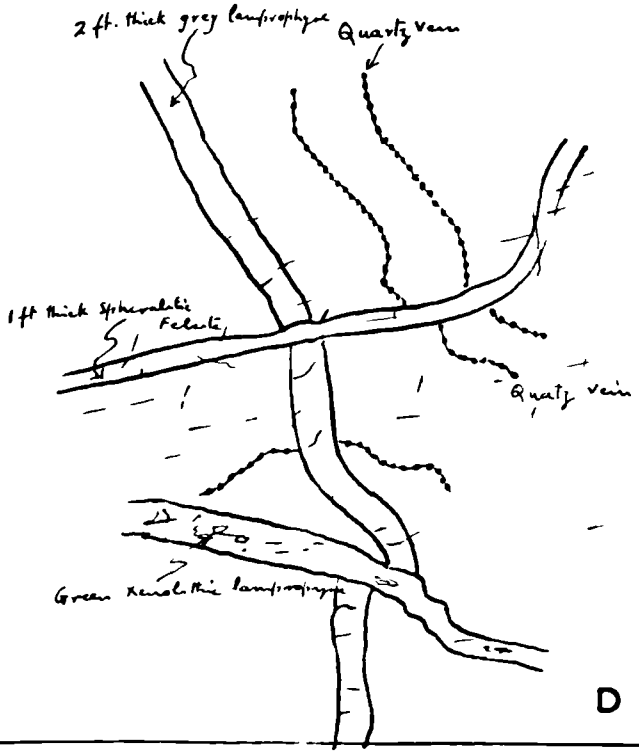
A


xenolithic dyke
Grey Felsite

B


Late Felsite
Grey Felsite

C


2 ft. thick grey lamprophyre
Quartz vein
1 ft thick Spherulitic Felsite
Quartz vein
Green xenolithic lamprophyre

D

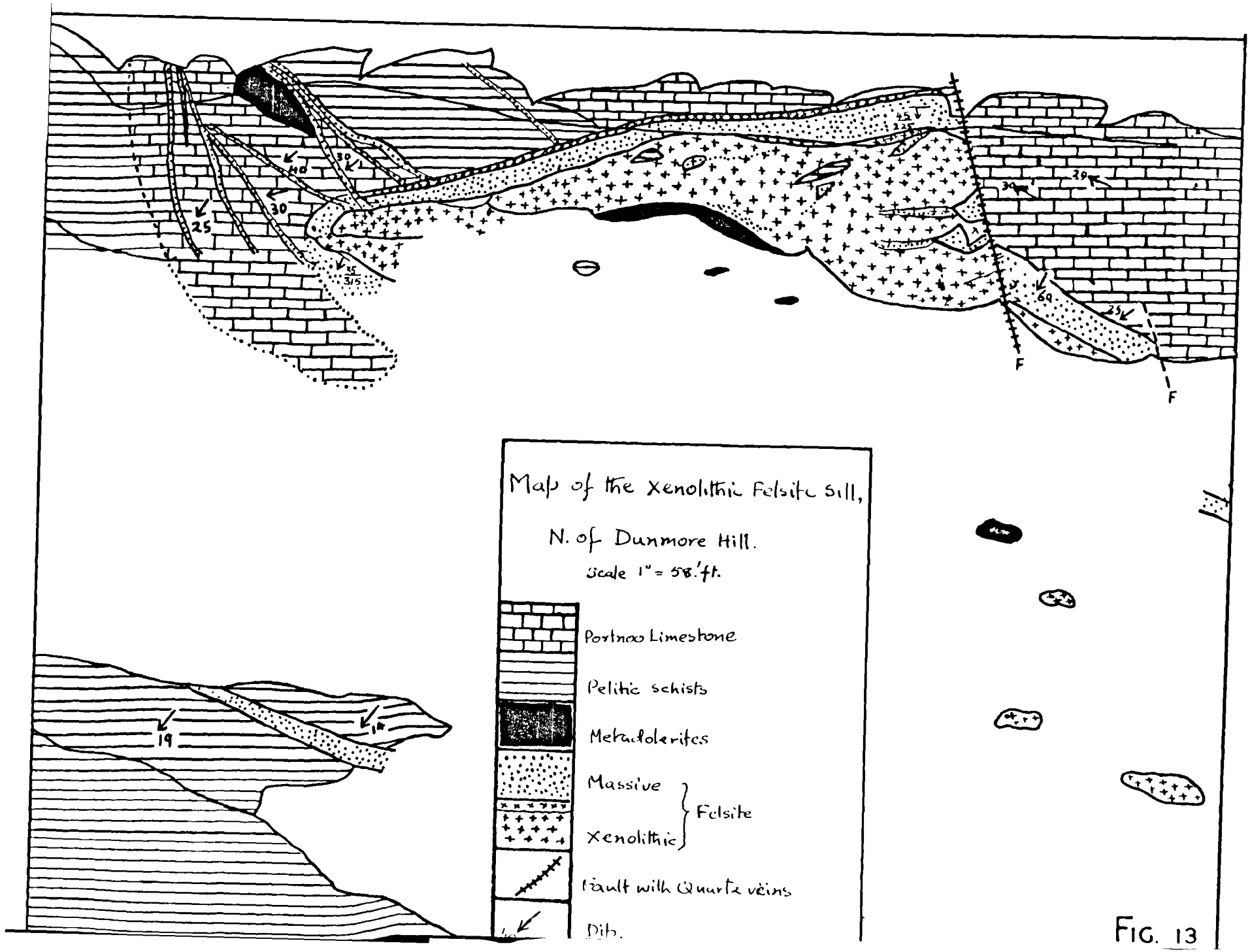

Map of the Xenolithic Felsite Sill,
N. of Dunmore Hill.
Scale 1" = 58.4ft.
Portnoo Limestone
Pelitic schists
Metadolerites
Massive
Xenolithic
Felsite
Fault with Quartz veins
Dip.
F
F
25
30
19

FIG. 13

Fig. 14 Generalised profile section of the granite and country hornfels between Ardara Road -- Mooney's Lough and West of Summy Lough.

Fig. 15A Field sketch showing faulted bands in the Semipelites and the growth of andalusite crystals across the fault and the individual bands of the hornfels near Narin Hill.

B Field sketch showing folded bands and the growth of cleavage and andalusite crystals across the bands (of hornfels) near Narin Hill

FIG.14

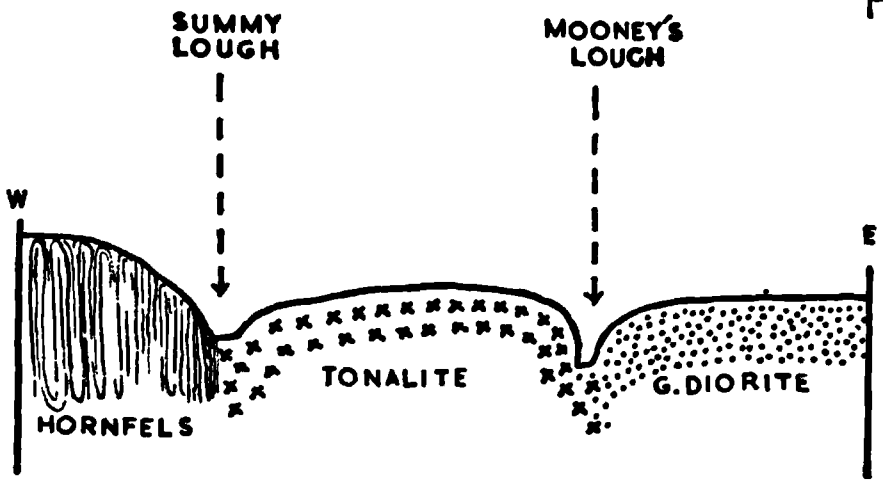
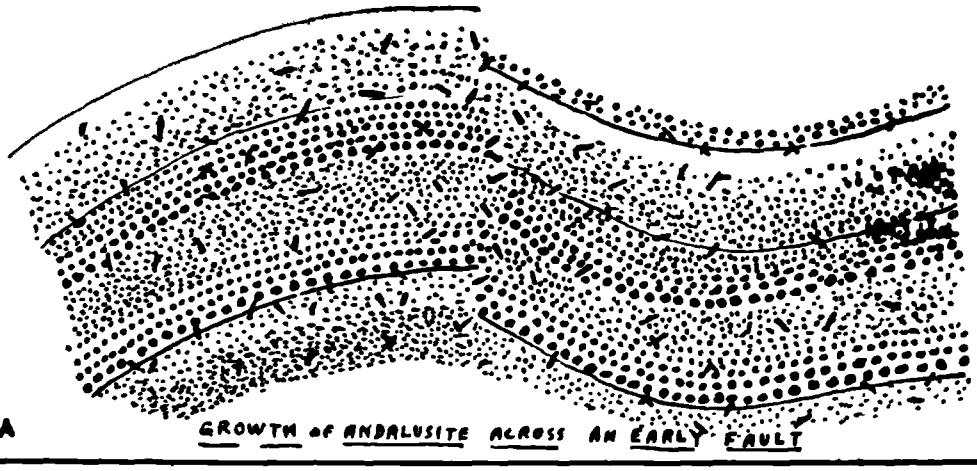

SUMMY LOUGH
MOONEY'S LOUGH
W
E
HORNFELS
TONALITE
G.DIORITE

FIG.15


A
GROWTH of ANDALUSITE ACROSS AN EARLY FAULT

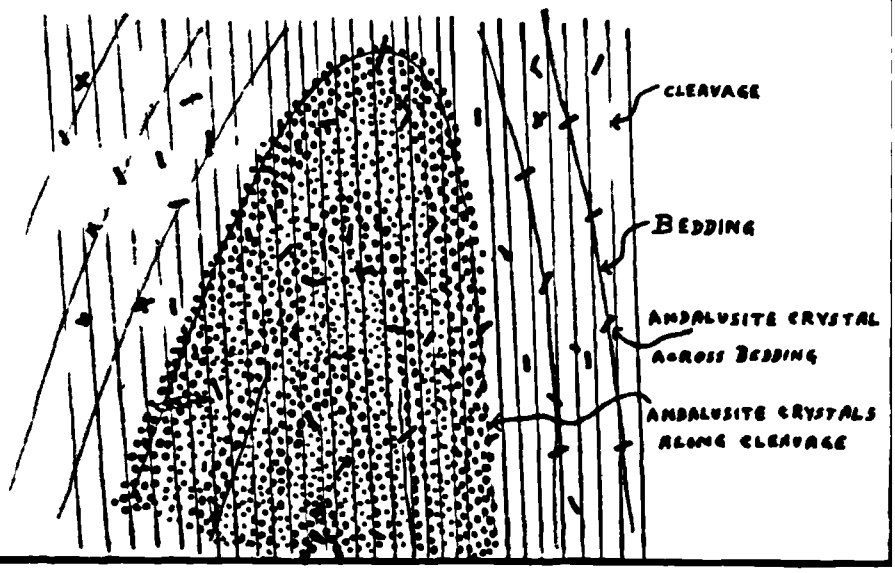
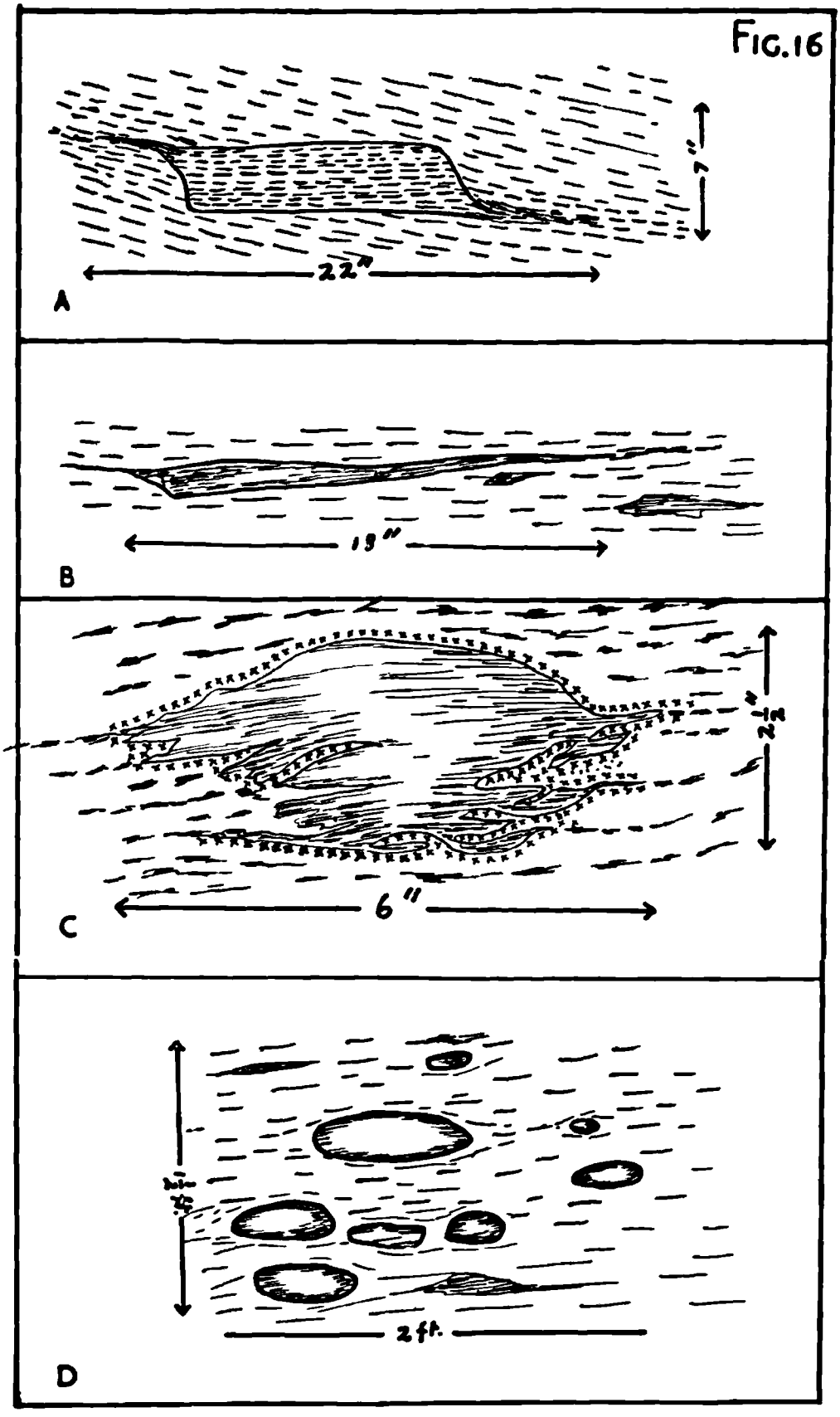

CLEAVAGE
BEDDING
ANDALUSITE CRYSTAL ACROSS BEDDING
ANDALUSITE CRYSTALS ALONG CLEAVAGE
B

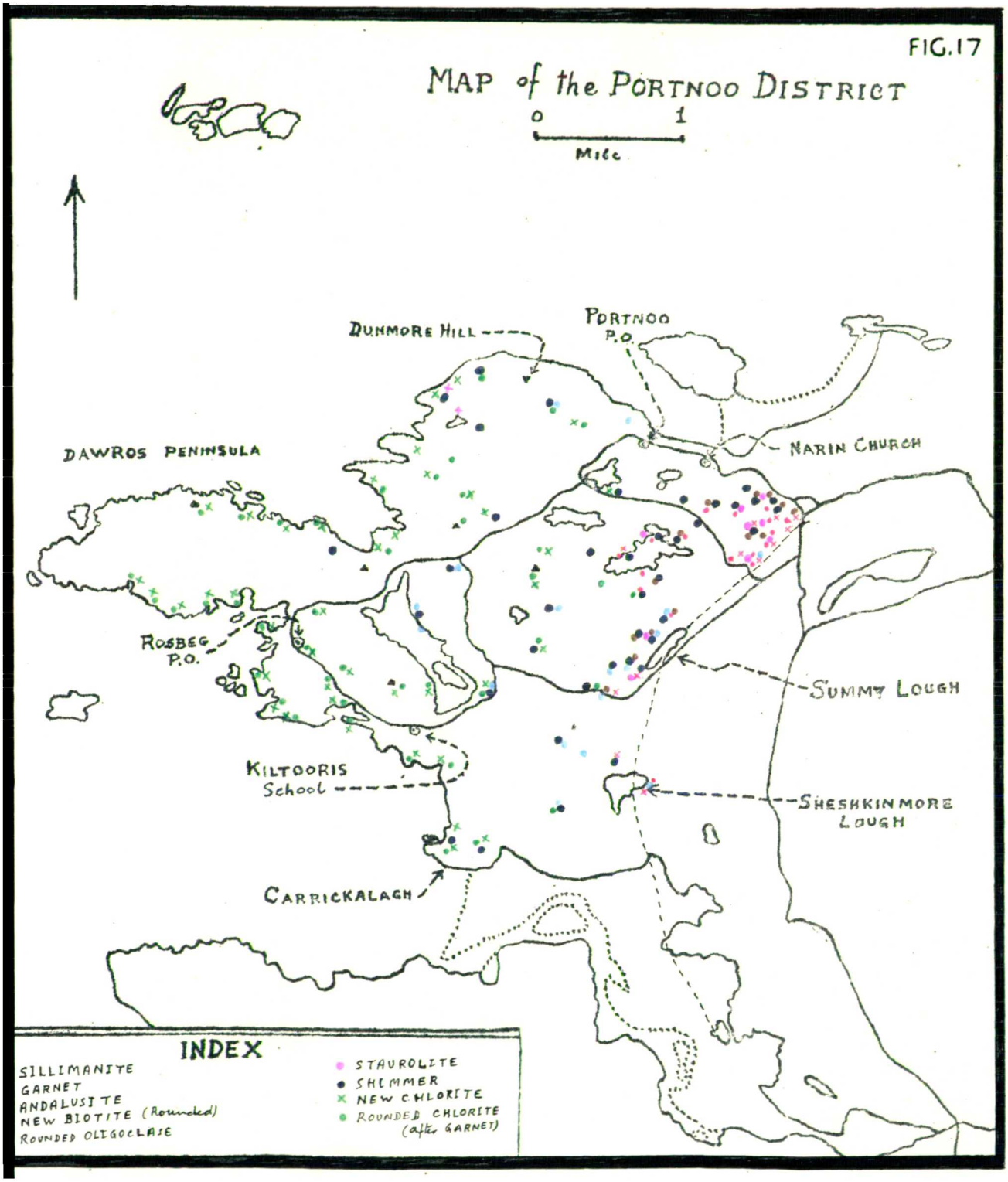
Fig. 16A & B Xenoliths of pelitic metasediments and the schlieren in the Foliated Tonalite, NE of Summy Lough.

C Semipelitic xenolith with chilled margins of Foliated Tonalite around it, NE of Summy Lough.

D Subrounded or oval cavities with dark brown rims of ferruginous material in the Foliated Tonalite, NE. of Summy Lough.

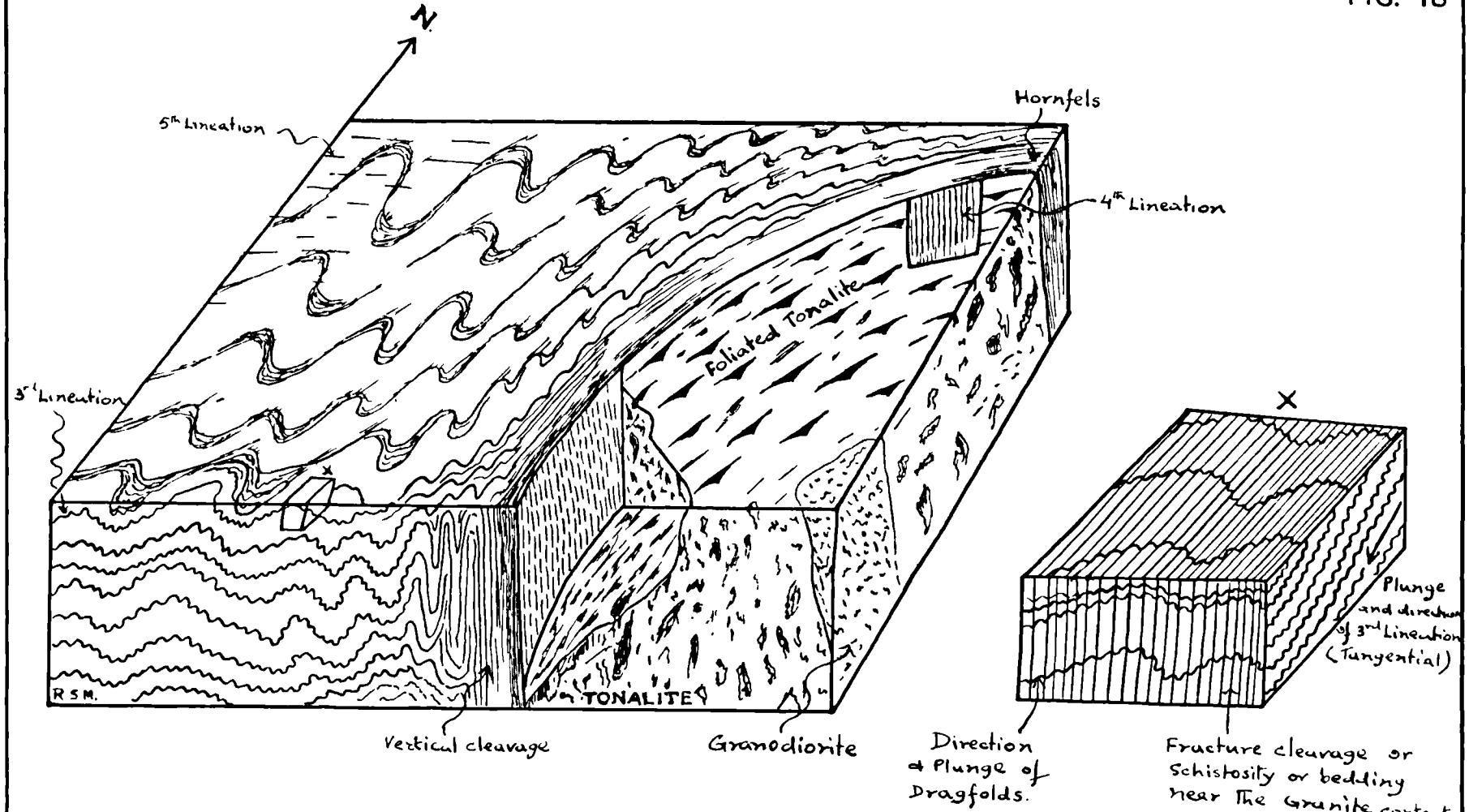
FIG. 16



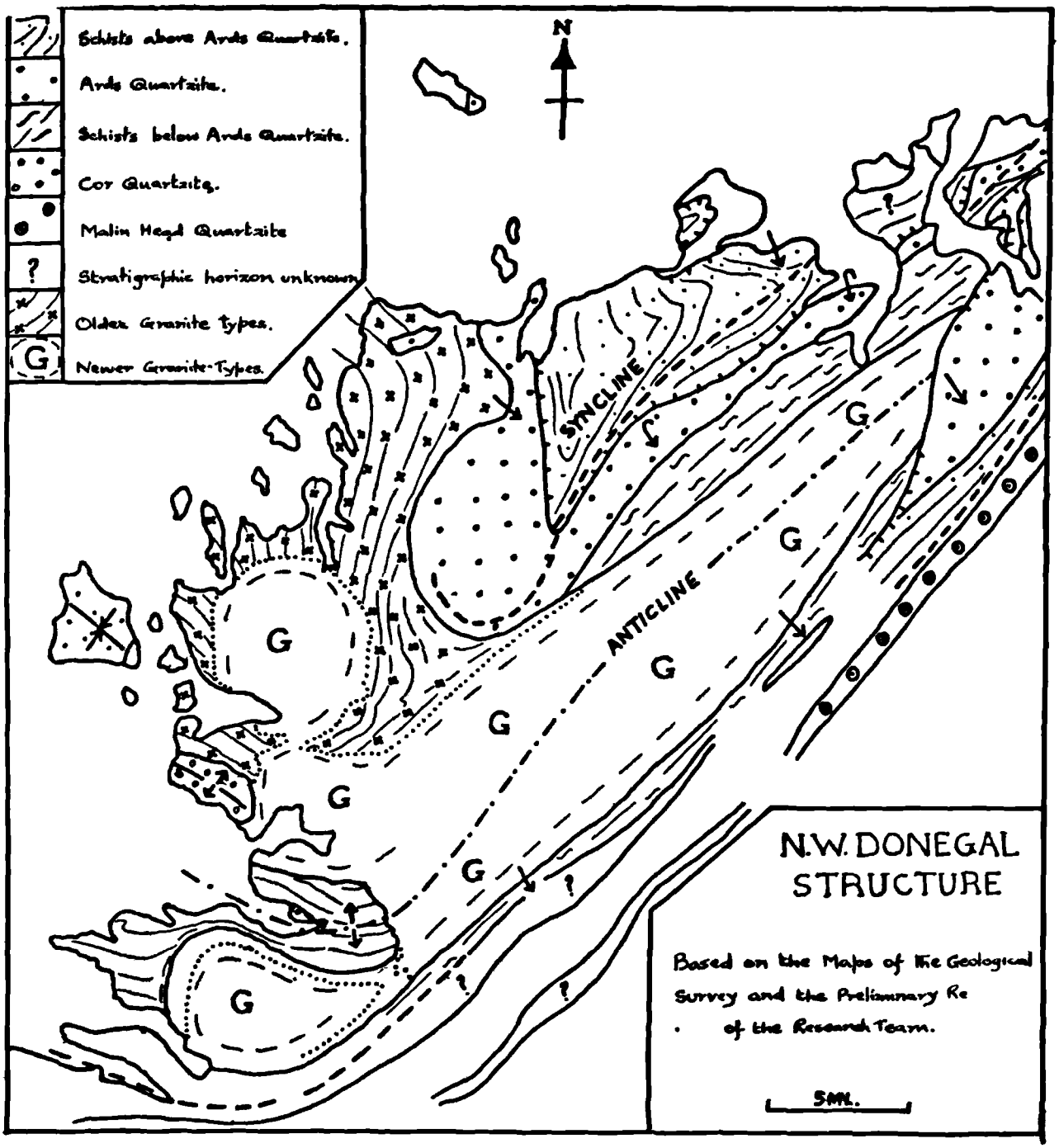


Sketch map showing the distribution of metamorphic minerals in thin sections of rocks studied.

FIG. 18



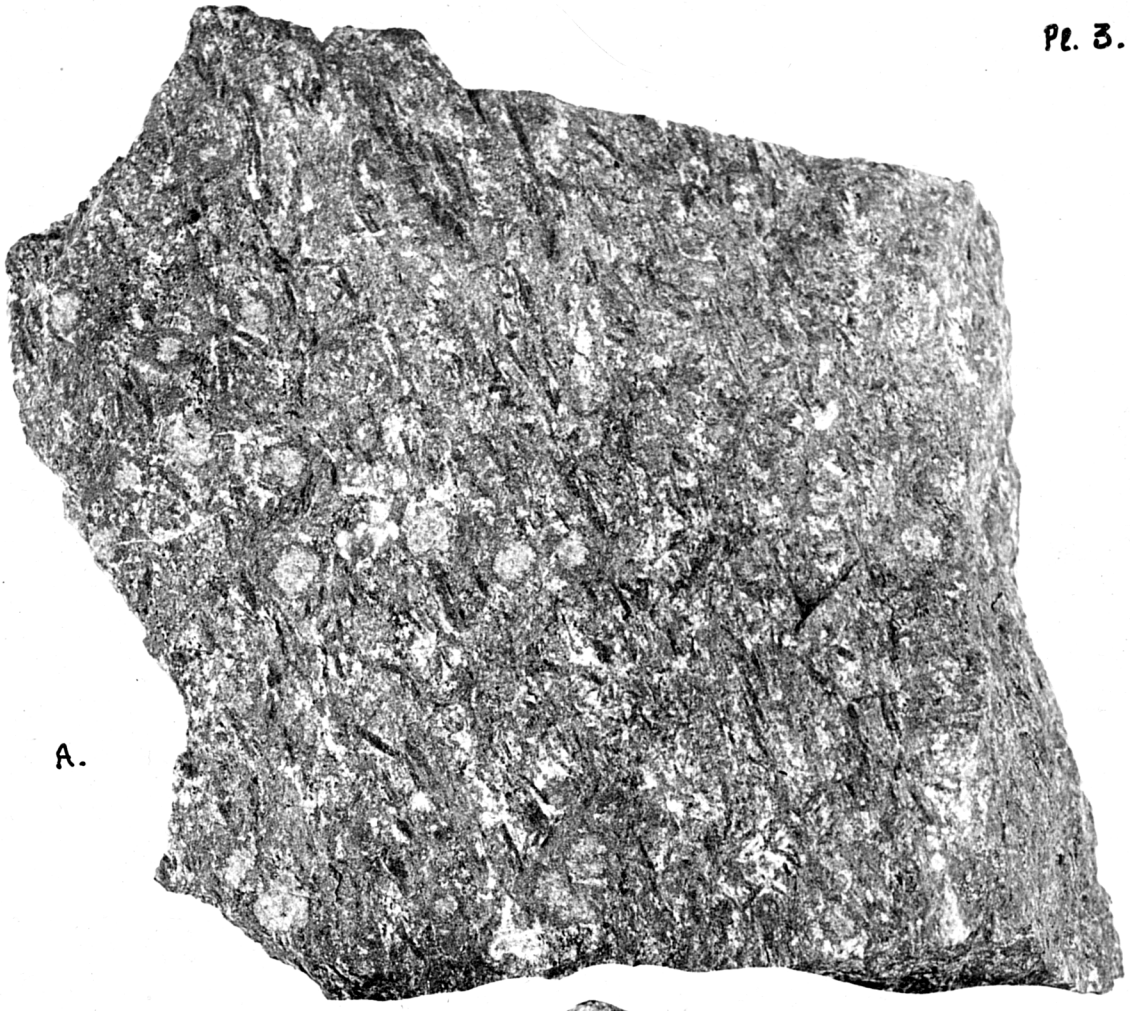
Diagrammatic Representation of the intrusion of the Granitic Pluton and pushing, Crinkling effects on the Metasediments (see enlarged inset 'x' diagram).


Schists above Ards Quartzite.
Ards Quartzite.
Schists below Ards Quartzite.
Cor Quartzite.
Malin Head Quartzite
Stratigraphic horizon unknown
Older Granite Types.
Newer Granite Types.
N
SYNCLINE
ANTICLINE
G
?
N.W. DONEGAL STRUCTURE
Based on the Maps of the Geological Survey and the Preliminary Re
of the Research Team.
5 MI.

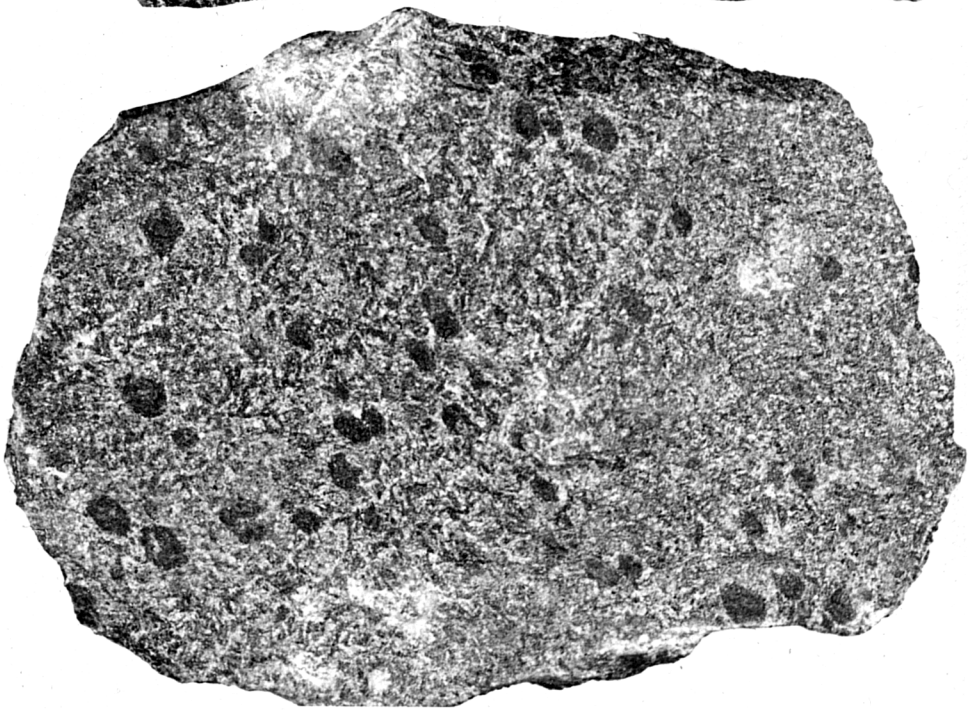
Explanation of Plate 3

A. Rounded unaltered or partially chloritised garnetiferous amphibolite, with a groundmass of up to 1 inch long subparallel prismatic crystals of hornblende from Pollmurry. (see p. 140).

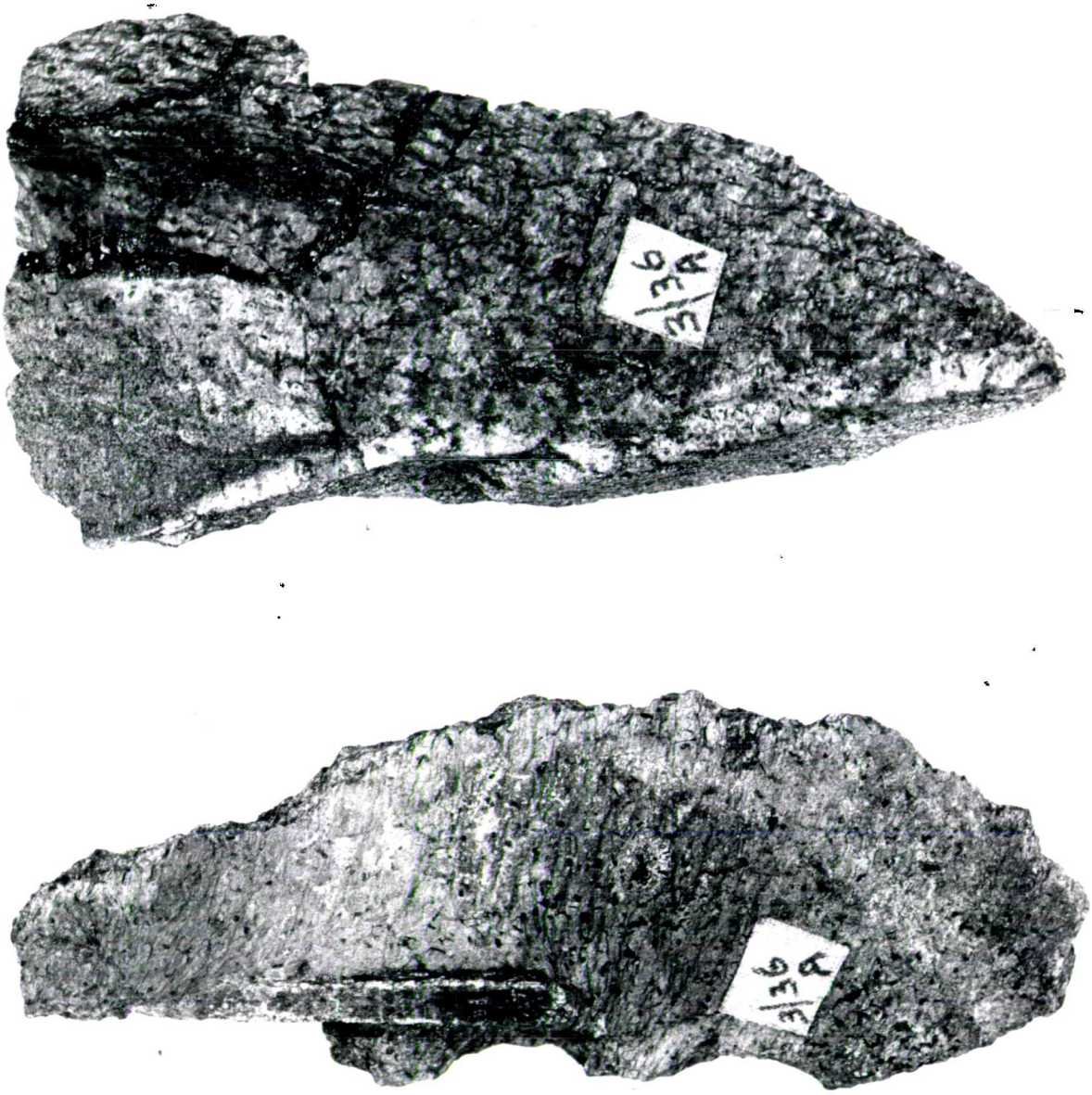
B. Sheared oval spotted chlorite amphibolite from Portnatrawbane in which all the garnets are chloritised and are elongated making a lineation parallel to the ist. regional lineation.



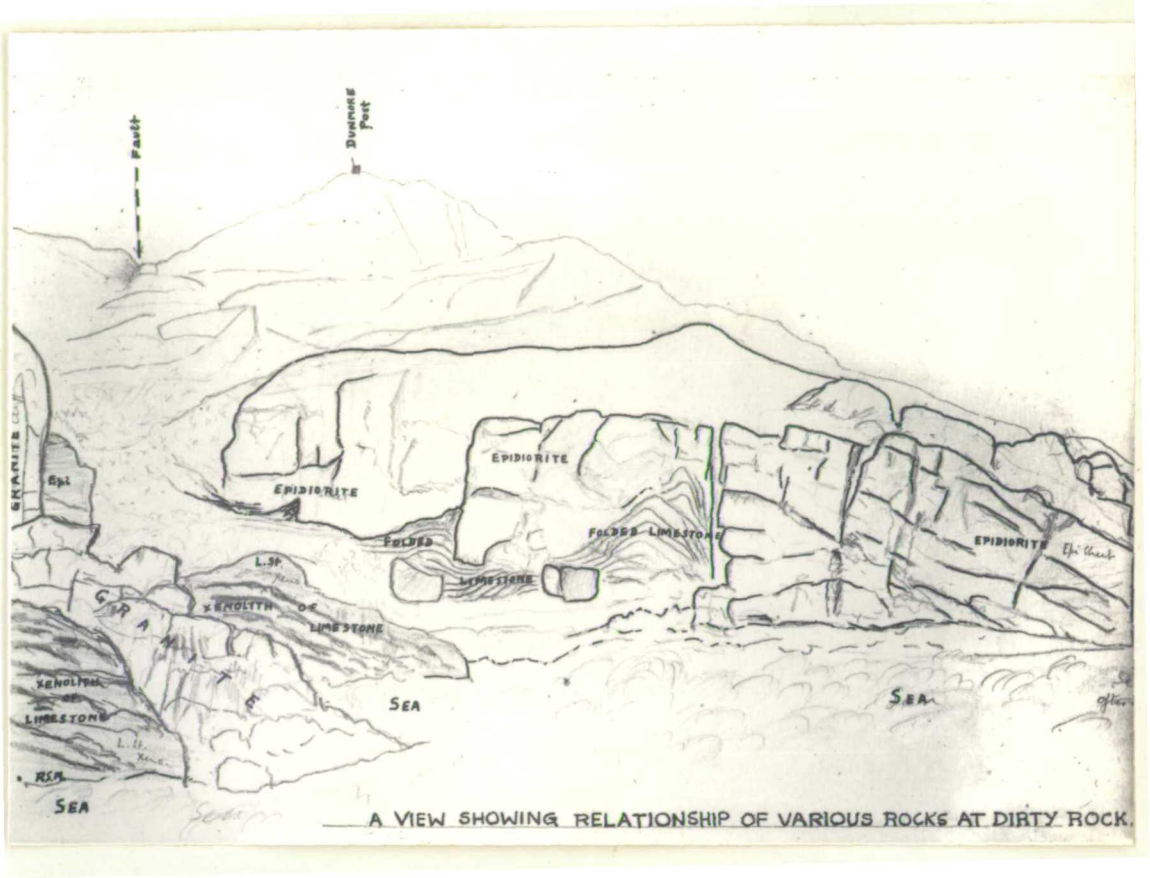
A.



B.



Andalusite-biotite-muscovite schists about 150 yards SE of Doon Lough (ESE of 'Bawn') - Size approx. 3/4 . In the lower specimen the Andalusite crystal is pushing the third tangential lineation in the outer part of the aureole.



Field sketch showing the huge xenoliths of folded banded limestone enclosed in an epidiorite - granite complex at Dirty Rock. The larger xenoliths of limestone seem to be unaffected both by the earlier metadolerite and granitic intrusions.
(see pp.52-53 and 227)

Explanation of Plate 6

A. Cross-cutting relationship of two low dipping grey felsite sills immediately at the coastal platform, south of Kiltooris School (Photograph of the east face from Pollmurry side)

B. Cross-cutting Felsite dykes at Carrickakuna

C. A 2½ ft. thick grey lamprophyre sheet cutting a 3-5ft. thick quartz dyke at Crockakun. This northerly dipping sill appears to meet another southerly dipping sill at the place where the boy is sitting 'X'.



A.



B.



C.

Explanation of Plate 7.

A. A xenolithic felsite sheet making a N - S ridge near the N. coastal cliffs of Dawros peninsula near Scoltaworth, W of Scoltia. The central portion is massive or with small xenoliths and at its bottom (near the hammer) and at the top surface are irregular portions of highly xx xenolit rich rock which are sometimes joined by irregularly similar xenolithic rock stringers.

B. A transgressive green lamprophyre in the coastal cliffs almost half-way between Scoltia and Illanglass. In a slightly elevated islet this body cuts through a ?grey lamprophyre.

C. A 2ft. thick grey lamprophyre sheet followed and cut by a 4-5 ft. thick dolerite dyke in which partially digested xenoliths of lamprophyre are present. (eastern coastal platform of Portnacully)



A.



B.



Explanation of Plate 8

A. An almost vertical xenolithic lamprophyre dyke about 4 ft. in thickness immediately at the water level of Illanglass. Like the grey sheet at Carrickalagh the xenoliths are easily made out on the weathered smooth wet surface.

B. Xenolithic portion of the great xenolithic Felsite sill N of Dunmore Hill (see description pp.197-198)

C. Mobilised sediments at the back of lonely house north of Doon Lough.

D. Subrounded xenoliths of epidiorite in granite peninsula at Dirty Rock. In addition to the rounded xenoliths, angular or subangular xenoliths of epidiorite are also present. Towards the central portion of the peninsula huge blocks of epidiorite are also present. These contain few rounded xenoliths of granitic material.



A.



B.



C.



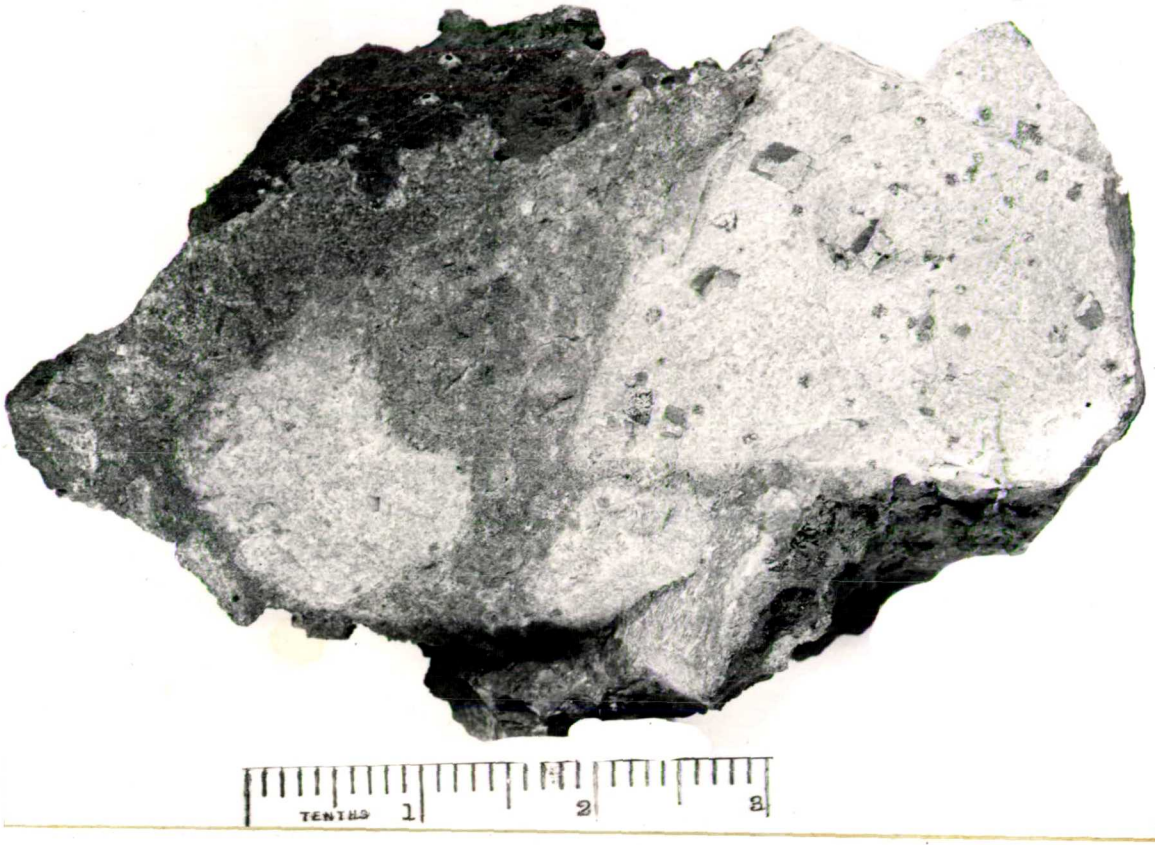
D.

Explanation of Plate 9

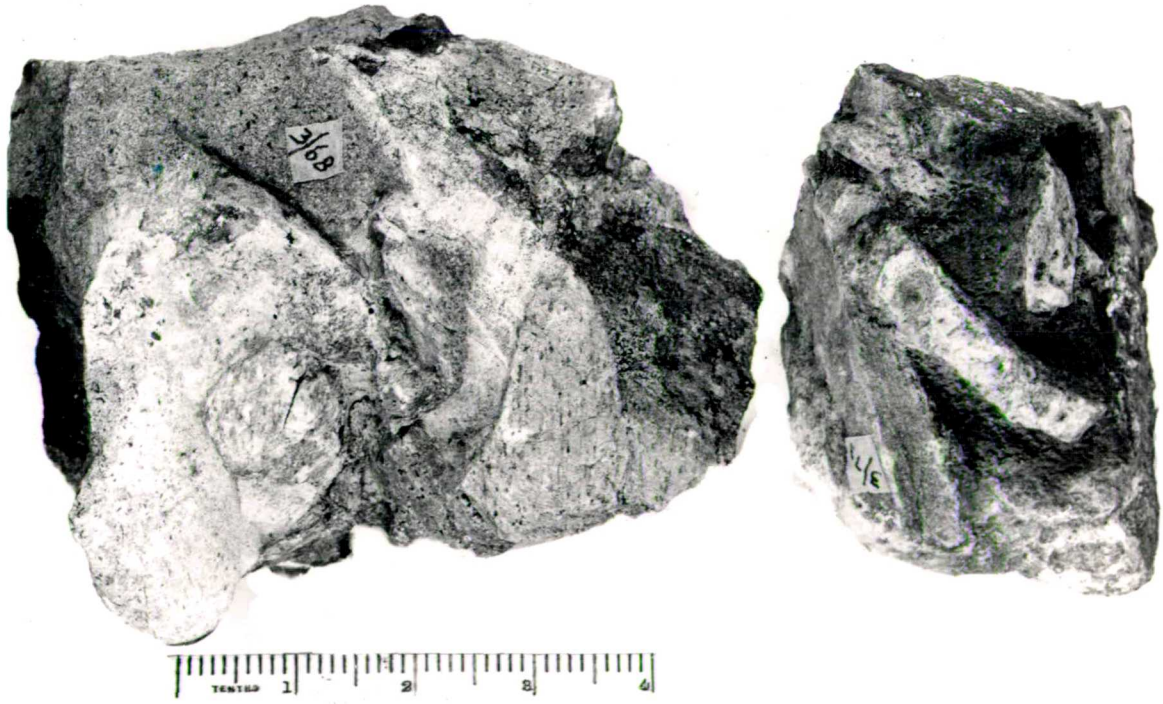
A. Hand specimen of green xenolithic sill near Rosbeg pier (Size: approx 1/2) - See description at pp. 193-8.

B. Hand specimens of Explosion Breccia from South Doon Lough region. The size of the xenoliths is very varying and most of them appear to be unaffected. The matrix of the rock is full of minute angular fragments of schistose rock in which dark brown or brownish green irregular spots of biotite or chlorite are present. In 3368 mark the lineations and the elongated dark spots which are actually the cavities due to the weathering of rounded chlorite after garnet (See pp.213-8).

A.



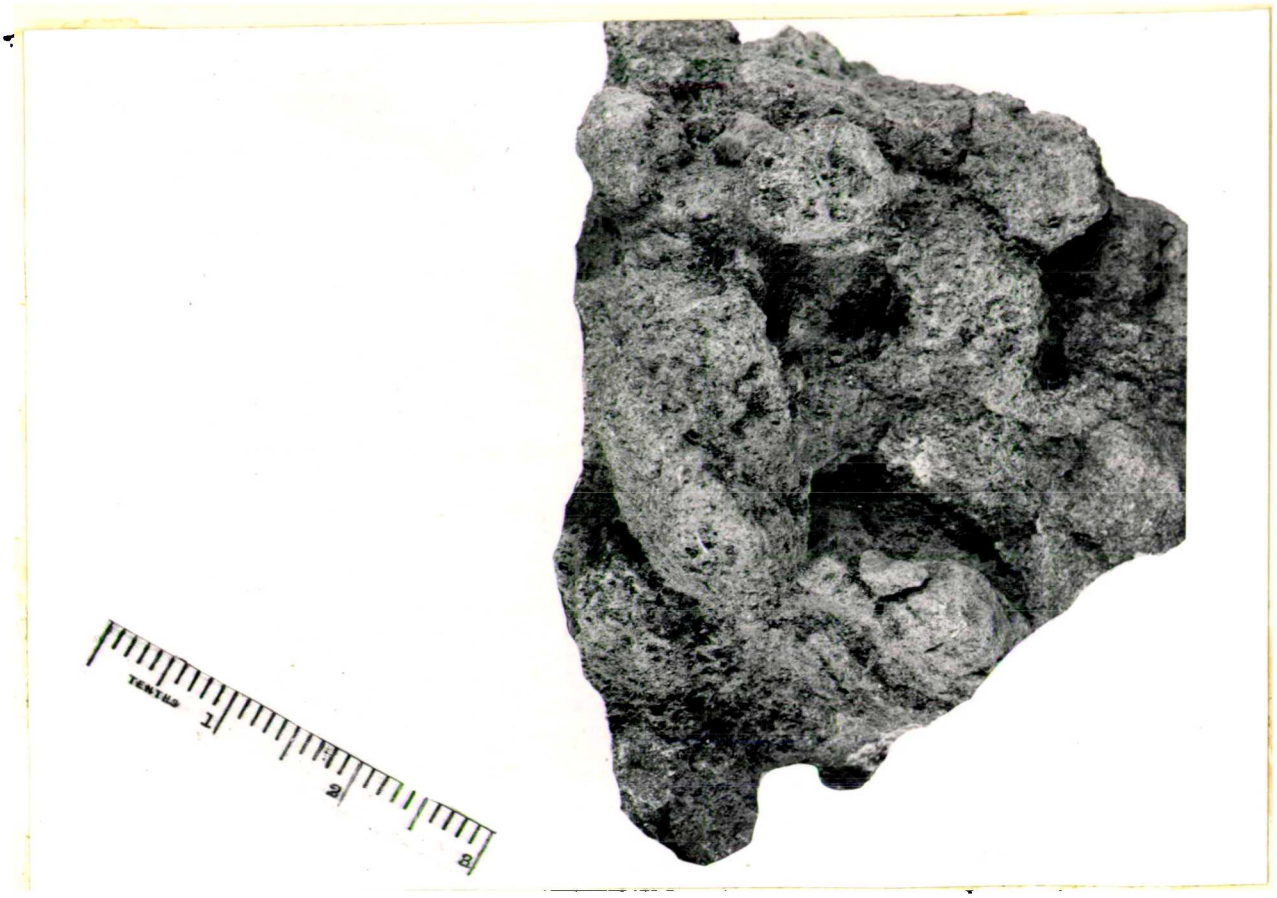
B.



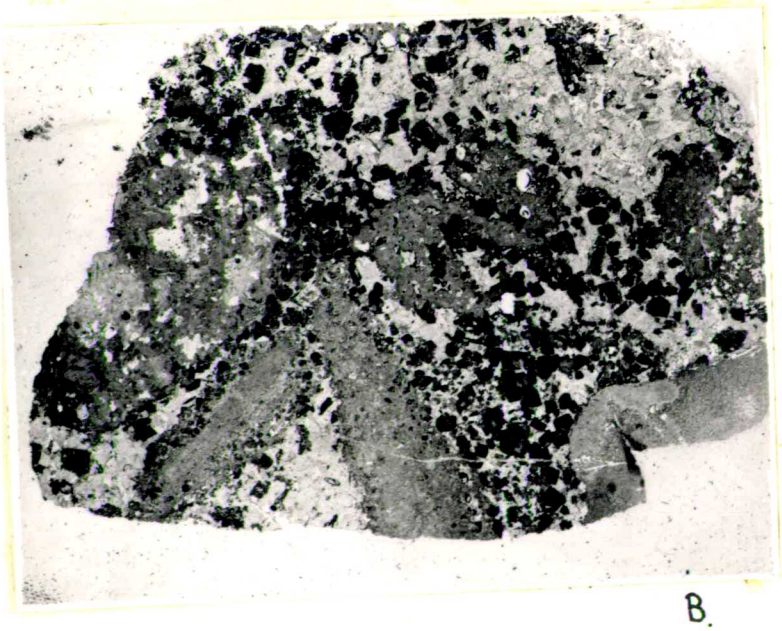
Explantion of Plate 10

A. Hand specimen of Explosion Breccia at the Road si near Lefrin Hill (See description pp. 205-210).

B. Large thin section of A. (3½ x 2½") shows the interrelationship of different xenoliths and the matrix. As would be seen from the descriptions on pp. 210-213 the xenoliths of metadolerite show a zoned appearance indicating an alkali metasomat



A.



B.

Explanation of Plate 11

Hand specimens of different types of Appinites.

(Size: 1/3).

Ex. 1, Ex. 8. — From road side near Rosbeg P.O.

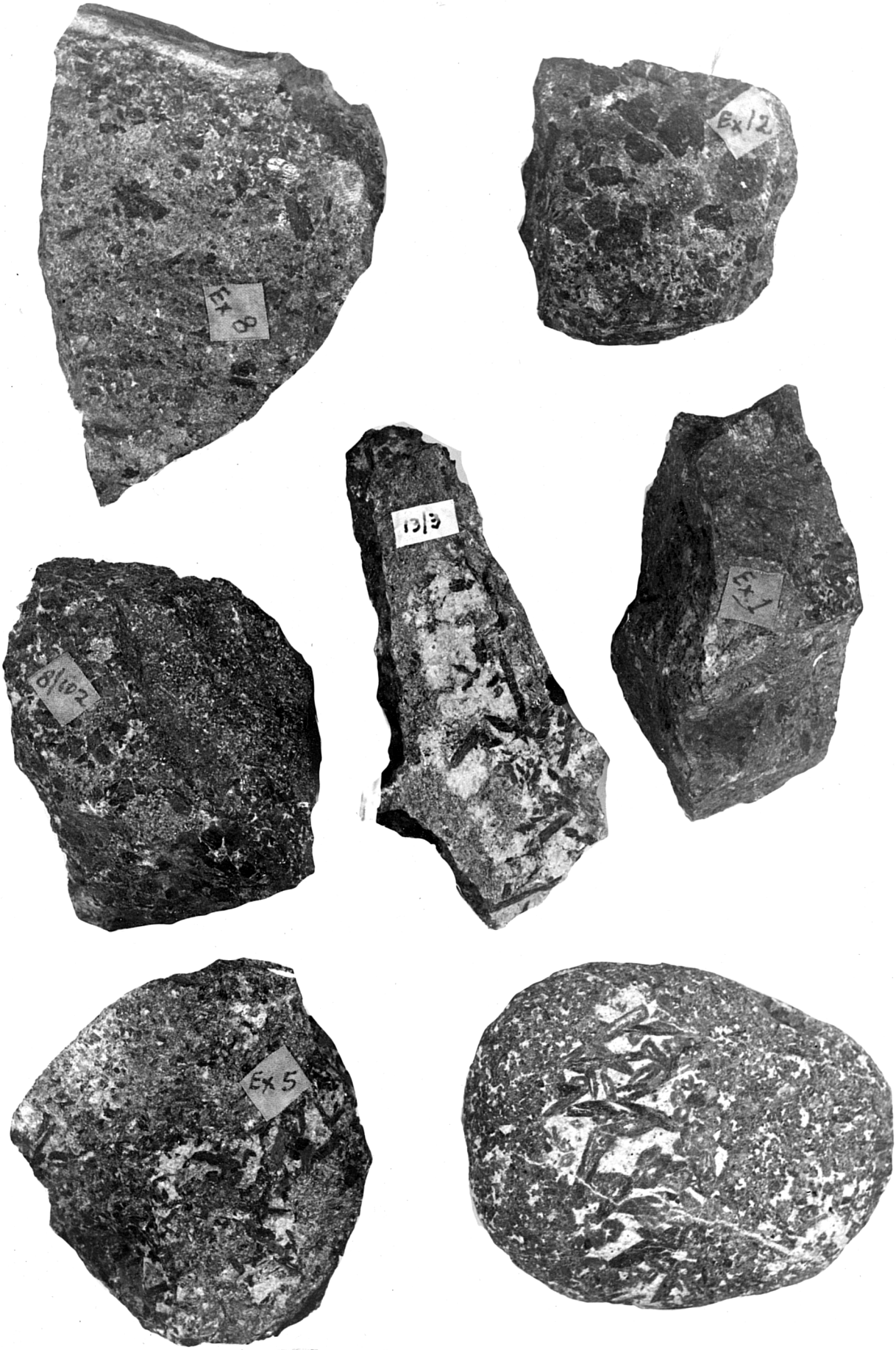
Ex.5. — From the eastern cliffs (near the house) at Portnatrawbane

Ex.12. — From Kiltooris Mass near the road junctic just opposite Kiltoorisia Hall gate.

8/102 — From the N Doon Lough region

13/3 — From the south facing high cliffs of Rilachoor.

108 — From the Sand Hole - Dunmore area.


Ex 8
Ex 12
10/3
8/102
Ex 1
Ex 5

Explanation of Plate 12

5/54. Rosbeg semipelitic schist showing the growth of New chlorite porphyroblasts due to which the general foliation is pushed and minor kinks are formed. Mark the parallel growth of all the individual porphyroblasts which give rise to a lineation across or at 60 degrees angle with the foliation.

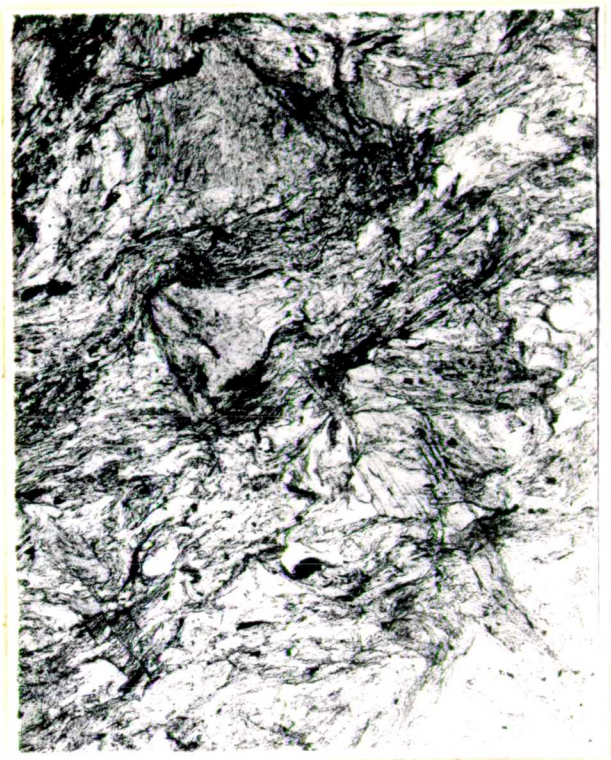
5/46. Rosbeg semipelitic schist showing the growth of New chlorite porphyroblast after garnet. Mark the comparative wavy nature of the lower foliation actually due to the later growth of New chlorite. The foliations are also made up of chlorite formed after biotite. This section therefore shows the three types of chlorite present in these rocks.

5/8. Quartz-felspar-biotite-chlorite schist of the Rosbeg Semipelitic group showing the growth of porphyroblastic flakes of New chlorite at an angle of 60 degrees (approx.) with the general foliation.

6/15. Biotite-chlorite-muscovite schist of the Rosbeg Semipelitic group showing the growth of biotite at an angle of 60 degrees (approx.) with the foliation. This dark brown biotite* appears be like stilpnomelane described by Hutton (1938)-(Min. Mag. Vol.XXV pp.172-206). It seems to be altering at its edges and the cleavages to a dark green chlorite similar to New chlorite. Mark the pleochroic haloes enclosed in the flake. At the right upper corner is also present the rounded chlo after garnet.

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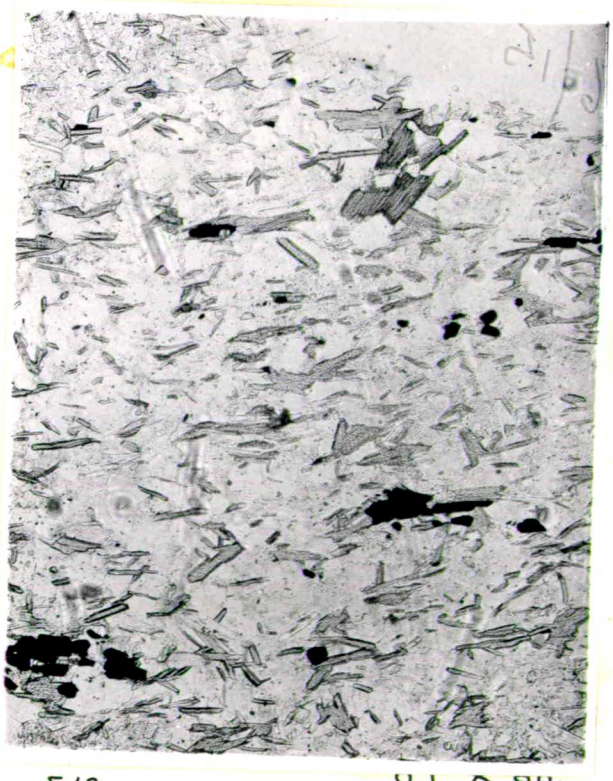
* As a result of X$ ray analyses by Mr. G.P.L. Walker, it h been found to be a biotite. The author thanks him for his



5/54. O.L. × 20.



5/46. O.L. × 20.



5/8. O.L. × 60.



6/15. O.L. × 60.

Explanation of Plate 13

6/39. Rosbeg Semipelitic schist showing growth of dark brown flakes of biotite (similar to that of 6/15) parallel to the foliations of the rock. In this slice as in many others particularly of the calc-pelitic schists irregular grains of clacite are also present.

5/[illegible]. Rolled chlorite after garnet, of which only minut traces are left unaltered.

5/50. Rolled chlorite after garnet in semipelitic schis Mark the partial wavy or herring bone pattern in lower right hand corner.

6/10. Rolled garnet which shows minor alterations only at the margins. The garnet is sieved, full of inclusions of quartz and the biotite or chlorite flakes of foliation appear to penetrate at its horizontal margins.



6/39. O.L. x 20.

5/50. O.L. x 20.



5/45. O.L. x 20.

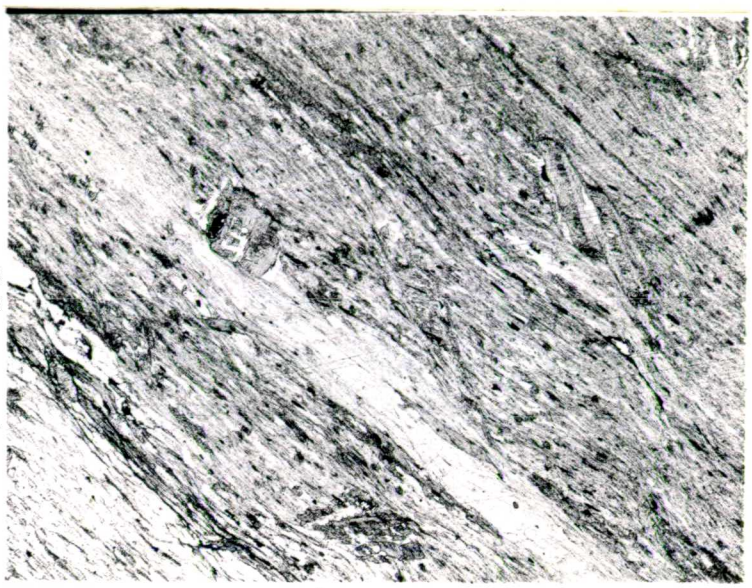


6/10. O.L. x 20.

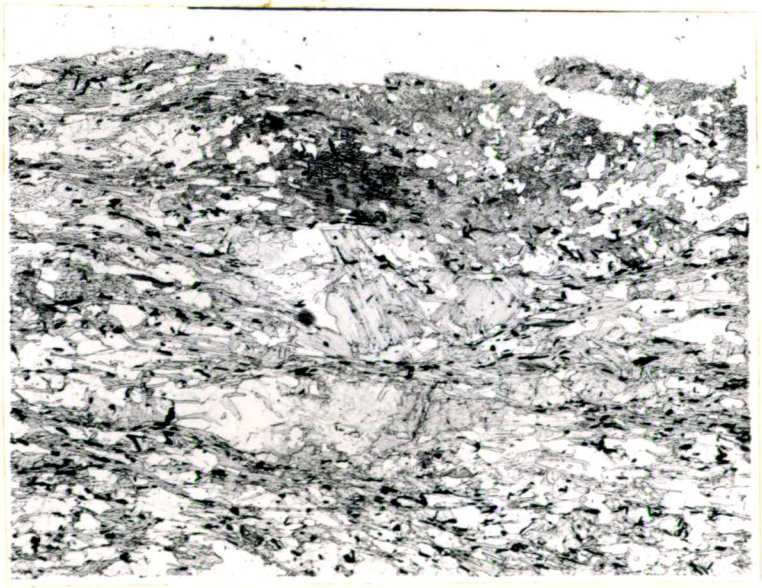
Explanation of Plate 14

4/18. Carbonaceous biotite-chlorite-muscovite schist of Aghros Hill - Eden House semipelitic schist showing the growth of porphyroblasts of New chlorite at an angle with the foliations, whi are only slightly disturbed. The rounded porphyroblast is the pseudomorph of chlorite after garnet.

6/15. Quartz-felspar-biotite-sericite schist showing the growth of porphyroblasts of New chlorite and the alteration of dark brown biotite to dark green biotite similar to 'New' chlorite.



4|18. O.L. X 15.

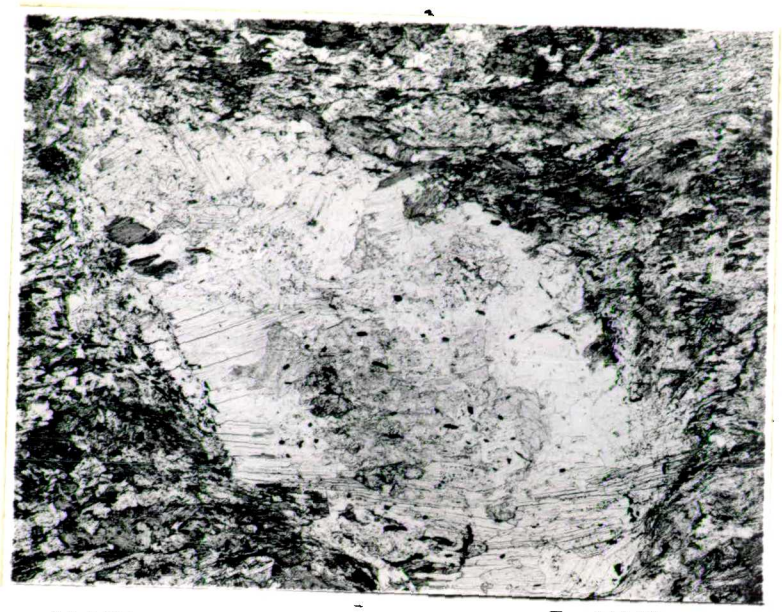


6|14. O.L. X 20.

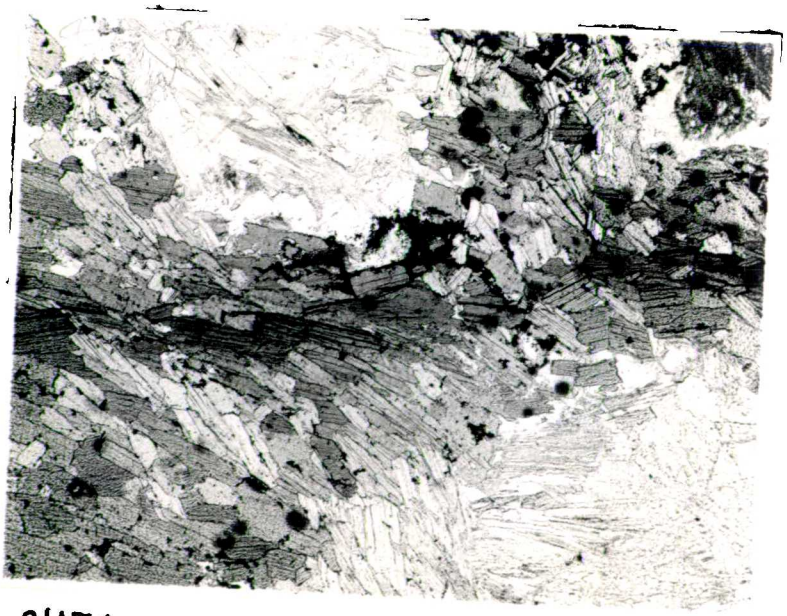
Explanation of Plate 15

8/52. Staurolite-biotite-schist from the southern Narin Hill region showing shimmer aggregate with irregular grains of staurolite, iron ore and biotite.

8/134. Andalusite (shimmer)-biotite-muscovite schist from E Narin Hill region with large rectangular clear shimmers after andalusite. Mark the regular and comparatively larger flakes of hornfelsic biotite and their pleochroic haloes.



8/152. O.L. x 20.



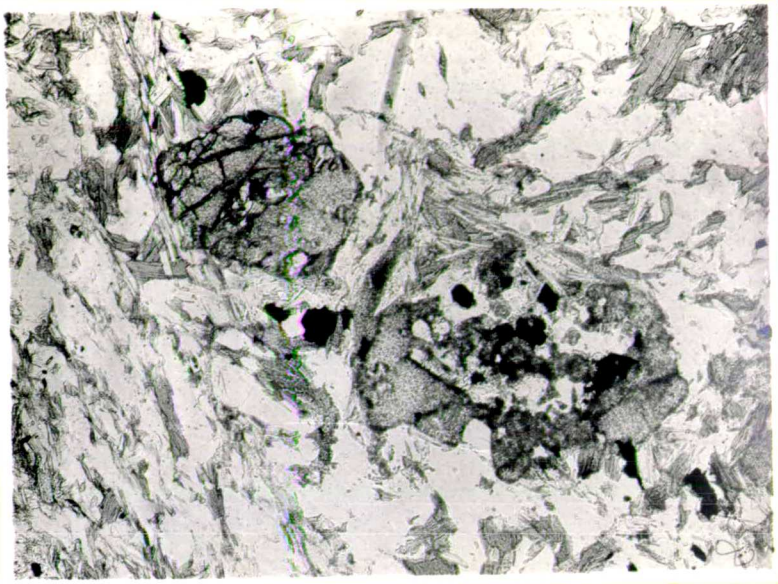
8/154. O.L. x 30.

Explanation of Plate 16

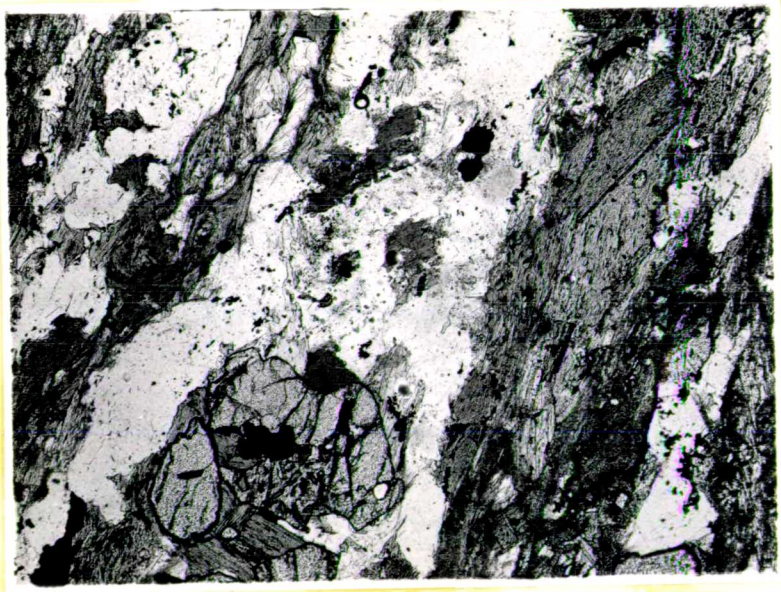
8/70. Sillimanite-garnet-biotite hornfels from the quarry near the E - W road bend (NE of Doon Lough). The irregular flakes of biotite are altering to fibrolite. In the right central portion the rock shows a cluster of minute irregular grains of biotite, garnet and well developed needles of fibrolite.

8/40. Garnet-biotite rock from the aureole immediately west of the house near the junction of Narin-Ardara and the upper branch roads. Here the pink garnets can easily be made out with a hand lens. The biotite breaks to a thick felt of fibroliteand the partially altered flakes show well developed pleochroic haloes.

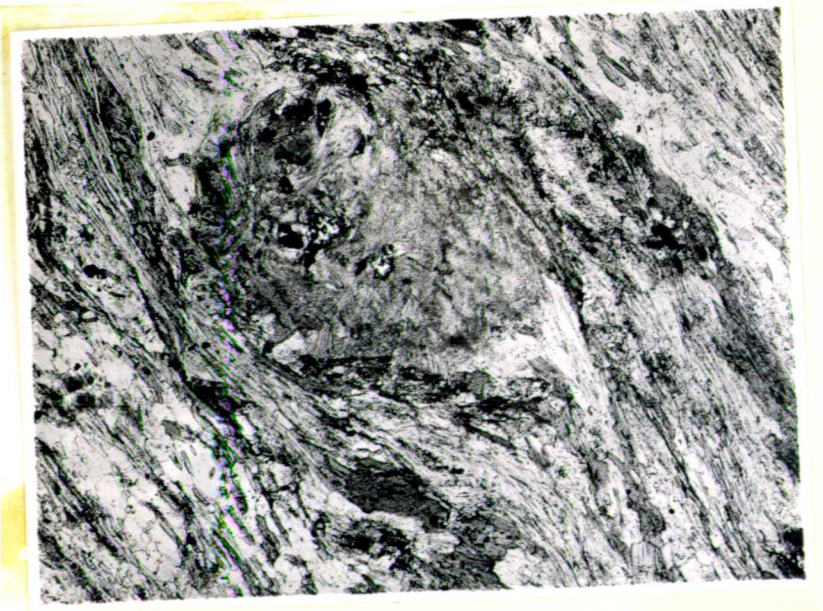
8/126. Growth of rounded New biotite lying in between the folia of partially formed fibrolite and biotite in the hornfels of Narin region.



8/70. O.L. x 60.



8/40. O.L. x 30.

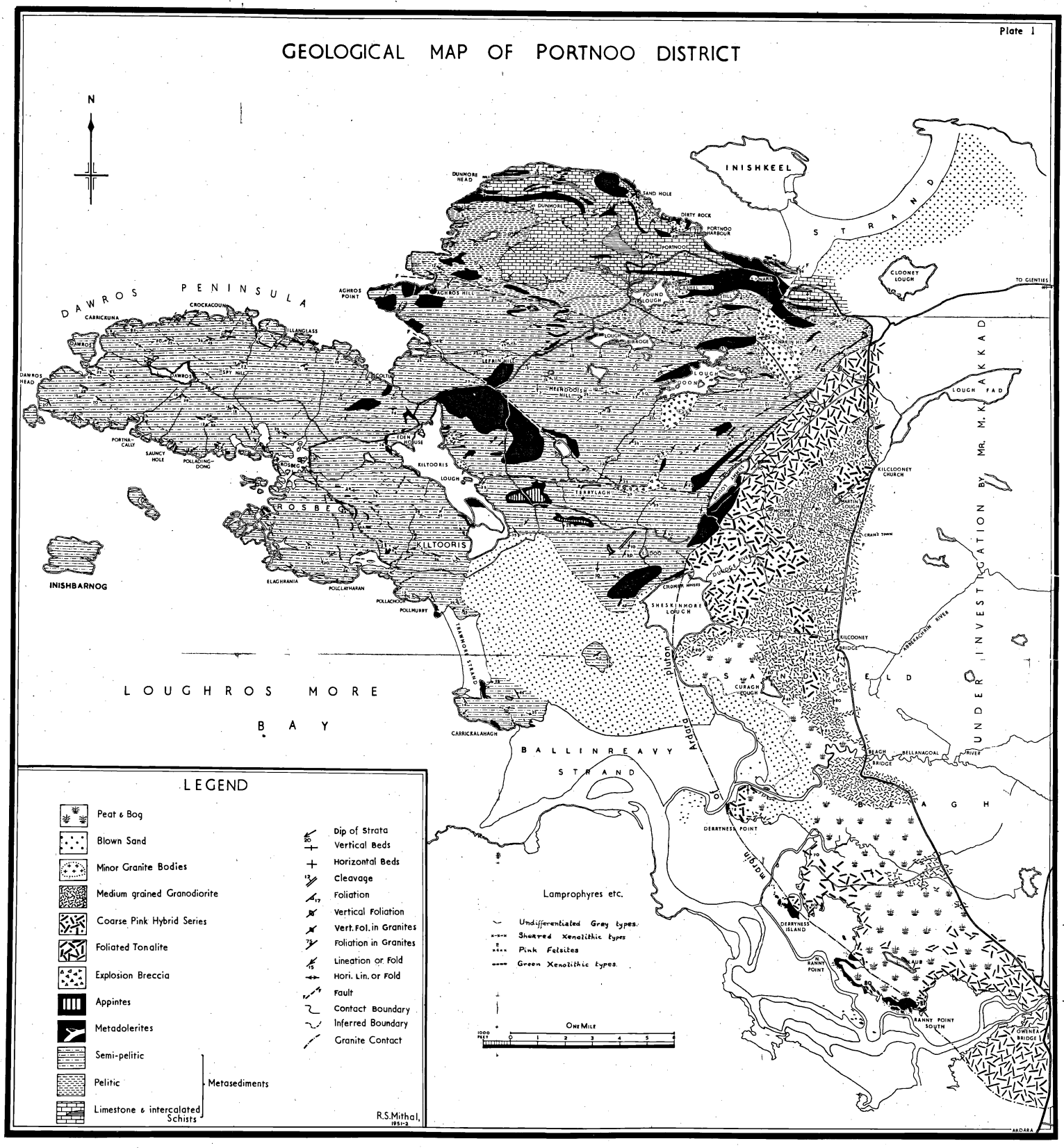


8/126.

O.L. x 30.

Plate 1

GEOLOGICAL MAP OF PORTNOO DISTRICT



LEGEND

- Peat & Bog
- Blown Sand
- Minor Granite Bodies
- Medium grained Granodiorite
- Coarse Pink Hybrid Series
- Foliated Tonalite
- Explosion Breccia
- Appintes
- Metadolerites
- Semi-pelitic
- Pelitic
- Limestone & intercalated Schists

(Semi-pelitic, Pelitic, Limestone & intercalated Schists: Metasediments)

- Dip of Strata
- Vertical Beds
- Horizontal Beds
- Cleavage
- Foliation
- Vertical Foliation
- Vert. Fol. in Granites
- Foliation in Granites
- Lineation or Fold
- Hori. Lin. or Fold
- Fault
- Contact Boundary
- Inferred Boundary
- Granite Contact

R.S. Mithal, 1951-2