THE LOWER PALAEOZOIC ROCKS OF SOUTH-WEST MURRISK, EIRE.

Abstract.

The geology of an area of Ordovician and Silurian rocks north of Killary Harbour, in West Connaught, is described in detail for the first time. The stratigraphical succession is:-

4. Cregganbaun Series		Llandovery.
	(Unconformity)	
3. Mweelrea Grits	)	
	)	Middle
2. Glenummera Slates	)	Ordovician.
1. Sheefry Grits		Arenig.

The Sheefry Grits, 8000 feet thick, belong to the zones of *Didymograptus extensus* and *D. hirundo*. They consist of bedded grits and slates, which were derived from the erosion of the Connemara Schists on the south, and were tightly folded during the Caledonian orogeny. There are extensive beds of tuff.

The Glenummera Slates, 1500 feet thick, rest on the Sheefry Grits, and are succeeded conformably by the Mweelrea Grits. This formation, 5000 feet in thickness, includes massive current-bedded grits and conglomerates, with three slate horizons. The sediments were all derived from the south, probably from the Connemara Schists, and are now folded into a simple syncline. The Mweelrea Grits contain five beds of welded tuff, four of which persist over the whole area. They, and the tuffs in the Sheefry Grits, are thought to be deposits left by *nuées ardentes*.

The Cregganbaun Series, including slates, a quartzite,

and a remarkable basal conglomerate, rests unconformably on the Sheefry Grits. The sediments were probably derived from the north. In S.W. Murrisk they form the southern limb of an east-west syncline.

The Arenigian and Llandoverian strata are intruded by a small Caledonian granite, with its associated dyke swarm. Palaeozoic and post-Carboniferous dolerites occur, as well as a series of appinite dykes.

The structure and geological history of the area are described, and the thesis ends with a list of type exposures and fossil localities.

THE LOWER PALAEOZOIC ROCKS OF S.W. MURRISK, EIRE.

A Thesis submitted for the
Diploma of Imperial College

by

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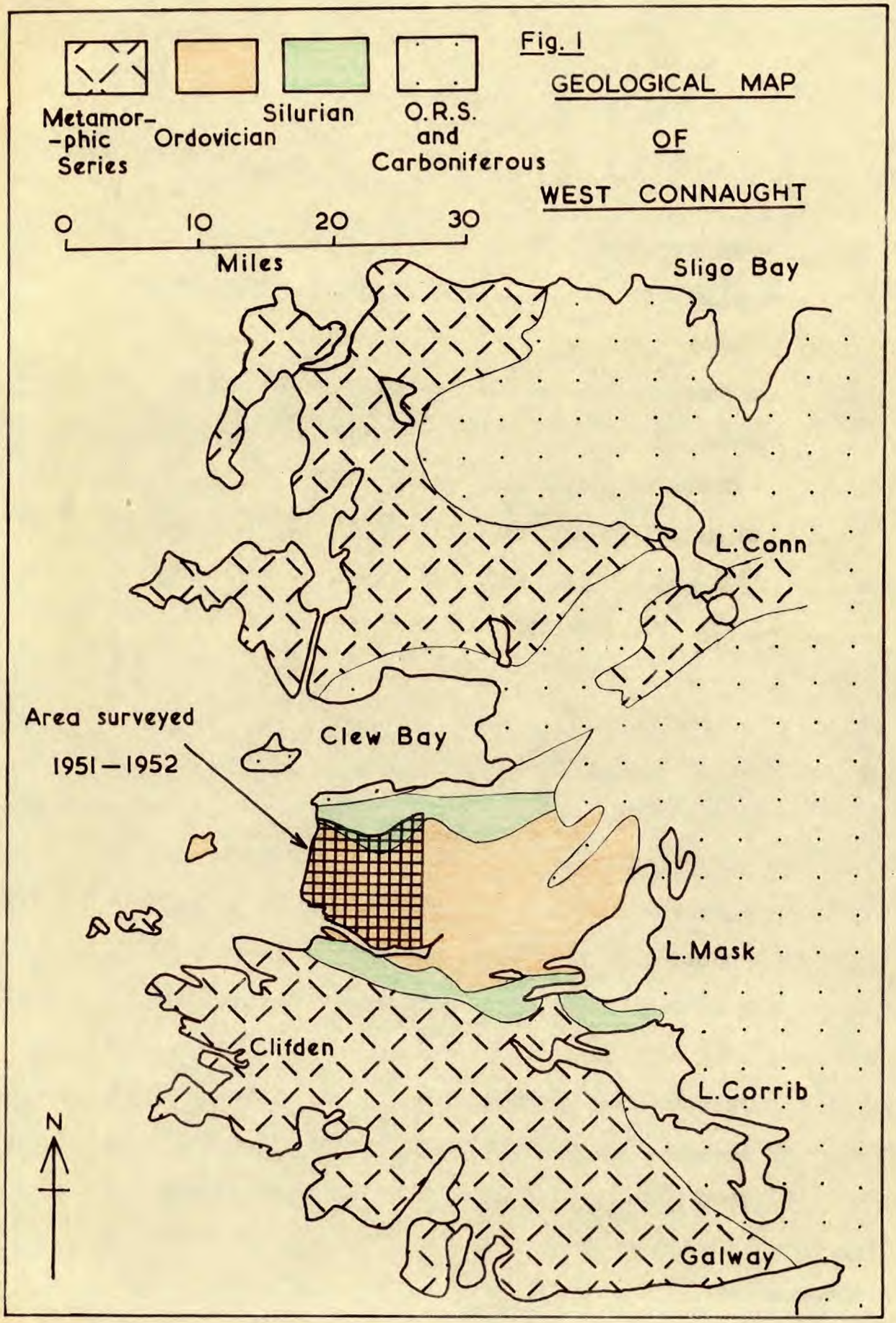
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Fig. 1
GEOLOGICAL MAP
OF
WEST CONNAUGHT
Metamor-phic Series
Ordovician
Silurian
O.R.S. and Carboniferous
0
10
20
30
Miles
Sligo Bay
L. Conn
Area surveyed
1951—1952
Clew Bay
L. Mask
Clifden
L. Corrib
Galway
N

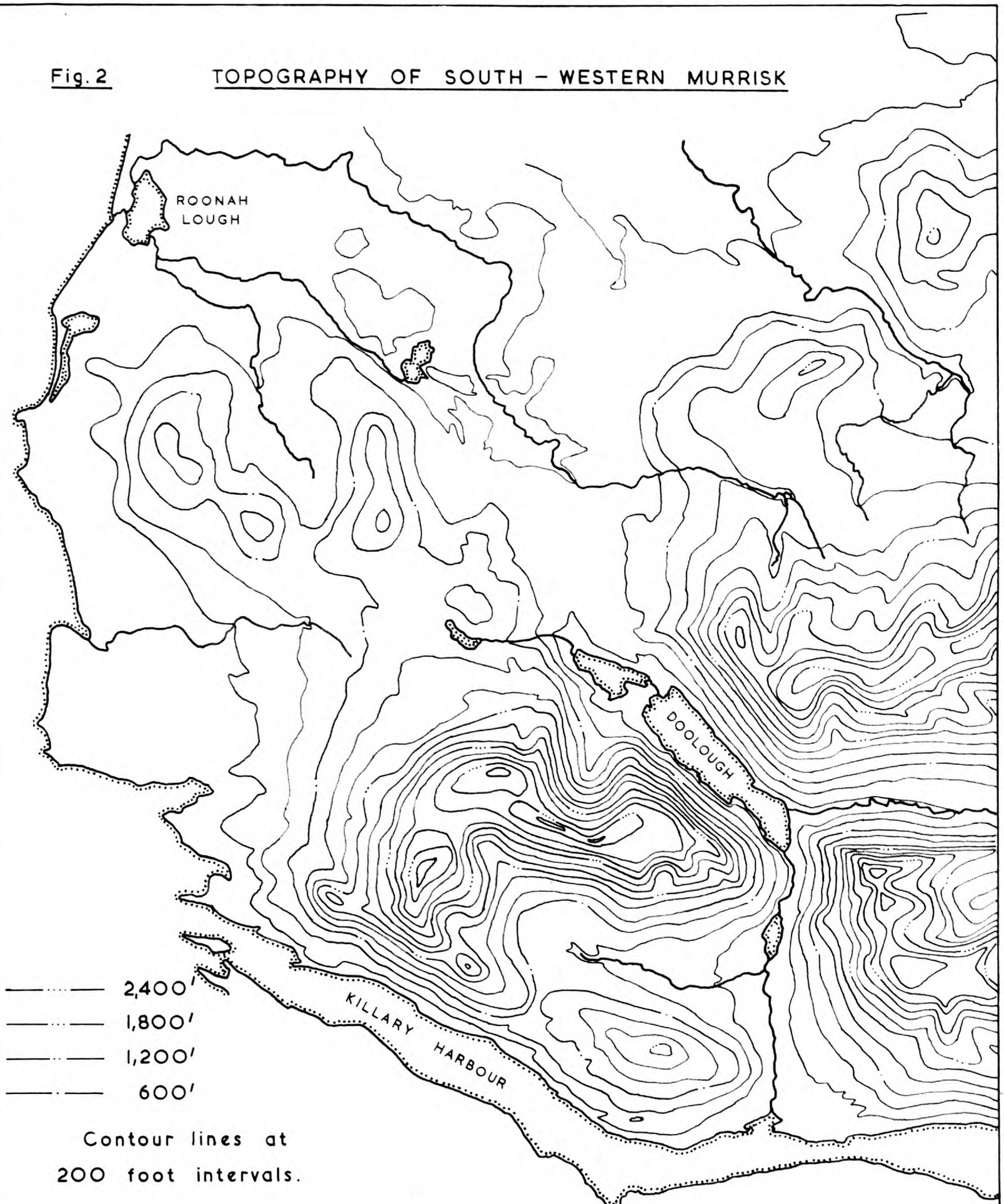
Chapter One. INTRODUCTION.

The portion of County Mayo illustrated in Figure 1. was surveyed during the years 1951 and 1952. It is nearly 65 square miles in area, approximately one fifth of the exposure of Lower Palaeozoic rocks in Mayo and Galway. The survey was carried out on the six-inch scale, on the Ordnance Survey sheets 95, 96, 105, 106, and 115 of County Mayo.

The district is bounded on the west by the Atlantic Ocean, and on the south by the fiord of Killary Harbour. The straight boundary on the east is defined by the borders of sheets 96, 106, and 115. The irregular northern boundary follows the edge of a great expanse of bog and glacial deposits.

The area may be divided into two topographical districts, (Figure 2.) In the north the ground is low lying with rolling heathery hills and large stretches of peat bog. In the south the great grit formations are exposed in three mountain blocks; Ben Gorm, the Mweelrea Mountains, and the Sheefry Hills. There are six peaks higher than 2,300 feet, one being Mweelrea (2,688 feet) the highest in Connaught. The mountain masses are intersected by deep glaciated valleys, one of which, Killary Harbour, is flooded by the sea and forms a typical narrow fiord nine miles long. In a similar valley the deep lakes of Doolough and Glencullin Lough lie in an ice-eroded fault zone.

Fig. 2 TOPOGRAPHY OF SOUTH – WESTERN MURRISK



In the mountainous southern district the rocks are very well exposed. Further north, among the lesser hills, the solid rock surface is often mantled by glacial deposits, which are in turn usually capped with peat. There are two great expanses of this "drift", into which the Owennadornaun and Carrownisky Rivers have cut steep-sided gorges more than 100 feet deep. Elsewhere, the post-glacial river erosion is very slight.

The traces of ice-action are abundant everywhere. Perhaps the most striking are the great corries, (especially well developed in the Sheefry Hills and the Mweelrea Mountains, where they are surrounded by thousand-foot cliffs). The glaciers eroded deep U-shaped valleys along lines of fracture and the outcrops of slate formations, and left erratic blocks and parallel scratches on rock surfaces 1,500 feet above sea-level. Drumlins occur in the lower drift country to the north. The erratics and roches moutonnées demonstrate that the ice moved in a general north-westerly direction, away from the mountain hub of Connemara. Alluvial terraces, composed of slightly sorted pebbles, gravel, and silt, exist at several distinct levels on the edges of Doolough Lake and Killary Harbour. They probably belong to a late phase of the Glacial Period.

Plate 1.

Lugmore, a corrie in the Mweelrea Mountains.

Plate 2.

A glaciated pavement in the Sheefry Grits.

The photograph illustrates the persistence and uniformity of individual beds. The strata young to the right.

Plate 1.

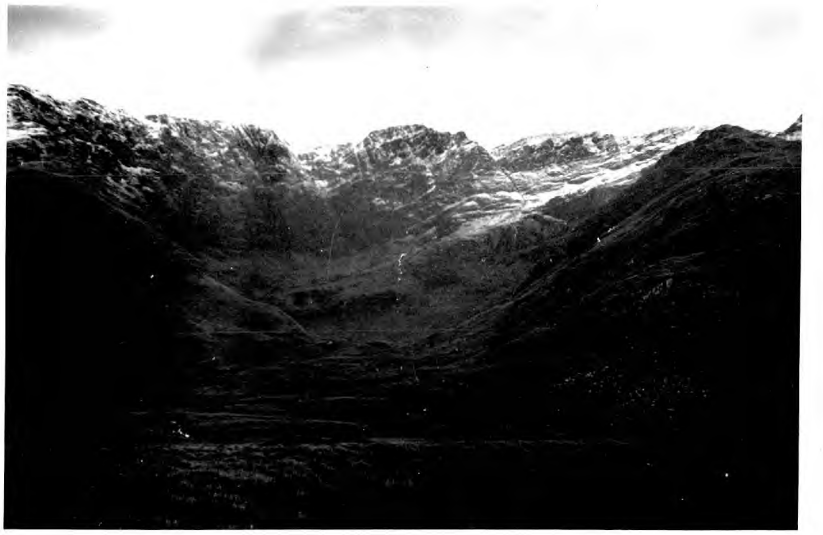


Plate 2.



Chapter Two. HISTORY OF PREVIOUS RESEARCH.

The first geological map of the area was made by Sir Richard Griffith in 1839. It marks the southern (Ordovician) district as "Lower Silurian Clay Slate", and the northern (Silurian) district as "Primary mica-schist".

Murchison, in his "Siluria", (1859) considered that the strata to the north of Killary Harbour were all younger than the Llandoverian rocks on the south, and suggested that the missing "Lower Silurians" had been metamorphosed to form the Connemara Schists. Kelly (1860) disputed Murchison's conclusions, and regarded the Connemara Schists as pre-Ordovician. However, Kelly's argument was founded on the assumed existence of a "Greywacke Formation", (and on what proved to be the haphazard correlation of nearly all the grit formations in West Connaught). He noticed the tuffs in the Mweelrea Grits, and thought that they were intrusive porphyries.

Between 1870 and 1874 the area was mapped by the Officers of the Geological Survey of Ireland, and their discoveries were summarised by Kinahan (1874). The Mweelrea Grits were accorded an "Upper Silurian" age, (although "Caradoc" fossils were found in them), and were considered to be a littoral facies of the Llandoverian slates on the south of Killary Harbour. They were believed

to rest unconformably on lower strata. No distinction was made between the Mweelrea Grits and the Arenigian grits of Leenane and Rosroe, south of Killary Harbour. North of the Mweelrea Grits the older rocks were united in the "Doolough Series", of Ordovician age, upon which the "Upper Llandovery or Wenlock" strata of Cregganbaun rested unconformably. To explain the variable metamorphic grade of the "Doolough Series", Kinahan postulated the existence of large faults, which brought up the more strongly metamorphosed strata. He believed the Arenigian tuffs to be intrusive dykes of "felstone".

Kinahan set down the following stages in the geological history of the area :

1. Deposition of Ordovician sediments (including the Connemara Schists).
2. Regional folding, and metamorphism of the Connemara Schists, in the late Ordovician.
3. Denudation.
4. Subsidence, and deposition of Silurian sediments.
5. Folding and elevation in the late Silurian.
6. Denudation.
7. Subsidence, and deposition of Carboniferous rocks.

Hull, in the same year (1874) described the Corvock granite, which the considered to be "eruptive". He remarked that the Ordovician was a period of great vulcanicity

in Ireland, and referred to the Mweelrea tuffs as uniform quartz-porphyry lavas, each flow capped with volcanic ash, probably erupted from submarine vents near Killary Harbour.

In 1832, Kinahan published a north -south section through Connemara and South Mayo. It showed a great anticline, in which the upper part of the Connemara Schists was the metamorphosed equivalent of the Ordovician rocks between Killary Harbour and Clew Bay; while the lower Connemara Schists were supposed to be Cambrian. More recent work has entirely refuted Kinahan's interpretation.

Kilroe revised the area for the Geological Survey of Ireland during the years 1893-95, and summarised his results in 1901 and again, more fully, in 1907. He established the existence of a Silurian syncline between Croagh Patrick (4 miles north-east of Knockaskeheen) and Cregganbaun, and suggested that some of the rocks north of Croagh Patrick, and even in North Mayo, might be metamorphosed "Silurians". He discovered that the Mweelrea Grit rested conformably on the "Doolough Series". Kilroe believed that the Connemara Schists were metamorphosed Ordovician rocks, and explained the unconformable "Wenlockian"/Connemara Schist contact by assuming a Llandoverian metamorphism and a thrusting of the Connemara Schists over the low-grade Ordovician sediments to the north. The zone of dislocation was then covered by Wenlockian sediments. His discovery of a "Wenlockian"/ Arenigian unconformity near Lough Nafooey supported his

argument, although he believed that "Llandeilian" strata at Doolough passed conformably up into "Wenlockian" strata at Cregganbaun. He considered that the Mweelrea Grit Series above the First Slate (i.e. above the lowest 1,500 ft.) was of Llandoverian age.

In 1909, Carruthers and Muff published the results of palaeontological work near Killary Harbour. Basing their conclusions on Graptolite faunas, they dated the "Doolough Series" as Upper Arenigian, and considered it to be the fine-grained equivalent of the Leenane and Rosroe Grit Series, (of coarse grits and conglomerates). They described the fresh felspars of the Mweelrea Grits, and suggested that they were indicative of arid continental deposition. They found "Ogygia" in the First Slate at Lough Bellawaum, and accordingly dated the Mweelrea rocks as "Llandeilian", possibly passing up into Bala.

Gardiner and Reynolds (1912) collected fossils from Kilroe's "Wenlockian" band near Lough Nafooey. The fossils were exmmined by F.C. Reed, who believed them to be of Llandoverian age. If this is the case it is not unlikely that the lower Silurian rocks of Cregganbaun should also be assigned to the Llandovery.

Wager and Andrews (1930) put forward evidence that, assuming no inter-Lower Palaeozoic orogeny, the Connemara Schists were of Pre-Cambrian origin and metamorphism.

Since no such orogeny was known in Britain they concluded that the Connemara Schists were in fact Pre-Cambrian.

In 1948, Miller and Maclaren described the Rosroe Grits, and postulated intermittent, perhaps rhythmic, subsidence with deposition of coarse sediment derived from the south. They believed that during Upper Arenigian time a roughly east - west shoreline lay nearby.

Theokritoff (1957) described certain portions of the Killary Harbour - Lough Nafooey district, and suggested that major thrusting from the north had brought Arenigian strata onto Ludovian south of Killary Harbour. He summarised the results of recent palaeontological work on the Faunas of the area. Theokritoff made traverses across the Doolough Series, and proposed 3 subdivisions :

3. Glenummera Slates.
2. Sheefry Grits.
1. Shanecroan Slates.

In fact, the Shanecroan Slates are non-existent, although the highly sheared Sheefry Grits north of Glencullin Lough appear at first sight to be slates.

Chapter Three. SUMMARY OF GEOLOGY.

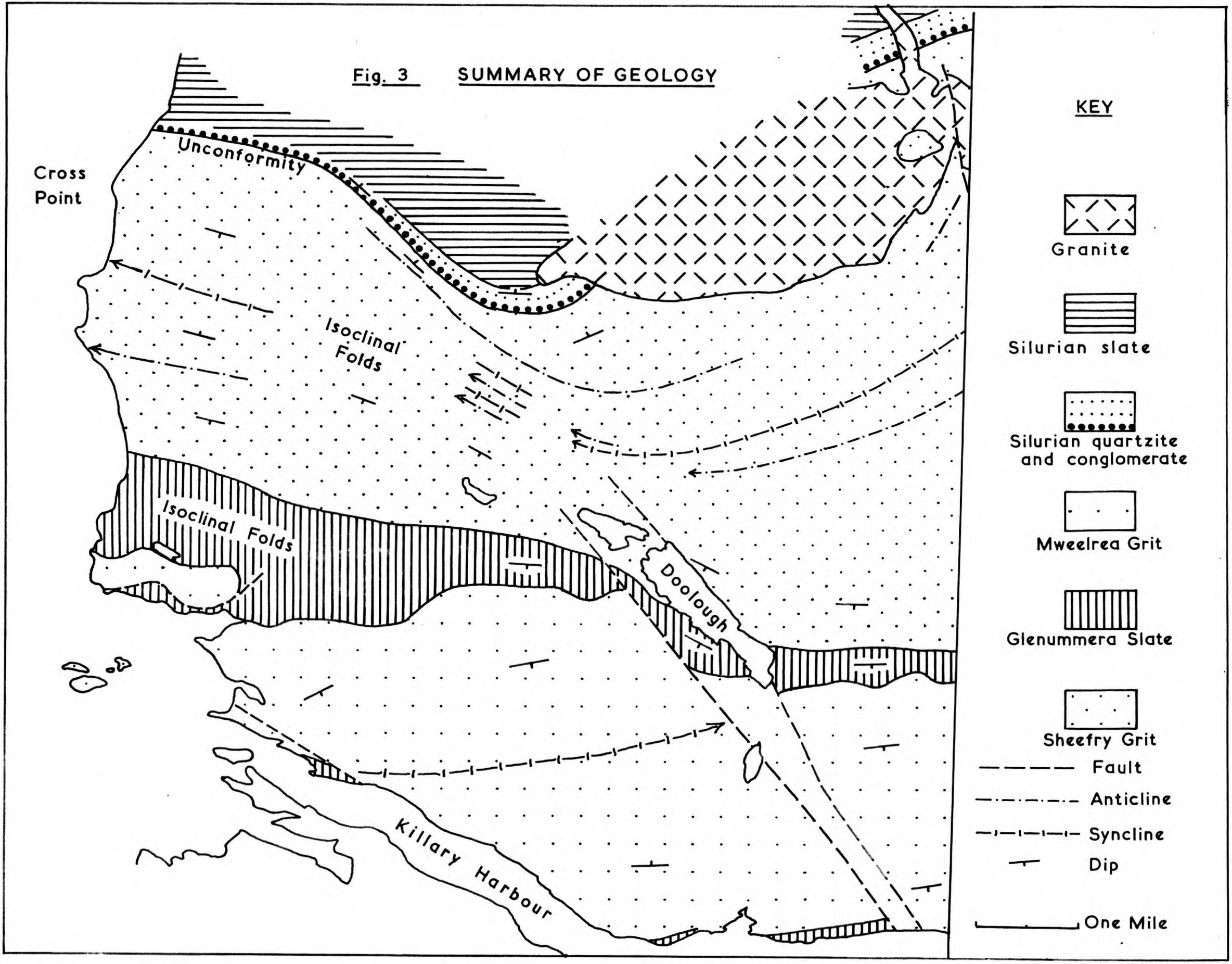
Figure 3.

Ordovician and Silurian sedimentary rocks are present in the area, their ages ranging from Arenigian to Lower Silurian (probably Llandoverian). They are intruded by a Caledonian granite, with its associated swarm of acidic and intermediate dykes. Palaeozoic and post-Carboniferous dolerites occur, as well as lamprophyres and a series of appinite intrusions. The granite is surrounded by a well defined aureole of thermal metamorphism.

The sedimentary rocks have undergone strong folding and faulting. The slates show a well developed cleavage, which becomes so intensified in certain places that the rock resembles a schist. The regional strike is roughly east - west, although to the east of the area it swings round into the normal N.E. - S.W. Caledonian trend. Two great left-handed tear faults cut the Mweelrea Grits in a N.W. - S.E. direction. In the older, less competent, strata, they are represented by a strong flexure, in which the N.W. - S.E. limb is much attenuated.

In the south of the area the great Mweelrea Grit formation, 5,000 feet thick, composed of false-bedded grits and conglomerates with interbedded slates, is folded into an east - west syncline. It is dislocated by 3 large tear faults and many smaller faults of both tear and normal type.

Fig. 3 SUMMARY OF GEOLOGY



In the lowest 2,000 feet are 5 remarkable beds of welded tuff, 4 of which persist throughout the area. The grits were accumulated under deltaic conditions, the material being derived from the south, probably from the Connemara Schists. They are believed to be of Middle Ordovician age. There was contemporaneous faulting and other movement during sedimentation.

The Mweelrea Grits rest conformably on the Glenummera Slates, a formation roughly 1,500 feet thick, consisting of a monotonous succession of green slates, becoming more gritty towards the top. There is a transgressive flaggy zone between the Slates and the Mweelrea Grit.

The Glenummera Slates, sandwiched between two grit formations, were strongly contorted during the Caledonian folding, and in many areas were thrown into small isoclinal folds. There is often a zone of bedding-plane thrusts in the slates just below the Mweelrea Grit. The age of the Slates is uncertain, but they appear to lie just above the Upper Arenig.

The Glenummera Slates pass down without a break into a series of thin-bedded grits and slates, the Sheefry Grits (of Theokritoff, 1950). The upper part of this formation is of Upper Arenigian age (Carruthers and Muff, 1909). About 8,000 feet of Arenigian strata are exposed in West Murrisk. In the topmost 5,000 feet 8 beds of tuff have been discovered, 3 of which persist throughout much of the district.

The structure of the Sheefry Grits is very complicated. Tight folds and faults (the latter very hard to distinguish in the field) are present everywhere, and are only to be detected by careful mapping.

The Sheefry Grits are believed to be the fine grained equivalents of the Leenane and Rosroe Grits several miles to the south; there is evidence that the sediments were derived from this direction. While the Grits contain an increasing proportion of slate as they are followed northwards, there is no evidence for the existence of the "Shanecroan Slates" as proposed by Theokritoff.

The Silurian (probably Llandovery) strata rest unconformably on Arenigian rocks, although the actual unconformity is rarely visible in the field. They consist of a thick basal conglomerate passing up into a quartzite and then into a series of quartzitic and calcareous slates, in which corals and brachiopods are plentiful.

Chapter Four. THE ARENIGIAN SEDIMENTARY ROCKS.

(a) Introduction.

In S.W. Murrisk the outcrop of Arenigian strata is more extensive than that of any other formation. From west to east its length is 9 miles, with an average width of 3 miles from north to south. Similar strata extend 15 miles north-eastwards to a point south-east of Westport. They are also seen on Inishturk, an island 7 miles west of Bunlough Point.

Following Theokritoff (1950), the grit formation exposed on the shores of Doolough and in the Sheefry Hills (which include the summits of Clashcame and Tievummera) is here referred to as the Sheefry Grits. Theokritoff further subdivided the Arenigian strata by creating the "Shanecroan Slates", which he supposed to be a slate horizon underlying the Sheefry Grits. It is evident that he was misled by the schistose appearance of the sheared gritty strata north of Glencullin Lough. In fact, there is insufficient lithological variation in the Arenigian rocks to allow of their further subdivision, and the name Sheefry Grits is here applied to the whole of the Arenigian outcrop.

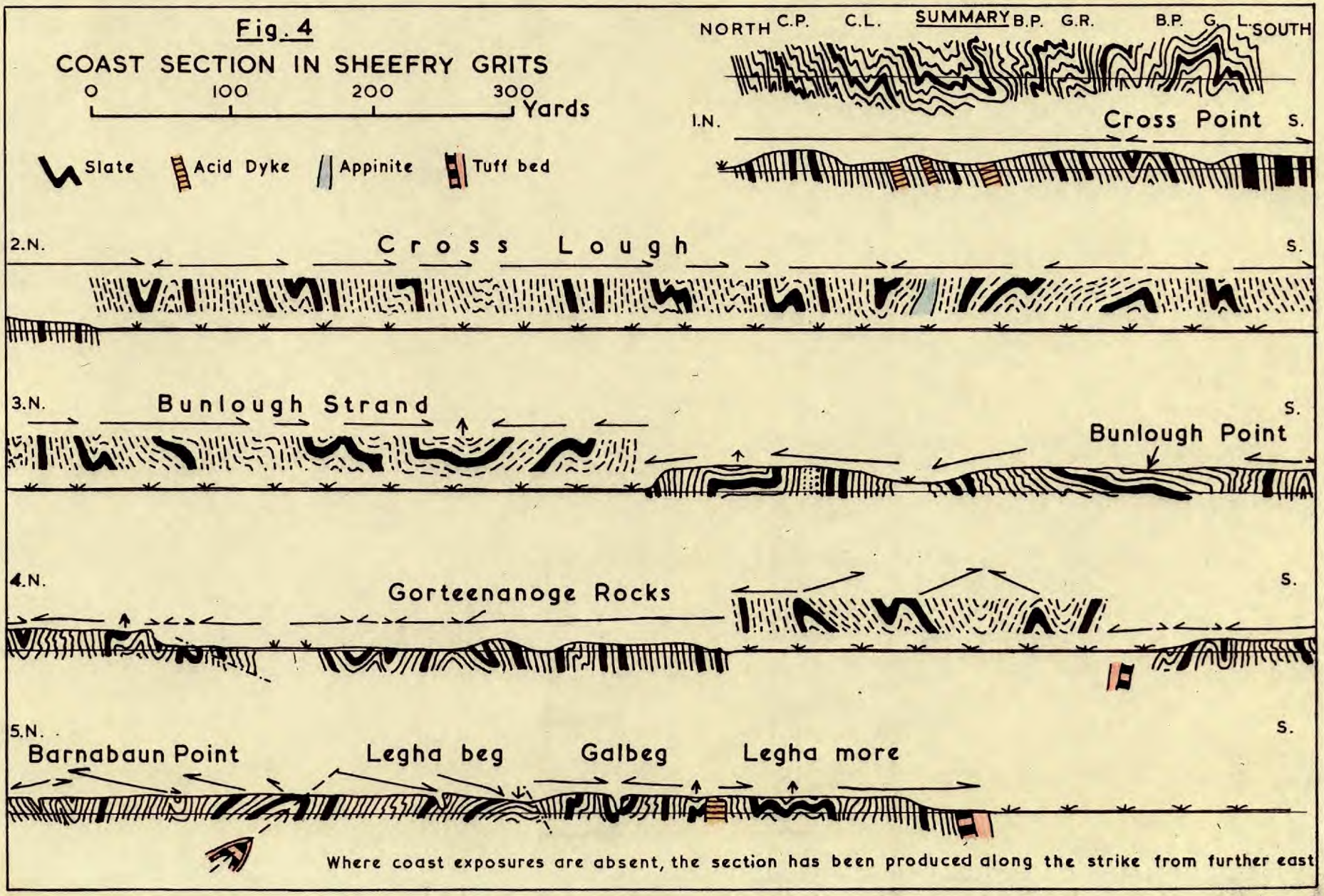
At their upper boundary, the Sheefry Grits pass conformably up into the Glenummera Slates through a zone of thin grits and slates. The lower boundary is not seen in

S.W.Murrisk. The thickness of the Sheefry Grits is at least 8,000 feet. Throughout the area the strata consist of bedded grits and slates, (Plate 2) and individual strata frequently grade upwards from grit into slate. The proportion of slate may locally exceed that of grit, but this is exceptional save in the extreme north.

In the upper 5,000 feet of the Sheefry Grits there are 8 beds of tuff, one of which is 50 to 120 feet thick, and is continuous through much of the district. Each tuff bed is graded, the upper portion being composed of much finer particles than the lower. They are here referred to as Tuff Bed (or T.B.) 1 to 8, numbered from the lowest upwards.

Graptolites have been found at several localities in the Sheefry Grits; on the shores of Doolough, on Clashcame, and west of Lough Nahaltora. They belong to genera which are normally found in Arenigian strata.

The Sheefry Grits have been subjected to great pressures from north and south, and have been bent into complicated tight folds (Figs 4 and 23). In the central area the dominant structure is the "Maam Flexure", a N.W. - S.E. flexure, represented in the competent Mweelrea Grits by the "Maam Faults", two tear faults with a combined horizontal throw of nearly two miles (Fig.8).


Fig. 4
COAST SECTION IN SHEEFRY GRITS
0
100
200
300
Yards
Slate
Acid Dyke
Appinite
Tuff bed
SUMMARY
NORTH
C.P.
C.L.
B.P.
G.R.
B.P.
G.
L.
SOUTH
1.N.
Cross Point
S.
2.N.
Cross Lough
S.
3.N.
Bunlough Strand
S.
Bunlough Point
4.N.
Gorteenanoge Rocks
S.
5.N.
S.
Barnabaun Point
Legha beg
Galbeg
Legha more
Where coast exposures are absent, the section has been produced along the strike from further east

(b) Age.

Carruthers and Muff (1909) collected graptolites, from near Doolough, which indicated an upper Arenigian age for this horizon in the Sheefry Grits (see Chapter Eleven). Theokritoff (1957) assigned this horizon to the Didymograptus hirundo zone.

In the course of the present work, graptolites were discovered west of Lough Nahaltora, at a horizon 4,000 feet below the strata at Doolough. Dr. O.M.B. Bulman, who has kindly examined them, considers that they are probably to be assigned to the D.extensus zone. (Kilroe (1907) believed that graptolites from approximately this horizon were "monoprionid", and indicative of Llandoverian strata).

On this evidence, the 8,000 feet of Sheefry Grits belong to the zones of D.extensus and D.hirundo, representing the middle and upper Arenig. The boundary between the two zones probably lies about 3,000 to 4,000 feet below the top of the formation.

(c) Field Description.

In S.W. Murrisk the Sheefry Grits have undergone considerable erosion, and it is only in the Sheefry Hills that they attain the level of the 2,500 foot peneplain of Connemara. Elsewhere they form low hills (which are nevertheless craggy with many rock outcrops); or are concealed

beneath accumulations of bog or glacial drift. The tuff beds are harder than their enclosing strata, and often stand up as ridges, as do the occasional thick beds of coarse grit.

In the coastal region the structure is esentially one of large anticlines and synclines, with smaller folds on their flanks. The good coast section between Cross Point and Legha More illustrates this (Fig.4). This simple structure is continued inland as far as the hill of Six Noggins and the un-named but equally well exposed hill north-west of it, on which T.B.7 and a thick grit band make prominent ridges.

Further eastwards, about Doogan Hill, the structure becomes more complicated as the Maam Flexure is approached. Doogan Hill itself is composed of tight isoclinal folds of grit, with a long exposure of T.B.4. on the north. Towards Lough Nahaltora the strata become more slaty, and this appears to represent a facies change across the long isoclinal Feenune anticline (Fig.7). This anticline lies in the elongated N.W. - S.E. limb of the Maam Flexure, and the strata are highly sheared and have a schistose appearance.

South and west of Lough Nahaltora the Silurian unconformity is exposed for a few yards. There seems to be little angular discrepancy between the two formations. The contact is much sheared, and only the absence in the slaty

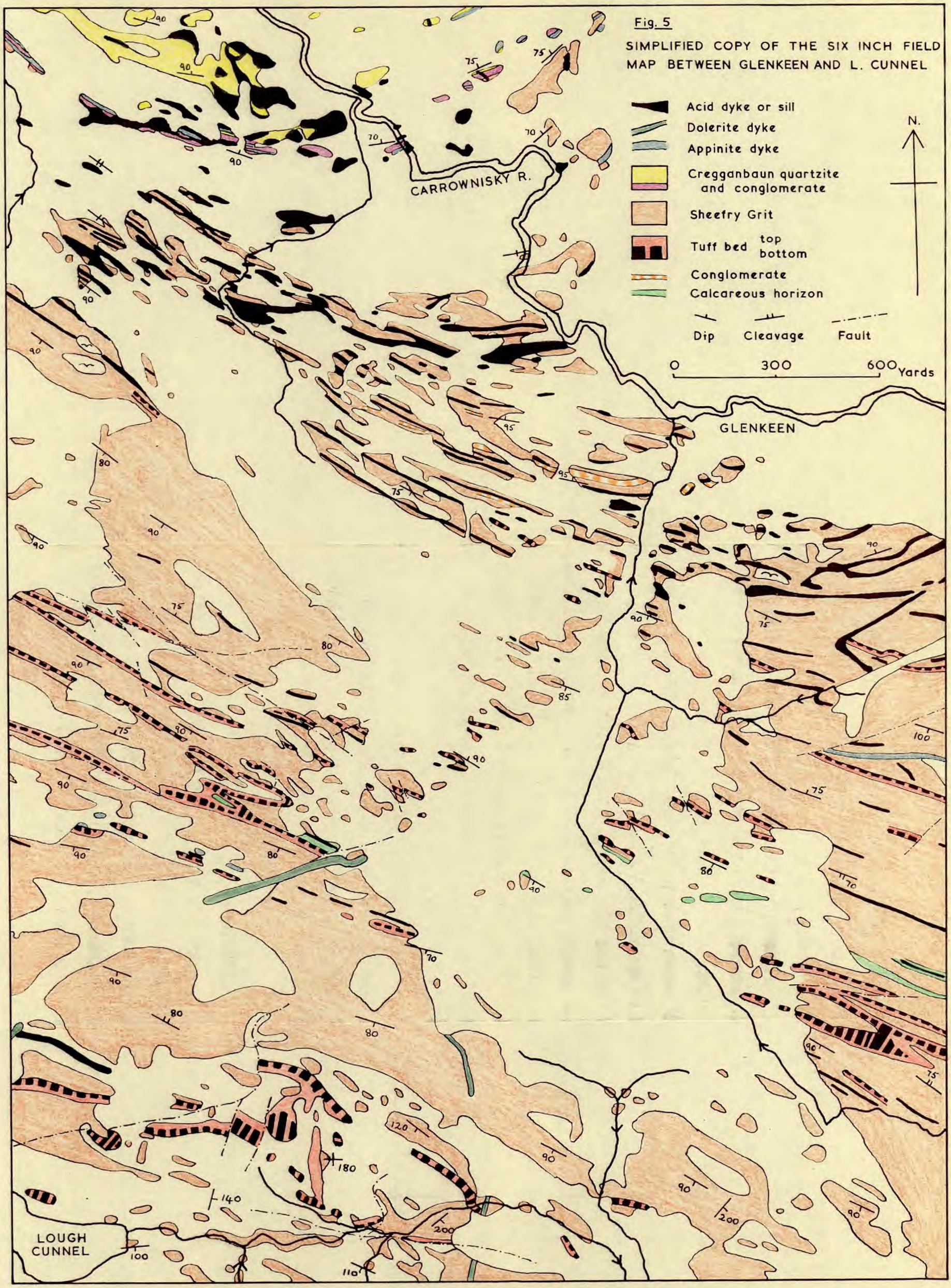
strata of pebbles similar to those of the overlying Cregganbaun conglomerate suggests that the conglomerate was deposited unconformably on a hard rocky surface, and not conformably on unconsolidated material. However, the presence of middle Arenig graptolites 300 yards to the south is conclusive evidence that a great unconformity is present.

Between Doogan Hill, Glenkeen, Lough Cunnel, and Lough Alisheen, is a region of bog with low hummocky rock ridges, crags, and glaciated pavements (Plate 2). The Maam Flexure passes through this region, and the structure is very complicated. The relevant six inch field map, with most of the dips omitted, is reproduced in Fig.5. Tight isoclinal folds and concealed faults frequently occur, and tuff beds form low ridges which often end abruptly at a concealed fault, or other discontinuity. Cleaved acidic and intermediate dykes and sills, associated with the Corvock granite, are present in great numbers. The grits often exhibit a schistose texture, due to shearing along the elongated limb of the Maam Flexure. It was undoubtedly this shearing which misled the surveyors of 1874 to name the rocks of this part of the "Doolough Series" the "Doolough Schists", and to postulate their elevation from a considerable depth by a fault.

South of Cregganbaun, near Boheh, and surrounding the granite hills of Knockaskeheen and Corvock, thermal metamorphism has hornfelsed the Sheefry Grits. Close to the

Fig. 5

SIMPLIFIED COPY OF THE SIX INCH FIELD MAP BETWEEN GLENKEEN AND L. CUNNEL



granite large spots of cordierite are developed, and further away the slates are compact and vitreous, due to the replacement of the pelitic material by biotite. In this region the Sheefry Grits are rather less coarse-grained than elsewhere, and there are frequent thin bands of current-bedded silt.

Between Corvock and the Sheefry Hills the rocks are generally concealed beneath deep glacial drift, but exposures in the bed of the Bunowen River show undulating strata pitching gently westwards. In the Sheefry Hills the gritty facies is dominant, with the strata lying vertically or overturned, and in the main younging southwards. There are some peculiar folds with nearly vertical axes, which are probably related to the Maam Flexure.

T.B's 7 and 5 are continuous throughout the Sheefry Hills. On the steeper slopes the strata are affected by hill-creep, which may bend originally vertical beds into a horizontal position.

(d) Lithology.

The type exposure of Sheefry Grits is a glaciated rock pavement on the north shore of Doolough, 100 yards east of the mouth of the river from Glencullin Lough. In 63 feet of strata there are 142 beds, of which 74 are less than an inch thick. Some of these show current or graded

bedding, but the majority are simple undifferentiated layers of grit, silt, or slate. Of the remaining 68 thicker beds, 49 are graded grits, 12 are undifferentiated slates, and 7 are coarse ungraded grits, often with current bedding. One ungraded grit stratum is 6 feet thick. Most of the graded beds are 3 inches to 8 inches thick.

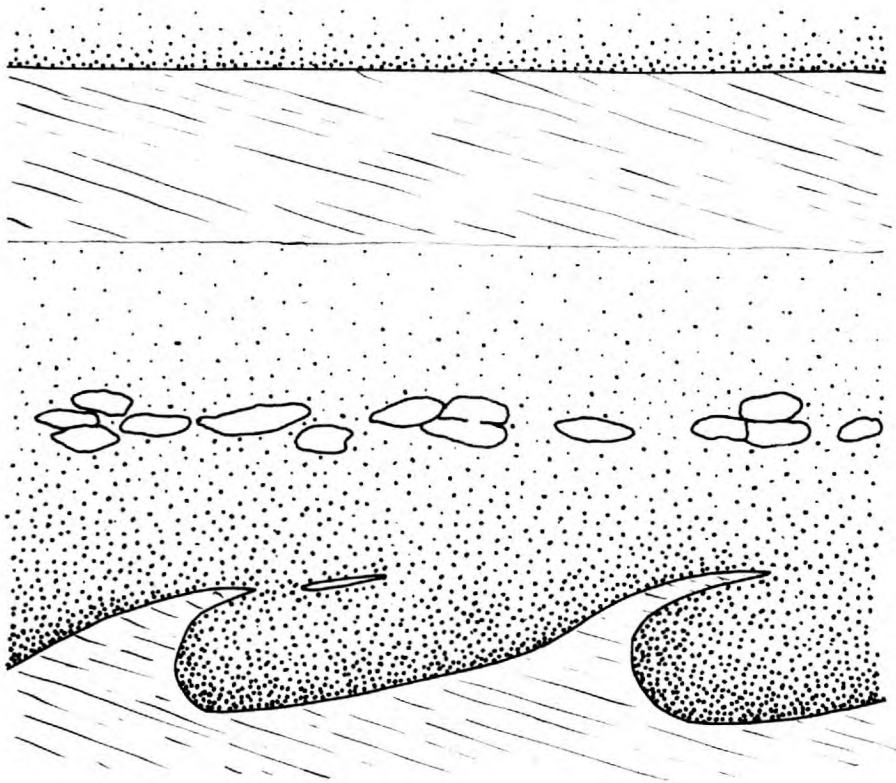
Each graded bed consists of a lower gritty portion and an upper slaty one, the amount of slate being usually less than that of grit. The gritty portion is itself graded, and at the base may contain particles more than 0·1 of an inch across. The transition from fine grit upwards into slate may be imperceptible, or it may take place suddenly in less than 0.1 of an inch, in which case a dividing line or ridge can be seen on a weathered surface. The slaty portion of the bed is not perceptibly graded.

The particles of grit are generally angular, and make up about 60 per cent of the rock (the remainder being the fine-grained calcareous and pelitic matrix). The main component is quartz, with subordinate orthoclase and sodic felspar. Grains of quartzite, myrmekite, muscovite, and microcline also occur. Shreds of carbonaceous matter are not uncommon, especially in the gritty portion of a bed and on the bedding planes.

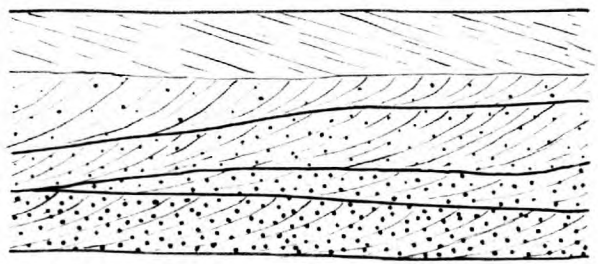
Calcite, with some dolomite, is always present, especially in the matrix of the grit, where it seldom constitutes less than 15 per cent of the rock. In such a

Fig. 6

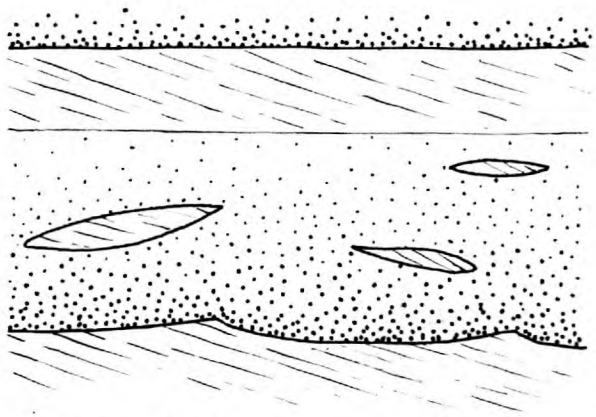
SEDIMENTARY STRUCTURES IN THE SHEEFRY GRITS



a. Flow Casts and calcite segregations, near Doolough (tracing x1)



b. Current bedding in a graded bed at Bunlough Point x1



c. Slate pellets in a graded bed Doolough x 1/2

case it is scattered uniformly through the rock as small recrystallised granules, but at other times the carbonates are segregated into bands of irregular nodules running parallel to the stratification in the gritty portion of a bed (Fig.6a). In the nodules the fine-grained matrix appears to have been completely replaced, since only the larger particles of quartz, felspar, and muscovite remain embedded in the carbonate.

Pellets of slate frequently occur in the grit (Fig.6c). They are always flattened in a plane roughly parallel to the bedding, and the average length: thickness ratio of about 4 : 1 may be a rough measure of the amount of compaction that has taken place in the slate. The pellets probably represent fragments of soft mud which were detached from the sea bed by bottom currents associated with the deposition of a graded bed. (Such currents often produced small-scale current bedding at the base of the bed). In rare cases the slate pellets may be the detached ends of flow casts (Fig.6a).

Graded beds are characteristic of the Sheefry Grits in every part of S.W. Murrisk, even in dominantly slaty sediments, of when current bedding is present.

The sheared and schistose grits of the Maam Flexure are seen under the microscope to consist of somewhat flattened particles of quartz and felspar, intercalated between gently-

Plate 3.

Photo - micrograph of sheared Sheefry Grit from the Maam Flexure.

(Ordinary Light, x 20)

Angular grains of quartz and felspar, with rare magnetite, are set in a fine-grained chloritic matrix. The rock is intersected by numerous foliation planes, along which large crystals of chlorite are developed.

Plate 4.

Schistose Sheefry Grit from the Maam Flexure.

It is still possible to distinguish the grading in the gritty strata. The beds young towards the top of the photograph.

Plate 3.

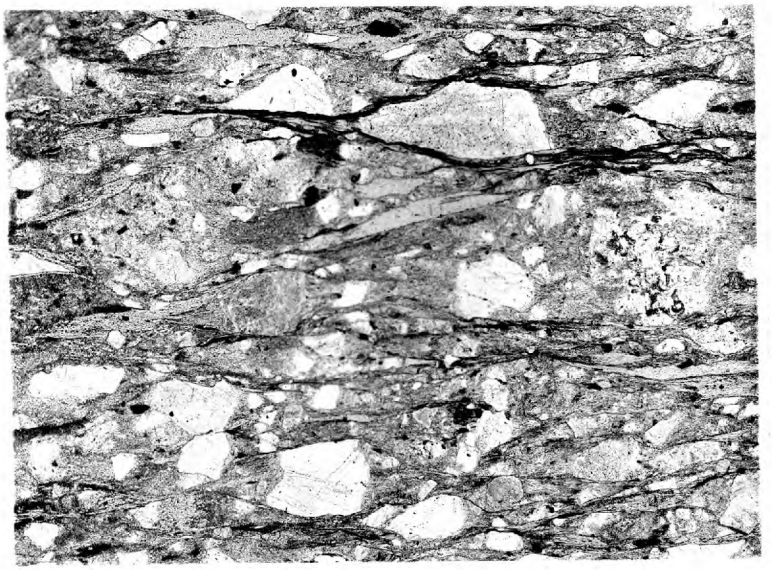


Plate 4.



curving foliation planes containing long shred-like crystals of chlorite and sericite. The quartz grains generally exhibit strain extinction (Plates 3 and 4).

Conglomerates are very rare in the Sheefry Grits. Only two are known in S.W. Murrisk; one south west of Glenkeen (Fig.5, Plates 5 and 6), and the other in the hornfelsed grits south of Boheh. The pebbles of the Glenkeen conglomerate are strongly flattened, since the conglomerate is well within the Maam Flexure. They attain a thickness of about an inch, and include fragments of vein quartz, quartzite, felspathic grit, black slate, dust tuff, calcareous silt, and an impure limestone, in a calcareous gritty matrix. No pebbles of jasper, so common in the higher formations, were seen.

Gravelly lenses, of similar composition to the conglomerate, occur sparingly near Glenkeen and north of Lough Cunnel. A graded bed 25 feet thick of coarse grit outcrops on the shore north of Bunlough Point, and a thick grit band forms a prominent ridge on the hill north-west of Six Noggins.

Cherty siliceous concretions are occasionally found in the Sheefry Grits. A few impersistent beds of thin-banded flinty material were mapped on the Sheefry Hills, and in thin section the rock was seen to consist of shards of volcanic glass and dust tuff. The 8 large tuff beds are described in detail in Chapter Seven.

Plate 5.

The Glenkeen Conglomerate.

The beds young towards the left of the photograph. The grass on the right conceals fine-grained slates.

Plate 6.

Close-up of the Glenkeen Conglomerate.

The photograph illustrates the intercalations of grit and conglomerate, and the elongation of the conglomerate pebbles due to shearing in the limb of the Maam Flexure.

Plate 5.

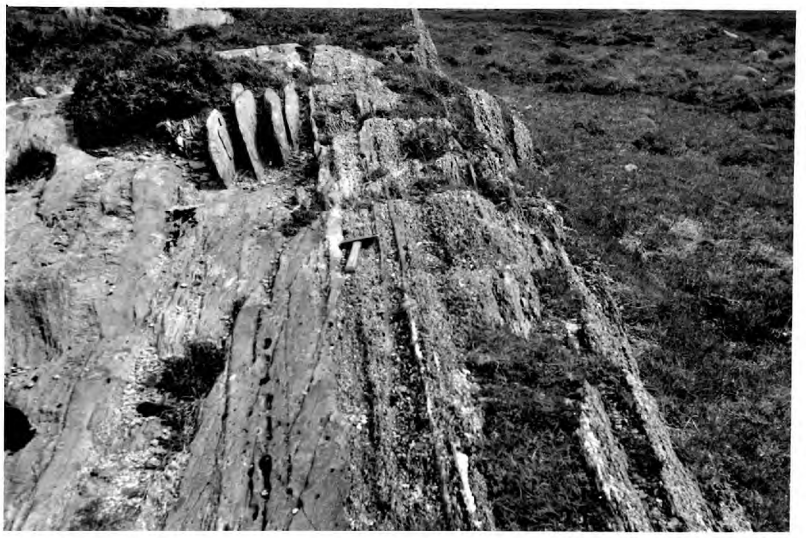


Plate 6.



Certain horizons between Doogan Hill and Clashcame, and at Barnabaun Point, are rich in carbonate, and probably represent a calcareous mud orsilt. The rock may contain up to 60 per cent of carbonate, which, in the Maam Flexure, has promoted the growth of large drawn-out crystals of calcite, muscovite, and chlorite. The latter often gives the rock a green tinge. Outside the Maam Flexure the carbonate has often recrystallised into spots, which may resemble scattered oolites. Weathering of the spots generally leaves a rusty deposit, which indicates that some siderite is present.

For distances up to half a mile away from the granite, the Sheefry Grits are hornfelsed. The effects of thermal metamorphism on the Grits are described in Chapter Nine.

(e) Sedimentary Structures, and Conditions of Deposition.

The dominant sedimentary phenomena of the Sheefry Grits are the thin but extensive graded beds. One such bed, a foot in thickness, was traced for 400 yards on Clashcame with no appreciable change in its structure. The thickness of another graded bed varied from 2 to 8 inches in 180 feet, and it was apparently lenticular. The continuity of single beds is a characteristic feature of the Sheefry Grits. It is well illustrated in Plate 2.

The lowest half-inch of coarse particles in a graded bed is often current-bedded. Not infrequently an apparently

normal graded bed is found to be current-bedded throughout when it is sectioned and polished (Fig.60). The water through which the sediments were settling to produce such beds must have been strongly agitated and moving rapidly over the sea bottom, while in the case of a normally graded bed the water near the sea bottom was calm.

Writers on the subject of "turbidity currents", (the fast-moving suspensions of sediment in water, posessing the properties of a dense liquid) suggest that these currents may, through their own impetus, follow a course at almost any level in the sea. The accumulation of a normally graded bed demands the introduction of masses of sediment without agitation of the water near the sea floor, such as is only possible through the action of strong currents in the upper levels of the sea. When the turbidity currents are at lower levels, they are likely to induce bottom currents, which may disturb the accumulating graded bed and initiate current-bedding. The intensity of the current-bedding may thus be a rough measure of the height of the turbidity current above the sea floor. In Plate 7, the current-bedding in the coarse-grained base of the bed is clearly visible.

The conglomerate of Glenkeen is lenticular from east to west, and was probably transported by a turbidity current of exceptional power.

Ripple-marks on bedding planes are very rare, and there is little evidence that bottom currents were important at times other than during the accumulation of a graded bed.

True ripple-marks, which occur but rarely, are symmetrical, with a wavelength of 2 to 4 inches and an amplitude of less than 0.5 of an inch. Apparent ripple marks, for which tectonic forces are responsible, are common in some districts, especially in the zone of the Maam Flexure. They are long continuous symmetrical grooves and ridges, with the cross-section of a flattened sine curve, and varying in wavelength from 3 inches to 2 feet. In thin-bedded strata they can be seen to be gentle folds, affecting all the beds, with their long axes parallel to the local lineation (as shown by a puckering of the cleavage surfaces).

Another type of false ripple-mark is due to slip along cleavage planes where they intersect a grit/slate contact at a high angle.

The peculiar sedimentary structures called "flow casts" (Schrock 1948), are occasionally found in the Sheefry Grits (Fig.6a). They occur along grit/slate contacts, where tongues of slate with the cross-section of a breaking wave intrude the overlying grit stratum. Certain bedding planes exhibit numerous flow casts, but isolated examples were not seen. The tip of the "wave" is sometimes separated from the remainder, and embedded in the grit.

The internal structure of the slate cast is obscure; that of the enclosing grit is illustrated in Fig.6a.

Lamont (1933) has interpreted the flow casts as fossilised "antidune ripples" in the slate. Such an explanation appears quite unjustified, for even if so unstable a structure could withstand the accumulation of coarse grit, the detached tip of the ripple could never be preserved in its true relative position. The characteristic shape of the flow casts, and their occurrence in a single horizon (in which all the crests point the same way), caused Schrock (1948) to suggest that they are produced when differential movement takes place, shortly after sedimentation, between adjacent unconsolidated grit and slate beds which still contain a high proportion of water. As the gritty stratum moves over the clay tongues of clay are dragged up into the grit, and the crests are bent forward in the direction of motion. The flow casts may perhaps be analogous to drag folds, but formed in unconsolidated strata.

False flow casts are produced by slip along cleavage planes in the same way as false ripple-marks.

The 8 tuff beds in the Sheefry Grits are all graded, and the particles range from a diameter of 0.4 of an inch at the bottom to microscopic dust tuff at the top. Even T.B.7 at its thickest (120 feet) is graded, with about 90 feet of coarse material beneath 30 feet of shards and

dust. The actual bottom of T.B.7. resembles a coarse gravel.

Slumped sediments are seen at a few localities, as in the bed of the Carrowmisky River a short way below Glenkeen Bridge. It is possible that the abrupt termination and apparent discontinuity of some of the lower tuff beds may be due to slumping of the unconsolidated material shortly after its deposition.

The deposition of the Sheefry Grits undoubtedly took place under marine conditions, since brachiopods, cepalopods, and graptolites occur as fossils, and the sediment is uniform over more than 150 square miles of exposure in West Connaught. The universal grading of individual strata suggests consistently deep water. The clear grading of the 120 foot T.B.7 into 90 feet of coarse and 30 feet of fine sediments must have taken place in a great depth of water, probably well over 1,000 feet. Even so, the supply of tuff must have been very rapid. The accumulation of 120 feet of tuff on the sea floor in no way changed the nature of the sedimentation, which went on precisely as before.

In Middle and Upper Arenig times, S.W. Murrisk was an area of deep water, invaded at intervals by turbidity currents which brought in most of the sediments. These sediments accumulated in graded beds after settling through the water. The scarcity of conglomerates suggests that the

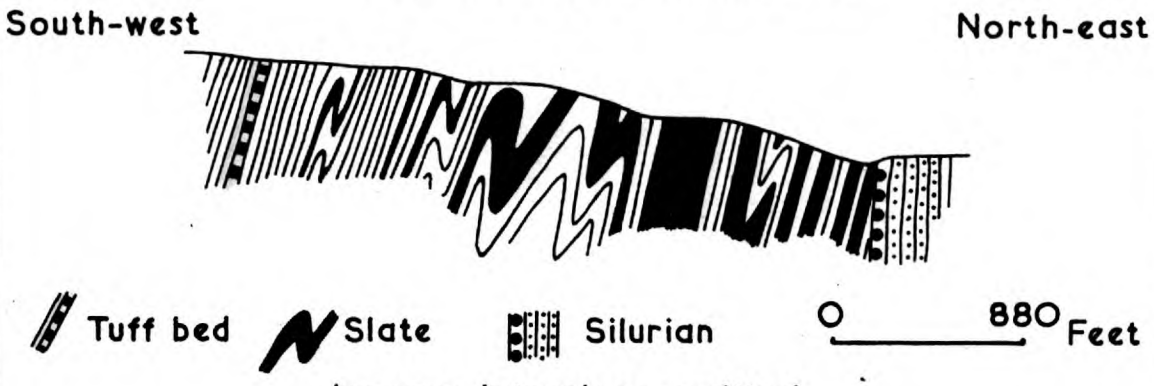
shoreline was at a distance, and that turbidity currents strong enough to transport such coarse detritus were rare.

(f) Stratigraphy.

Carruthers and Muff (1909) attributed an Upper Arenigian age to the Sheefry Grits, and to the Leenane Grits on the south side of Killary Harbour, 3 miles south of Doolough. They compared the coarse grits, gravels and conglomerates of the Leenane Grits with the finer-grained Sheefry Grits, and suggested that the Leenane rocks were littoral deposits whose off-shore equivalents were the Sheefry Grits. Miller and Maclaren (1948) drew attention to the lithological similarity between the grits and conglomerates of Leenane and Rosroe, 6 miles apart in an east - west direction, and suggested that during upper Arenigian times a roughly east - west shoreline lay a short distance south of the present line of Killary Harbour. They believed that most of the Arenigian sediments were derived from the Connemara Schists on the south. Theokritoff (1950) extended the correlation eastwards from Leenane to Rinavore in the south, and eastwards from Doolough to Erriff in the north.

Considered by themselves, the Sheefry Grits in S.W. Murrisk contribute little positive evidence towards clarifying the Arenigian stratigraphy. Carruthers and Muff

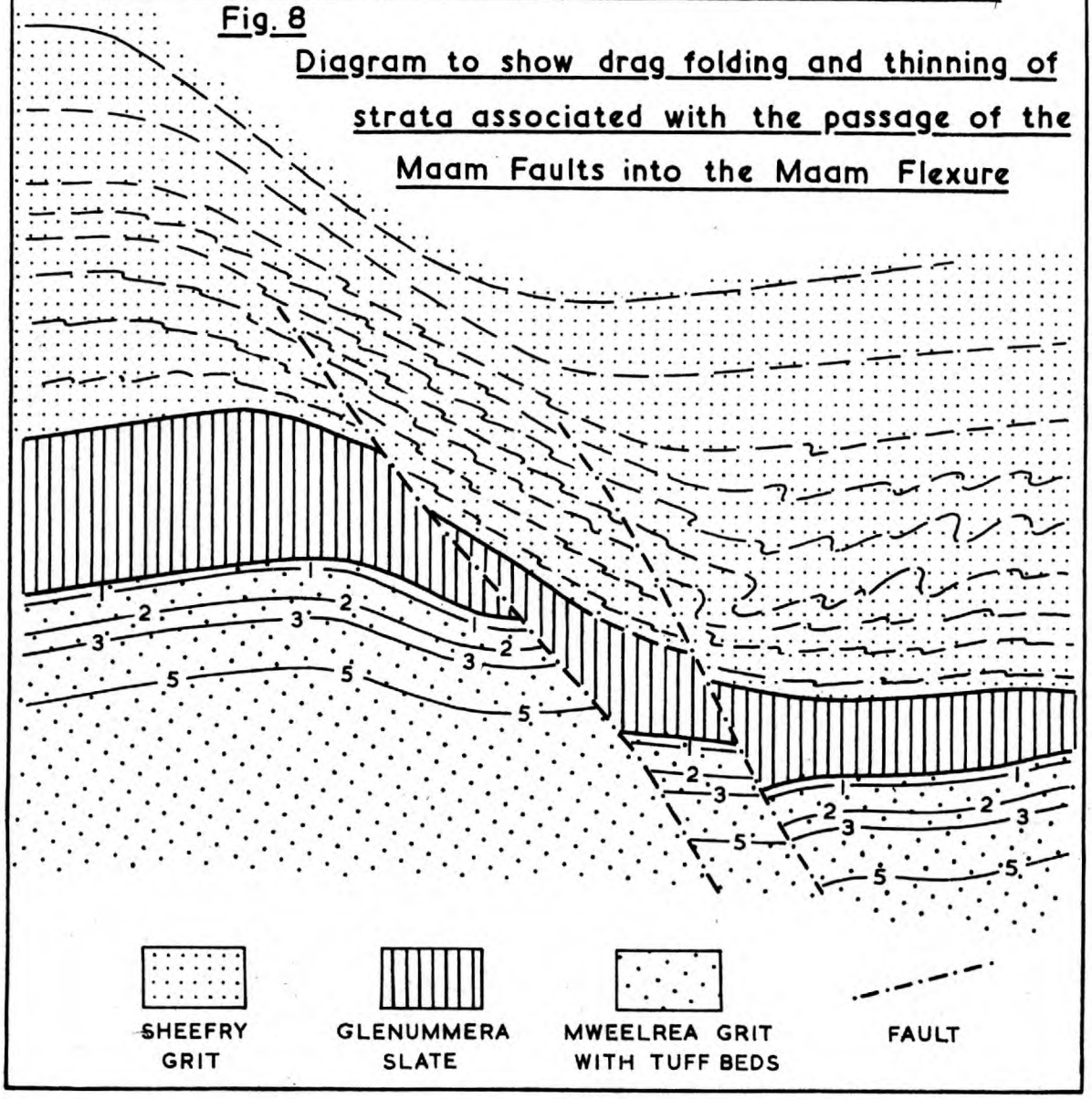
Fig. 7 SECTION SHOWING FACIES CHANGES ACROSS THE FEENUNE ANTICLINE



Igneous intrusions omitted

Fig. 8

Diagram to show drag folding and thinning of strata associated with the passage of the Maam Faults into the Maam Flexure



established that the main stratigraphical change was from south to north, and in S.W. Murrisk the only continuous exposures of one horizon are from east to west. Thus, along the line of T.B.7. from the extreme east of the area to Legha More, a distance of 9 miles from east to west, there is no appreciable alteration in the lithology of the grits. On Inishturk, 7 miles west of Legha More, similar grits are exposed, and it is evident that the Sheefry Grits do not show significant changes in an east-west direction.

There are only a few opportunities for ascertaining the north-south variation in any horizon. Reference to the coast section (Fig.4) will show that the rocks at Cross Point are roughly the equivalent of those between T.B.'s 7 and 8 a mile further south. Graded gritty beds are present at both places, but at Cross Point there are several bands of dark grey or black slate which are not seen in the southern exposure.

Fig.7 illustrates the facies change across the isoclinal Fennune anticlune, west of Lough Mahaltora. There is a very marked increase in the amount of slate in the north limb of the anticline, so much so that a small slate quarry has been opened at one place. West of Lough Mahaltora the Feenune anticline lies in the elongated limb of the Maam Flexure, and has been considerably thinned.

The facies change, therefore, appears to take place more rapidly than is really the case.

In the neighbourhood of Boheh, in the extreme north of the area, the Sheefry Grits are represented by slates and thin silty bands, which often show small-scale current bedding. Their exact horizon is uncertain, but they are probably the equivalent of grittier strata further south.

The foregoing evidence, though meagre, supports Carruthers and Muff's correlation of the Sheefry Grits near Doolough with the coarser Leenane Grits further south. It is now possible to extend this correlation, and to state that, in general, the grain size of the Arenigian rocks becomes less as they are traced from Killary Harbour to their northernmost exposures near Cross Point, Lough Nahaltora, and Boheh. In all probability, therefore, the Arenigian sediments were derived from the south. It is remarkable that no pebbles resembling the Connemara Schists have been found in the conglomerates of Glenkeen and Boheh. On the other hand, the fragments of limestone may be referable to the "Limestone breccias" of Arenigian age which occur in the Leenane Grits and the Shangorb and Tourmakeady beds west of Lough Mask. (Gardiner and Reynolds, 1912).

(g) Structure.

The Sheefry Grits, with their steep, often over-

turned folds, concealed faults, and unevenly distributed exposures, pose a difficult structural problem. The interpretation has been based almost entirely on sedimentary structures; the ever-present graded bedding and the less frequent current bedding, with occasional assistance from flow casts, all of which reveal the way up of the strata. The 8 graded tuff beds, especially T.B.'s 7 and 8, are valuable marker bands, although the correlation of the discontinuous and poorly exposed lower members is by no means sure.

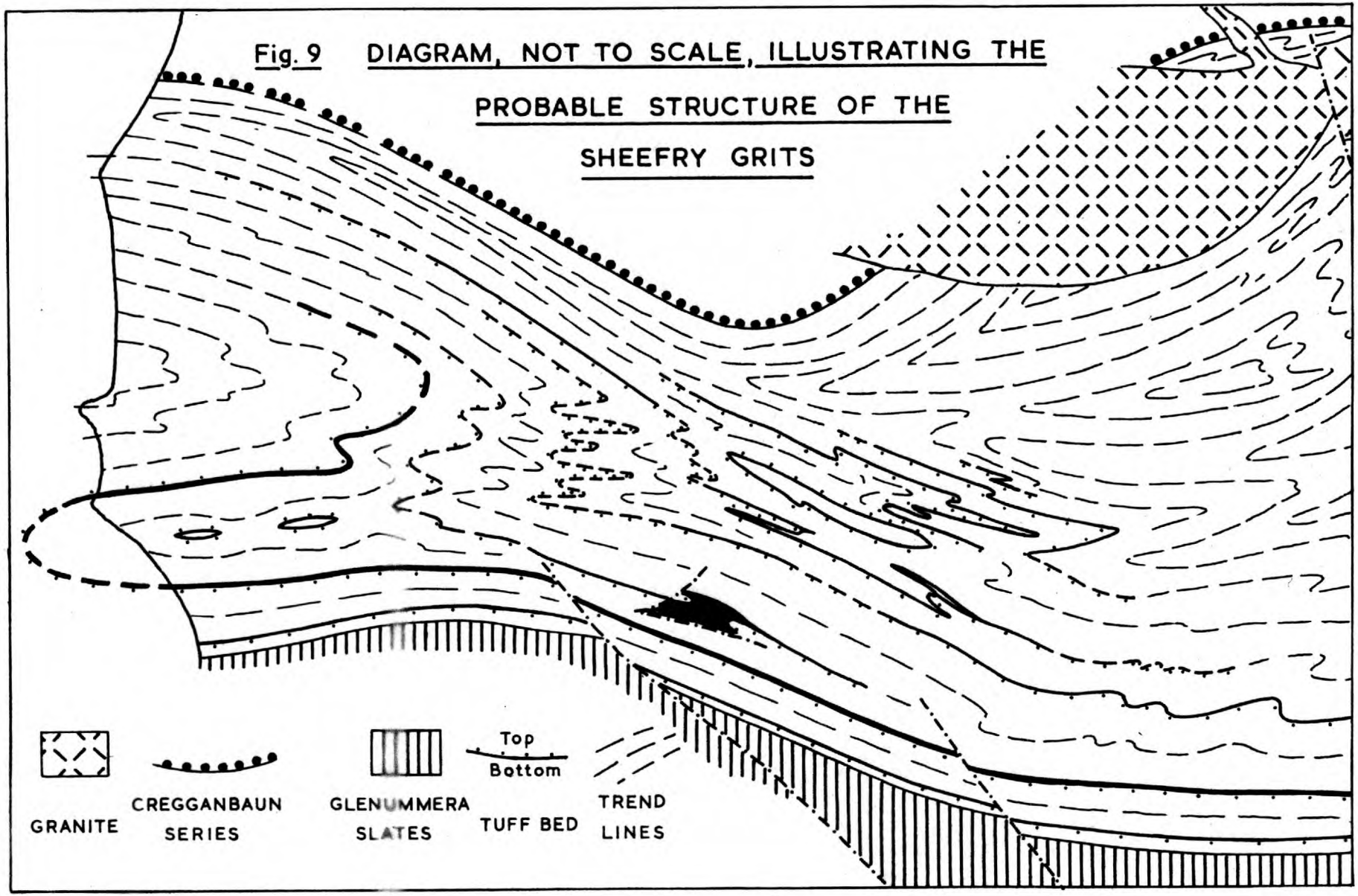
The structure is essentially a series of simple folds in a general east-west direction, but deflected from their normal trend in the central area by the big Maam Flexure. In S.W. Murrisk the folds usually pitch gently westwards. The part played by faulting is difficult to determine, as faults are hard to detect in the field. Where a fault plane is exposed, the zone of disturbance is often seen to be less than an inch across. Faulting is probably subordinate to folding, since the Sheefry Grits are only semi-competent strata and are readily bent and sheared (vide the passage of the Maam Faults into the Maam Flexure). Occasionally a fault-zone is wider and is eroded into a gully; such faults seldom have a large displacement, and appear to have originated subsequently to the main folding.

The main folding took place during the Caledonian orogeny, since Silurian, but not Carboniferous rocks, are affected by it. There is some evidence of weak pre-Silurian folding (Chapter Ten).

Figure 9 is an attempt to present a simple picture of the structure of the Sheefry Grits, as reconstructed from the field maps.

On the sea coast, in the west, the simple anticlines and synclines are only complicated by frequent small puckers on their flanks (where they may be compared to large drag folds), and in their cores. In the core of the syncline near Bunlough Point the strata are overturned through 180 degrees for a short distance (Fig.4). Further east, in the zone of the Maam Flexure, the big, simple folds are replaced by small, distorted, isoclinal ones. It is likely that some of the limbs of these tight folds have been sheared or thrust out, and this type of dislocation might explain the absence of some of the tuff beds at places where they would otherwise be expected to outcrop.

East of the Maam Flexure, between the Glenummera River and Corvock, simple anticlines and synclines are again seen. They are complicated in the Sheefry Hills by the presence of folds with nearly vertical axes, which appear to be related to the Maam Flexure (q.v.). Around Knockaskeheen,


Fig. 9 DIAGRAM, NOT TO SCALE, ILLUSTRATING THE PROBABLE STRUCTURE OF THE SHEEFRY GRITS
Top
Bottom
GRANITE
CREGGANBAUN SERIES
GLENUMMERA SLATES
TUFF BED
TREND LINES

where the granite intrusion retains a thin cap of hornfelsed Sheefry Grits, the strata are involved in innumerable small folds. Apparently, as the country rock was rendered more plastic by the heat of the intruding granite it flowed into irregular contortions, which yet follow the regional trend.

In the Sheefry Grits between Doolough and Lough Cunnel there are many small drag folds with vertical axes, as shown in Fig.8. (Some minor examples can be seen in the middle foreground of Plate 2). Similar folds, on a much larger scale, occur in the Sheefry Hills, where they affect T.B.5. Their vertical axes make it hard to correlate them directly with the forces that produced the regional folding. They appear to be the result of left-handed slip along the bedding in the area of the diagram (Fig.8), and thus seem to be genetically connected with the left-handed Maam Flexure, which is similarly in a vertical plane. Probably some of the left-handed shearing stress which caused the flexure was absorbed in this bedding slip, and resulted in large and small drag folding.

In Fig.8 the trend lines reveal the apparent thinning of the strata in the limb of the Maam Flexure between Glencullin Lough and Lough Nahaltora. The effect of the Maam Flexure on the field appearance of the Sheefry Grits, flattening the grit particles and giving the rock a schistose

appearance, has already been mentioned. Reference to Plates 31 and 32, which illustrate the Cregganbaun conglomerate, shows that in the zone of the flexure the pebbles are much more strongly flattened than elsewhere; indeed, they appear to be less than half their original diameter. The same is true of the pebbles in the Glenkeen conglomerate (Plate 5). Under the microscope the component grains of the Cregganbaun quartzite and the Sheefry Grits near Nahaltora are seen to be similarly flattened, with numerous shearing planes and other evidences of elongation. Since the individual rock particles are thus proved to be elongated in the direction of the limb of the Maam Flexure, it may be concluded that the limb itself is elongated, and consequently that its apparent attenuation is genuine.

Cleavage is well developed in the slaty strata of the Sheefry Grits. The map (Fig.26) shows only small variations in the cleavage strike in S.W. Murrisk. In areas removed from the Maam Flexure, the cleavage generally intersects the bedding at a small angle, which renders difficult the discovery of graptolites. In a graded bed the cleavage swings round normal to the bed as it enters the grittier lower portion, and this phenomenon is useful in the determination of the "way up" or "direction of younging", at a glance (Plates 8 and 9). Plate 9 also illustrates the slip which can occur along cleavage planes.

Plate 7.

Current-bedding in a graded bed, Doolough.

The beds young towards the top of the photograph. The gritty stratum above the hammer is graded, though disturbed on the left of the photograph. Current-bedding can be seen in it on the right.

Plate 8.

Fracture cleavage at Feemine Quarry.

The hammer rests on a graded bed, which youngs towards the top of the photograph. At the top of the bed the cleavage is inclined at its usual angle; in the coarser-grained base it swings round normal to the bed.

Plate 9.

Cleavage in graded beds, Cross Lough.

The beds young towards the top of the photograph. The dark strata are grits. At the base of the topmost bed, slip has occurred along the cleavage planes.

Plate 7.

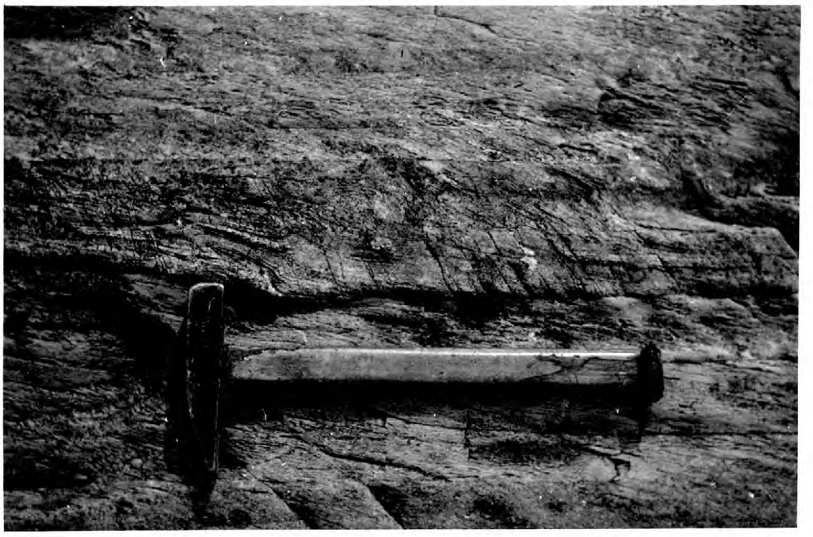


Plate 8.



Plate 9.



At several localities along the coast and further inland, the dip of the cleavage varies from 90 degrees to the horizontal, although the strike direction is fairly constant. The cleaved slates are not contorted, and do not appear to have been disturbed since their formation. There are two possible explanations :

1. The cleavage was once uniformly steep, and has since been folded.

2. Local internal shearing stresses in the latter stages of folding (e.g. as an effect of bedding plane slip in the formation of small core and flank folds) caused local variations in cleavage orientation.

Against (1.) is the undisturbed appearance of the cleavage, and the fact that an attempt to reconstruct an earlier fold-system with uniformly dipping cleavage produces a well-nigh impossible structure.

Wilson (1946) describes the production of internal shearing stresses in slaty beds by the warping and resultant differential slip of interstratified hard beds. These subsidiary stresses result in the local formation of fracture cleavage in the appropriate direction, which may be completely at variance with the regional orientation. It is considered that such fracture cleavage has been formed in the localities where the cleavage orientation appears to be anomalous.

Between Lough Cunnel and Glencullin Lough is a curious structure which is difficult to explain, but seems to be an effect of thrusting from the north. A considerable area of Sheefry Grits, including T.B.6, appears to be undulating and nearly horizontal, but using graded bedding, it is found to be completely inverted. The cleavage is also flat-lying, but is greatly contorted, indicating that this movement has taken place after the main folding. T.B.6 is exposed in an inverted syncline, but is not repeated, which indicates that it has been thrust, not faulted, out. (Fig.5). On the north-east shore of Glencullin Lough a number of similar inverted synclines are exposed, and it is suggested that a thrust plane with a small displacement runs from Lough Cunnel along the north side of Glencullin Lough. Another small thrust is proposed to explain a discontinuity a few hundred yards further north. The suggested section is incorporated in the cross-section (Fig.28).

In the field it is difficult to understand the abrupt termination of some of the lower tuff beds (T.B's 2 to 5). There are at least 7 places where a tuff bed with a constant thickness of 20 or 30 feet suddenly ceases to be exposed, and its place is taken by a zone of contorted strata. Thereafter it may not be re-exposed for hundreds of yards, or it may vanish entirely. In some cases the disappearance

may be explained by a fault or thrust, which in the Sheefry Grits is likely to be well concealed; but it is hard to understand why, in such cases, the tuff bed should vanish completely and not reappear. Another possible explanation is that parts of the tuff bed were carried away by slumping before the sediments consolidated. North of Lough Alisheen T.B.3 occurs as isolated outcrops in line, a hundred yards apart, separated by contorted gritty strata. Here at least it appears that small scale slumping has occurred, to break the continuity of the tuff bed.

Chapter Five. THE GLENUMMERA SLATES.

(a) Introduction.

The Officers of the Geological Survey of Ireland, in their Memoir of 1876, applied the name "Doolough Series" to all the strata underlying the Mweelrea Grits on the north of the Mweelrea syncline. However, they recognised that in the neighbourhood of Doolough the "Doolough Series" comprised a lower massive grit formation and an upper series of green slates, overlain on the south by the Mweelrea Grits. Carruthers and Muff (1909) assigned an Upper Arenigian age to the "Doolough Series" near Doolough. Theokritoff (1951) mapped part of the boundary between the slates and the underlying grits, and named the former the Glenummera Slates from their exposure in the valley of the Glenummera River. This name has been adopted in the present work.

The Glenummera Slates are abundantly exposed north of the Mweelrea syncline, and are seen in three small areas on the south, bordering Killary Harbour. It is also not impossible that the Slates are present in the core of the syncline, just north of Dinloughmore, concealed beneath alluvium and glacial deposits.

Where the Slates are followed southwards they are seen to pass conformably into the Sheefry Grits, with the

incoming of more and more gritty strata. Upwards, too, grit bands appear, and there is a rapid transition into the lower flaggy zone of the Mweelrea Grits. This boundary is diachronous, the gritty upper portion of the Slates near Doolough being equivalent to the flaggy base of the Mweelrea Grits near Bundorragha. The lower boundary is best seen in the Glenummera valley, and the upper one is well exposed south of Doolough, near Deoaghtry, and a mile east of Bundorragha.

The incompetent Slates, sandwiched between two massive grit formations, have undergone extensive crumpling and contortion, so that their true thickness is difficult to determine. The disturbance is least in the Glenummera valley, and from the exposures there it can be calculated that the formation is not more than 1,500 feet, and probably not less than 1,000 feet, thick.

The slates were readily eroded by glaciers, and generally occupy low ground, the only exception being the hill slopes between Lough Cunnel and Oughty Craggy. The Glenummera valley, Killary Harbour west of Leenane, and the low ground about Corragaun Lough, reflect the presence of the Slates. The rock was easily moulded into lines of roches moutonées, which dominate the scenery south - west of Doolough and near Corragaun Lough.

(b) Age.

The Glenummera Slates lie between strata of known Upper Arenigian age (the Sheefry Grits at Doolough), and the supposedly Llandeilian or Caradocian Mweelrea Grits. Until recently the formation had yielded no organic remains, but in 1951 and 1952 eight fossil localities were discovered. They contained gastropods in abundance, together with trilobites, brachiopods, and lamellibranchs, all of which are described in Chapter Eleven. Unfortunately, they only provide enough evidence to date the Glenummera Slates as Lower or Middle Ordovician.

(c) Field Description.

East of Bundorragha nearly 560 feet of Glenummera Slates dip steeply northwards, and are truncated further to the east by one of the two Maam Faults. On the south they pass beneath the waters of Killary Harbour. The strata are not greatly contorted, but on the shore some small drag folds and strike faults are evidence of the southward over-riding of the Mweelrea Grits. Slaty cleavage is well developed. West of Gubgar there is a thin band of tuff, graded like those in the Sheefry Grits, and extending about 200 yards between low and high water marks. Slump structures (Plate 10) are to be seen in the small slate quarry on the shore at Gubgar.

On the coast west of Bundorragha the Slates are again brought up by a series of left-handed tear faults. The topmost 300 feet are exposed, but the horizon of the tuff is not reached. A series of very small strike faults, both thrust and normal, find topographical expression as low bluffs. On the coast low cliffs descend precipitously into deep water, and care must be taken in the collection of trilobite-bearing nodules, which occur in the western and central portions of the outcrop. On the little island of Illanballa an acid dyke cuts the slates.

Near Carricklea the great left-handed tear fault of lower Killary Harbour brings in about 400 feet of Slates. They are much contorted along side the fault, and on Carricklea peninsula there are gentle folds. A lens of coarse grit is intercalated between the finer-grained strata.

North of the Mweelrea syncline, at Trawlecknackoolia, the Slates appear from beneath the Mweelrea Grit, but are soon faulted down again south-east of Dooaghtry. In the coastal strip the beds dip southwards at about 30 degrees, and the cleavage is 10 to 20 degrees steeper. One lens of conglomerate and gravel is 300 yards long and attains a thickness of 20 feet. There are occasional nodules, some of which contain badly preserved gastropods.

In the country about Corragaun Lough a large area of Slates is well exposed in low ridges and roches moutonées.

There are numerous tight folds, some isoclinal, but the strata become gradually older as they are followed northwards. The fold axes generally pitch at low angles to the east. Close to the Mweelrea Grit outlier at Doogahtry the folding is less intense, and there are areas of gently dipping or horizontal strata. Cleavage is well developed, but is sometimes contorted, due to movement in the Slates since its formation. There are two very thin beds of dust tuff, one 30 feet below the lowest Mweelrea tuff bed southwest of Corragaun Lough, and the other north of the Owennadornaun River half a mile upstream of the Lough. Four or five lenses of coarse grit have been mapped.

East of this region the Slates vanish beneath an extensive cover of glacial drift, to reappear a mile west of Oughty Craggy. Here they dip gently beneath the Mweelrea Grits, but undergo small scale folding further to the north. The exposures are continuous, and the thin grits of the upper part of the formation form wide, flat, bedding-plane surfaces, on which ripple-marks are sometimes preserved. There are bands of large nodules, but only a single brachiopod cast was found in them.

The Slates swing round as they approach the Maam Faults, which obtain a surprisingly small topographical expression; insignificant in comparison with the gully of a dolerite 12 feet thick which runs north-west over the

shoulder of the hill from the great corrie of Lugmore (Plate 1.). South of Doolough the strata are intensely folded into tight anticlines and synclines which pitch eastwards at 20 to 40 degrees. This is the result of a combination of the over-riding of the Mweelrea Grits with the shearing action of the Maam Faults.

In the Glenummera valley the Slates are not fully exposed, but appear to be less contorted than in the regions further west. It is only here that the full thickness of the formation may be calculated, and it is found to be between 1,000 and 1,500 feet. On the map the formation appears to thicken westwards towards Doolough, at the expense of the Sheefry Grits, but, owing to the increase in folding and faulting near the Maam Faults, it is not possible to verify this possibility.

(d) Lithology.

The Glenummera Slates consist mainly of grey-green slate, with thin layers of fine silt. The slaty material is of exceedingly fine grain, and much of it has been altered to chlorite. Minute particles of quartz and felspar are scattered through it. The silt grains which are angular and sub-angular, rarely exceed a diameter of 0.01 of an inch, and grade from this size down into clay.

Fragments of quartz, sodic plagioclase, and muscovite occur, (in order of decreasing abundance). The matrix enclosing the silt grains is chloritic, and constitutes up to 40 per cent of the silt, as it does in the Sheefry Grits. In some places carbonate is concentrated in the silty bands. It is never found in any quantity in the fine slate.

The lenses of conglomerate and coarse grit contain pebbles of jasper (very rare), quartzite, silt, and slate, with abundant fragments of quartz and some sodic plagioclase.

Many of the thin silty layers are well graded, and rest with a sharp junction on the underlying slates. The junction may be irregular due to differential compaction of the slate and slip along the cleavage planes. Graded silts are often continuous, and traceable for scores of yards. Other bands are discontinuous, occurring in lenses and stringers, which indicate that the settling of sediment was not always undisturbed.

The concretionary nodules which sometimes contain fossils have already been mentioned (section c). They occur singly and in bands, but when found singly there are usually others at intervals along the same horizon. The material is grey-green, hard, and flinty in the hand specimen, but under the microscope a large proportion is found to be crystalline calcite, intimately associated with fine-grained siliceous and chloritic material. The nodules occur in slates, and not in silt bands, though they

may contain particles of quartz and muscovite. A crystal of iron pyrites is often found in the centre, at other times a fossil, or there may be no discoverable nucleus. In large nodules, more than 4 inches across, the centre may be cracked in the same way as a septarian nodule.

The nodules appear to represent the partial replacement of the fine-grained clay material by calcite, since the calcite-free patches in the nodules bear a close resemblance to the surrounding slaty material, save that they are uncleaved. It is therefore suggested that the nodules are segregations of calcite formed during or shortly after deposition, and partially replacing the clay minerals of the slate. The material of the nodule is hard, and readily scratches glass, and it is probable that the quartzose fraction of the original clay was unreplaced by the calcite, which bound it firmly together.

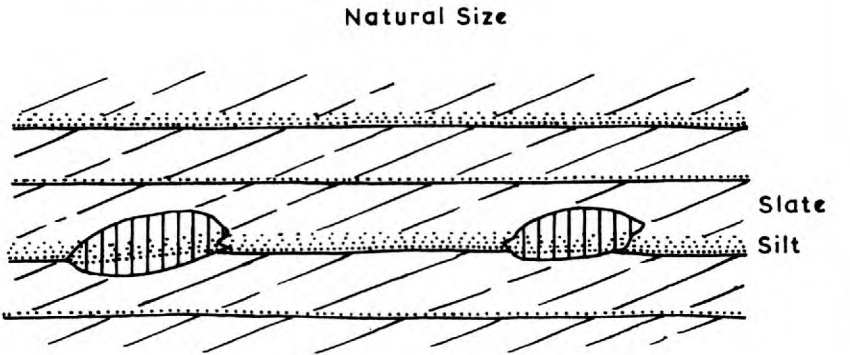
Bands of coarse grit and conglomerate are occasionally found in the Slates. They are lenticular in cross-section, and may reach a length of 100 yards and a thickness of 10 feet. In all the occurrences except one the coarse material is an unsorted mass of consolidated gravel and small pebbles. The exception is the large lens of grit and conglomerate on the shore south-west of Donaghtry, in which the grit is bedded and becomes coarser upwards. It can hardly have been deposited during a single violent disturbance. However, in the other cases the lens of unsorted gravel was probably

deposited suddenly. The lower surface, where it is visible, shows evidence of disturbance, for isolated pebbles are found in the slate several feet beneath it. The coarse lenses are small-scale phenomena, and are probably best explained by postulating very strong localised currents capable of transporting the coarse material over great distances (for no widespread coarse deposits are known in any part of the Glenummera Slates outcrop). It is not impossible that turbidity currents initiated by slumping (Chapter Four, section e.) were responsible. In this connection, it is significant that a coarse conglomerate is found immediately below the tuff bed at Gubgar, as it is at such times of volcanic disturbance that slumping is to be expected.

These isolated gravelly lenses are quite different in appearance and extent to the widespread gritty strata which indicate the onset of grit-depositing conditions at the top of the formation.

Plate 10 illustrates one of the rare exposures of small slump-structures in the slates, in the quarry at Gubgar. In this case a thick silty bed partially replaced by calcite has been involved in a limited slip from west to east. The small elongated white blobs visible in the lower part of Plate 10 are common in the Slates. In the field they

Fig.10 Section of calcite segregations in the cleaved Glenummera Slates near Gubgar.



resemble the fossil-bearing nodules already described, except that they are softer, easily weathered, and unfossiliferous. In thin section they are seen to be segregations of calcite in a band of silt (Fig.10). The graded quartz grains of the silt bed pass unaltered through the segregation, which is clearly post-depositional. The segregations are characteristically developed in the same thin horizon for considerable distances, and the silt bed itself often contains much calcite. There is no sign of compaction round these nodules, indicating that they were formed long after deposition, although they are somewhat flattened parallel to the cleavage. To summarise, it is believed that the nodules are the products of migration and segregation of calcite along silt bands subsequent to the deposition of sediments, which probably contained a high proportion of calcite.

In the grittier strata at the top of the formation current bedding is sometimes present. Small ripple marks exist also, but they must not be confused with a ripple-like effect (Plate 11) that is produced where steep cleavage intersects thin, nearly horizontal, grit bands. Widely-spread cleavage planes are developed in the grit, and the pseudo-ripple effect is seen wherever bedding plane surfaces are exposed.

Plate 10.

Slumping in the Glenummera Slates, Cubgar.

The whitish band is calcareous silt.

Plate 11.

Pseudo-ripple-markings, near Uggool.

The rock surface is one wide bedding plane, above a thin bed of silt. The ripple effect is produced by slip along cleavage planes.

Plate 12.

A drag fold near Doolough.

The fold is in flaggy strata near the top of the Glenummera Slates.



Plate 10.



Plate 11.



Plate 12.

(e) Structure.

The Glenummera Slates underlying the Mweelrea Grits, are only exposed in the two limbs of the Mweelrea Syncline.

The complicated intraformational folding, due to the sandwiching of the incompetent Slates between the more competent Sheefry Grits and Mweelrea Grits, has already been mentioned. On the north of the syncline the Sheefry Grits are vertical, while the Mweelrea Grits dip southwards at 30 to 60 degrees; here, the folding is more intense than on the south of the syncline, where the Mweelrea and Leenane Grits both dip northwards at 40 to 60 degrees. Where the overlying strata are nearly horizontal, as they are near Doogahtry and Corragaun Lough, the Slates are thrown into small tight folds with small areas of horizontal strata. The complex fracturing of the Mweelrea Grits at Doogahtry probably reflects the folding of the Glenummera Slates a few hundred feet beneath.

Near Doolough the Maam Faults traverse the Slates, and the intraformational folding is more complicated. The faults are clean breaks in the Mweelrea Grits, but in the incompetent Slates the strata tend to swing round into the Maam Flexure, and the amount of throw diminishes. There has thus been great differential movement between the Slates and the Mweelrea Grits in the Maam Fault zone, near Doolough, which has given rise to the shear zone and folding illustrated

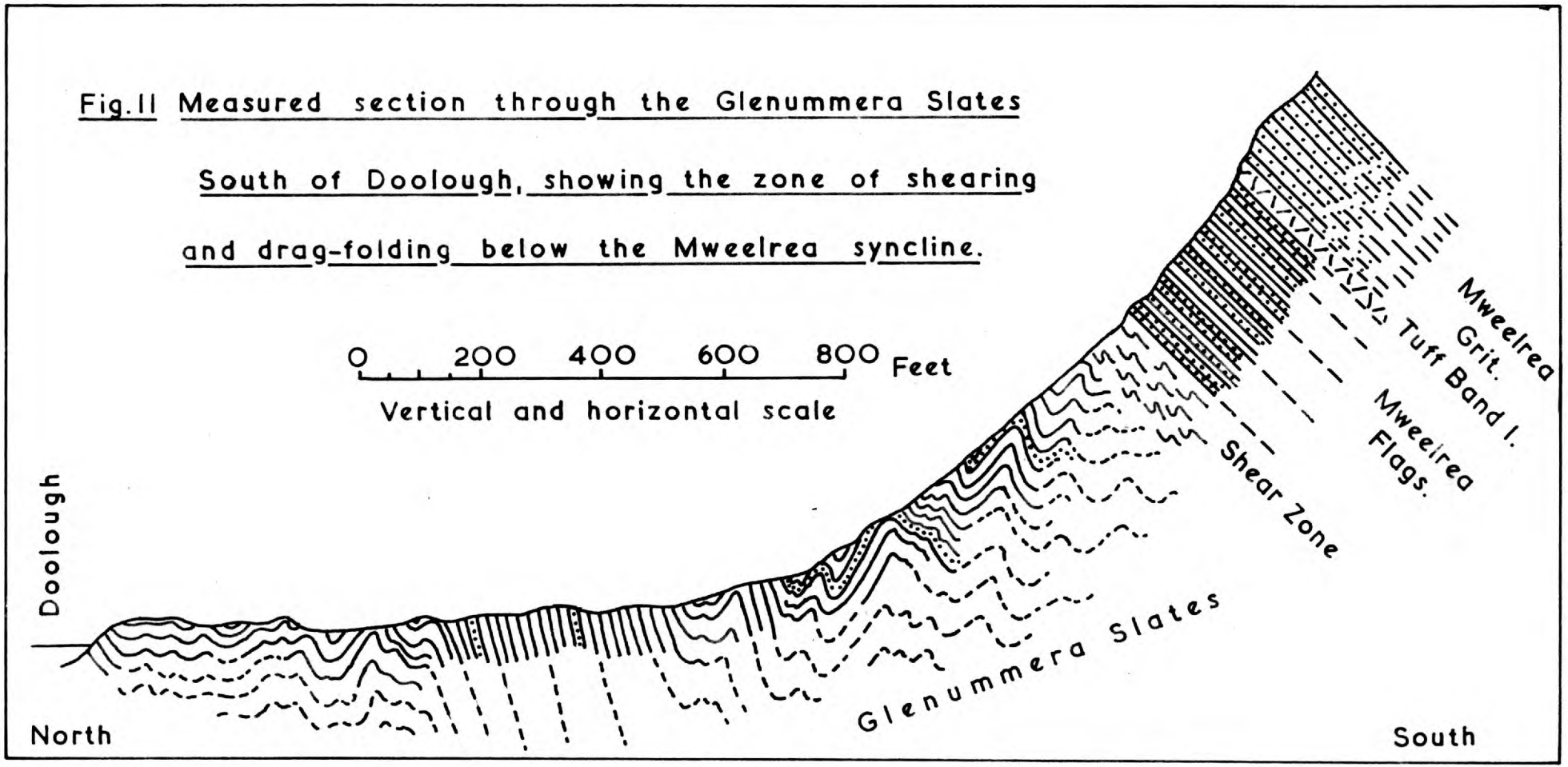
in Fig.11. Plate 12 shows a small drag fold in the Slates beside Doolough.

Cleavage is well developed throughout the Glenummera Slates. Reference to the cleavage map (Fig.26) will show that its normal trend is west-north-west, but there is considerable local variation depending on the presence of faults and the altitude of the strata.

The passage of the Maam Faults into the Maam Flexure has already been described in Chapter Four. It is repeated, on a small scale, whenever a minor fault in the Mweelrea Grits enters the Glenummera Slates. The clean-cut fault plane is replaced by a sharp flexure, which diminishes and is soon lost in the general contortion of the Slates. On the north scarp of Oughty Craggy this phenomenon may be observed at several places. A shearing stress finds expression as a bend in the Slates and a fault in the Grits.

(f) Stratigraphy, and Conditions of Deposition.

There is little variation in the lithology of the Glenummera Slates in S.W. Murrisk. No tuff bed persists throughout the outcrop, and time-planes are consequently lacking. The upper boundary of the formation is undoubtedly diachronous (Chapter Six, section f.), an effect of the gradual advance northwards of the coarse deltaic sediments of the Mweelrea Grits. Field observations suggest that the two


Fig.11 Measured section through the Glenummera Slates
South of Doolough, showing the zone of shearing
and drag-folding below the Mweelrea syncline.
0 200 400 600 800 Feet
Vertical and horizontal scale
Doolough
Shear Zone
Mweelrea Grit.
Tuff Band I.
Mweelrea Flags.
Glenummera Slates
North
South

conglomerates which were mapped south of the syncline are rather coarser than those on the north, and that the proportion of coarse material is slightly greater in the south. This vague indication that the source of sediments lay to the south is the only one that may be derived from the field evidence.

The marine fossils, the uniformly fine sediments, the rarity of current bedding, and the graded nature of the silts and tuffs, indicate that the material of the Slates was deposited in a sea of considerable depth, little disturbed by currents. The supply of sediment was slow, suggesting that either the coastline was at a considerable distance or that the relief of the source area was low. The latter is unlikely, as the occasional lenses of coarse material contain grains of fresh felspar, which rarely survive when erosion and transportation are slow.

It is probable that further stratigraphical information could be obtained by mapping of the remainder of the Glenummera Slate outcrop in S.Mayo and N.Galway.

Chapter Six. THE MWEELREA GRIT SERIES.

(a) Introduction.

This great grit formation occupies the south of the area, where it forms the mountain masses of Ben Gorm and Mweelrea. A small outlier also exists on the coast at Doogahtry. In the area under consideration about 5,000 feet of strata are exposed, although in the Formnamore Mountains, further east, a thickness of at least 12,000 feet is to be seen.

The Mweelrea Grits pass conformably downwards into the Glenummera Slates, through a transition zone of flags. The base of these flags is taken as the base of the Series. It is a lithological boundary only. The upper limit of the Series is not seen.

The greater part of the Mweelrea Grits consists of a succession of grits and sandstones, with a variable proportion of conglomerates. The bedding planes are generally more than a foot apart, and are sharply defined. Minor slickensides are often present on them, showing that bedding plane slip occurred as the strata were folded. (Plate 13).

Throughout the Series the grits are current-bedded, and in every observed case the truncation was at the top of a bed, demonstrating that it was the right way up. The individual current beds are not large, rarely exceeding a

thickness of two feet from top to bottom.

Interbedded with the grits on the north, but absent on the south, are three bands of grey-green slate, here referred to as the First, Second, and Third Slate, in ascending order. Their thicknesses vary along the outcrop, reaching maxima of 800 feet, 900 feet, and 300 feet respectively, north of Mweelrea. The slates are well cleaved, but fossils have been found in all three horizons.

In the lowest 2,000 feet of the Series there exist 5 beds of welded tuff, which frequently form prominent ridges elevated above the softer grit strata. They are here referred to as Tuff Bed (or T.B.) 1, 2, 3, 4, and 5, in ascending sequence. Four of these tuff beds are demonstrably continuous throughout the area of Mweelrea Grits that was mapped. It will be shown that the deposition of each bed must have taken place in a matter of days, or even of hours. This new discovery allows the recognition of 4 exact time planes in the Series, and thus makes a detailed stratigraphical interpretation possible. The thickness of each tuff bed varies within small limits, the thickest being T.B.3 (60 to 110 feet) and the thinnest T.B.4 (Nil to 15 feet).

(b) Age.

Between 1872 and 1875 the Officers of the Geological Survey of Ireland collected fossils from 5 localities in the "greenish shales of Mweelrea", now recognisable as the First and Second Slates. They listed 29 species, which, they believed, were indicative of "caradoc" strata. One locality in the Slate east of Lough Bellawaum (the small lake east of Mweelrea) was nevertheless believed to be Llandoverian. (It was on this evidence alone that Kilroe (1907) assigned a Llandoverian age to the strata above the First Slate). This "Llandoverian" locality is in the Second Slate, which, at Uggool and elsewhere, was accorded a Caradocian age by the officers of the Irish Survey.

Carruthers and Muff (1909) reported the discovery of "the typical Llandeilo trilobite Ogygia" in the slates at Lough Bellawaum. Their identification of the trilobite has lately been disputed by Stubblefield (Theokritoff 1950), who, even so, considers that the "Ogygia" belongs to the Asaphid group, which has only been found in pre-Ashgillian strata in Britain.

In 1951 and 1952 fossils were collected from 9 localities in the First, Second, and Third Slates. Similar fossils were found at all three horizons. However, there is still insufficient palaeontological evidence to date the Mweelrea Grits exactly. The discovery of further Asaphid -

trilobites in 1952, considered together with the position of the Mweelrea Grits well above Upper Arenigian strata, suggests that Llandeilian or Caradocian strata, or both, are present.

(c) Field Description.

Between Mweelrea (the mountain whose name was given to the Grit Series by the Irish Geological Survey) and the Maam Faults east of Bundorragha, the rocks of the southern limb of the Mweelrea syncline are well exposed. Only in the valleys of the Bundorragha and Owenmaglogh Rivers are there extensive areas of bog and drift.

East of Bundorragha T.B.'s 1, 2, and 3 stand up as prominent ridges that have resisted glacial erosion. They are often shifted by small tear faults. Lenticular conglomerate bands of all thicknesses up to 20 feet are abundant, and may contain boulders up to 2 feet in diameter.

The interbedded slates are absent until, a mile west of Bundorragha, the First Slate appears as a rapidly thickening wedge between T.B.'s 4 and 5. It is repeated, east of Bunaglass, by a normal fault with a downthrow to the south. At Bunaglass the First Slate strikes into Killary Harbour, and is soon lost. Here, however, the Second Slate appears as a thin wedge, closely overlying an important conglomerate with a maximum thickness of 30 feet

Plate 13.

Mweelrea Grits, Bundorragha Hill.

Massive grits with thin interbedded conglomerates.

Plate 14.

A minor unconformity in the Mweelrea Grits.

The thin-bedded flags between T.B.1 and T.B.2 are truncated by coarse grits, which may be filling an erosion channel.

Plate 15.

Current-bedding in the Mweelrea Grits, near Oughty Craggy.

Current-bedding in black magnetite sand, derived from T.B.1, which is seen in the lower left corner of the photograph.

Plate 13.



Plate 14.



Plate 15.



and a lenticular cross-section from east to west. The Second Slate thickens slowly towards Funshoge, where it is truncated by a normal fault that passes into a flexure further to the north-east. T.B.6, after being several times repeated by minor tear faults, finally vanishes beneath Killary Harbour a short distance east of Funshoge.

West of Funshoge, from the level of Killary Harbour to the summit of Mweelrea, 2,688 feet higher, there is a monotonous unbroken succession of grits with thin conglomerates, lying nearly horizontally.

The great tear fault of lower Killary Harbour traverses the isthmus between Carricklea and Uggool, and brings the Glenummera Slates into contact with strata much higher than the Third Slate. T.B.'s 1, 2, 3, and possibly 4 are present on the isthmus, T.B.3 reaching its maximum thickness of 120 feet on the promontory of Dooneen. T.B.2 is duplicated south of Uggool by a strike fault.

North and east of Uggool the Second Slate is exposed in the north limb and core of the Mweelrea Syncline. There is an extensive coarse conglomerate in the middle of the Slate. Fossils are plentiful just north of Uggool. There is complex faulting in this region, and one normal fault plane exhibiting large slickensides is continuously exposed as a steep cliff.

In the small outlier of Doeaghtry the nearly-horizontal Mweelrea Grits are much faulted. The appearance of T.B.'s 1 and 2 is unusual, and they appear to be less welded than elsewhere. There is an isolated exposure of T.B.1 which has apparently been brought up inside a quadrilateral of faults. On the coast several intercalations of slaty and silty beds are exposed, and T.B.1 is seen to rest directly on the Glenummera Slates, with no intervening zone of flags.

Along the course of the Bunanakee River, which enters the sea at Uggool, the Mweelrea Grits dip gently southwards, and their outcrop is complicated by tear and strike faulting. T.B.3 is completely concealed by one strike fault, and T.B.1 is duplicated by another. Between the Bunanakee River and Oughty Craggy a large area of Grit is hidden beneath glacial drift.

A strike fault with a considerable downthrow to the south runs from near Uggool to the corrie of Lugnore, and is displaced by several tear faults. The fault plane is well exposed at Lough Bellawaum, where it brings the First and Second Slates into contact. Near the summit of Mweelrea the Third Slate is exposed on a dip slope, which gives it an irregular outcrop. The Third Slate is also present on the craggy hill of Knockglass, between Mweelrea and Uggool.

On the great north-facing scarp which culminates in

Oughty Craggy, the strata dip to the south at angles up to 35 degrees. T.B.'s 1, 2, and 3 are exposed, separated by thick-bedded grits without any important conglomerates (except the conglomerate which fills an erosion channel in T.B.3 near Oughty Craggy). T.B.4 is absent, as it is along the whole length of this limb of the Mweelrea Syncline. In contrast to their durability on lower ground, the tuff beds readily succumb to frost weathering at high altitudes, and on a moderate slope they may be represented by a scree-filled gully between exposures of grit.

In Lugmore all the tuff beds (except T.B.4), and the First and Second Slates, are visible in the excellent cliff sections. There is considerable faulting, and a dolerite dyke is intruded into the Grits. A flaggy zone is present below T.B.1, which, as elsewhere on the north limb of the syncline, has a curious nodular appearance, and contains lumps of volcanic glass.

East of Lugmore the plane of the western Maam fault is eroded into a smooth steep cliff nearly 100 feet high. The material of T.B's 2 and 3 is smeared out along the fault-plane to produce the "intrusive felsite" mentioned in the Irish Geological Survey Memoir (1876, p.50); the phenomenon is repeated in many other faults. The western Maam Fault, a tear fault with a horizontal throw of one and a quarter miles, brings the Glenummera Slates into contact

with strata above the First and Second Slates (which here are unusually thin). Between the western and eastern Maam Faults there are many small dislocations, but T.B.'s 1, 2, and 3 are continuously present in the cliffs south of Doolough. The eastern Maam Fault is a vertical tear fault, with a horizontal throw of about half a mile.

In the Ben Creggan - Ben Gorm mountain block the dips are all to the south. T.B.'s 1, 2, and 3 are continuously exposed in the cliffs east of Ben Creggan, and are sometimes affected by right-handed tear faults. The First and Second Slates are abnormally thick, and are eroded into deep valleys. The Third Slate is absent. T.B.5 is only present as angular fragments in slumped material on the ridge between Ben Creggan and Ben Gorm, but it is complete further to the east. The whole of Ben Gorm is composed of unvaried grits and thin rare conglomerates.

In the core of the Mweelrea Syncline, between Mweelrea and Fin Lough, the strata pitch eastwards at 5 to 15 degrees. The Maam Faults shift the synclinal axis from Fin Lough to the south side of Killary Harbour, north-east of Leenane.

(d) Lithology.

The grits of the Mweelrea Grit Series are, in general, grey-brown or reddish-brown on a weathered surface; a fresh surface is often a pale buff or greenish-grey. In a

representative set of 16 grit specimens, the diameters of individual grains are seen to vary from 0.01 to 0.04 of an inch. In certain areas, notably near Doaghtry and in the strata at the base of the Series, finer-grained flaggy beds are common (Plate 14). Thus the original arenaceous sediments of the Mweelrea Grits ranged from gravel through sand to silt.

Under the microscope the component grains are seen to be angular and sub-angular, and never show the rounded edges characteristic of desert sand grains. The dominant mineral is quartz, which makes up 60 to 90 per cent of the rock. The crystals frequently show strain extinction, and evidence that a certain amount of recrystallisation has taken place is provided by the semi-interlocking nature of the grains. Felspars, chiefly oligoclase and andesine, are present in lesser quantities, never exceeding 15 per cent of the rock. They occur in all stages of alteration to clay minerals, but the majority are fresh, or nearly so. Carruthers and Muff (1909) noticed the fresh felspars, and believed that their presence indicated arid conditions of deposition. However, the only valid conclusion to be drawn from such evidence is that during erosion, transportation, and sedimentation the effect of weathering on the felspars was small. This result might equally have been achieved by very rapid mechanical erosion and de-

position, which would allow little time for chemical decay. In the present work it is considered that the latter explanation is correct.

Other components of the grit include small fragments of metamorphic rocks, among which a fine-grained quartzite is especially common. Pieces of muscovite gneiss, biotite schist, slate, and jasper are occasionally found. Large flakes of muscovite are not uncommon.

These materials occur at all levels in the grit. There are also two other constituents which only exist within definite horizons. These are fragments of tuff, and magnetite (in quantity). They do not occur beneath T.B.1, nor at levels high above T.B.6, but are concentrated in the beds directly above each tuff bed. The magnetite grains often emphasise the current-bedding in the grit (Plate 15). Since the tuff fragments are lithologically similar to the underlying tuff beds, which also contain quantities of magnetite, it is concluded that the tuff beds underwent a certain amount of local erosion directly after deposition, thus contributing tuff and magnetite detritus to the sediments. In fact, the upper surface of a tuff bed is frequently seen to be eroded.

The matrix of the gritty strata is very subordinate to the grit particles themselves, seldom comprising more than 10 per cent of the rock. It consists in the main of

smaller fragments of the same material, but occasionally it is chloritic, or a shimmer-aggregate of sericite mixed with carbonates.

In a few areas, notably on the plateau-like summit of Ben Gorm, the weathered surface of the grit is studded with irregular nodules, which may attain a diameter of one inch. A thin section shows that in these nodules the matrix of the quartz grains is crystalline calcite. It is unlikely that the calcite was deposited contemporaneously with the grit, but, since the quartz grains are much more widely separated inside the nodule than in the surrounding grit, the segregation of calcareous material probably took place before the rock became consolidated. Calcareous segregations have already been described (Figs. 6a, 10) from arenaceous strata in the Sheefry Grits and Glenummera Slates.

The distribution of conglomerates in the Mweelrea Grits is fairly random. They may occur as bands up to 30 feet thick, with hundreds of boulders reaching 2 feet in diameter, or as scattered patches of small stones. Isolated pebbles are often to be seen, entirely surrounded by grit. Conglomerates are characteristically associated with the upper surfaces of tuff beds, on which they may form sheets persisting for hundreds of yards alongthe outcrop.

The pebbles are invariably well-rounded, whatever their size, suggesting that strong water action accompanied their deposition (Plate 16). No pebble has been observed to bear the stched and polished surface characteristic of dreikanters.

The great majority of the conglomerate pebbles have been derived from igneous and metamorphic rocks. Perhaps the most abundant single type is a coarse red quartz - orthoclase granite in which the felspar is cream or bright red and the quartz has a purple tinge. This rock type is especially common in the big conglomerate between Funshoge and Bunaglass, on the shore of Killary Harbour. Fragments of siliceous schist, composed of quartz with subordinate plagioclase, biotite, and muscovite, are very numerous in the district east of Bundorragha. A similar rock makes up much of the Connemara Schists in the Maam Valley region. Pebbles of quartzite comparable to that of the Twelve Bens of Connemara are not uncommon. Other types of granitic and gneissose rocks occur sparingly.

In the horizon of the tuff beds pebbles of tuff are common. Blood-red jasper is abundant. Pieces of sandstone, black slate, and vein quartz are present in small quantities. It is interesting that no fragments of basic igneous rock have been found in the conglomerates.

Plate 16.

A Mweelrea Grit conglomerate, Doogahtry.

The hammer head rests on a large boulder of granite. Adjacent to it is a larger boulder of tuff. The small dark pebbles are jasper.

Plate 17.

Graded beds in the Mweelrea Grits, Bunaglass.

The lower graded bed, which rests on slumped slates, is about 1.5 feet thick.

Plate 18.

Large ripple-marks, Glendavock.

The hammer is just left of the centre of the picture.

Plate 16.



Plate 17.



Plate 18.



The three slate horizons in the Mweelrea Grits are lithologically similar, consisting of alternating thin bands of fine quartzose silt and very fine-grained green slate. The lower portion of each horizon is generally uniformly fine-grained, but further upwards coarse grits appear in beds or lenses and become more and more numerous until the slate has passed up into grits. This succession is well seen in the Second Slate on the ridge just north of Ben Gorm.

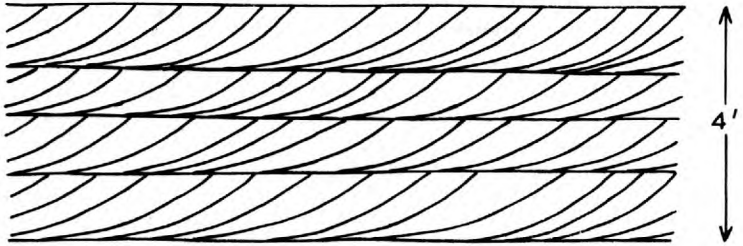
The lower boundary of a slate is generally sharp, and often there are signs of contemporaneous disturbance, notably slumping. Thus, in the First Slate at Bunaglass, the transition zone consists of strongly slumped lenses of grit and slate, on which rest two perfectly graded beds of typical Mweelrea Grit (Plate 17), the only ones seen in the Grits, and clearly the product of the settling of two water-borne clouds of sediment stirred up by sudden movements.

At several places in the slates, notably in the Second Slate at Uggool, and on Ben Lugmore, coarse conglomerates are associated with the grit bands.

(e) Sedimentary Structures, and Conditions of Deposition.

The Mweelrea Grits are current-bedded throughout, and the individual current-bed seldom exceeds a thickness of two feet from top to bottom. Not infrequently whole strata

Fig. 12



False bedding in the Mweelrea Grit, Doolough.

consist of uniform current-beds truncated by the overlying stratum. (Fig.12).

The small size of these current-beds, and the persistence of individual strata (Fig.12), suggests deposition under subaqueous rather than sub-aerial conditions. Twenhofel (1939, p.285) states: "Cross-laminated units of marine deposition have extensive distribution, and are bounded by planes that are essentially parallel. The laminations are inclined in various directions". This description is applicable to much of the Mweelrea Grit Series.

If the Mweelrea Grits were accumulated under shallow-water marine conditions, they should display the other characteristics of such deposition. The sand grains should be, and are, angular and sub-angular. The material should be badly sorted, as in fact it is, but, since the sediments are coarse sand and gravel with little interstitial matter, it must be assumed that wave and current action were strong enough to transport and deposit coarse material, while they winnowed out and removed the clay and silt to deeper water.

About half a mile north of Ben Gorm is a well-exposed bedding plane in the grits which bears large asymmetrical ripple-marks several inches in amplitude and 1.5 feet apart (Plate 18). The long axes of the ripples run north-south, and the steep side faces west. The wavelength is not more

than ten times the amplitude, and according to Twenhofel (1939) this indicates formation by aqueous currents (coming from the east in this case). The scoop-like hollows seen in the photo might well be due to the action of currents. Smaller sinoidal ripple-marks are occasionally seen on bedding planes, especially in flaggy strata.

Whilst it is very probable that the grits were deposited in shallow water, there can be no doubt that the interbedded slates, with their fauna of brachiopods, trilobites, and gastropods, are marine accumulations. Their silt bands and grits are frequently graded, (Plate 17), demonstrating that the water was deep enough to permit the differential settling of sediments. The absence of widespread coarse sediments implies that the shoreline was at a considerable distance.

A significant feature of the slates is their abrupt boundary with the underlying grits, and the gentler upward passage into those above. There is some resemblance to a Coal Measure cycle, in that there is a sudden change from grit deposition to mud deposition (consequent on a sudden subsidence), followed after an interval by the gradual reintroduction of coarse sediments as the area silted up.

The association of slumped beds with the lower boundary supports the theory of rapid subsidence, as the unconsolidated sediments must have easily become unstable.

Direct evidence of this is to be found on the ridge between Ben Creggan and Ben Gorm. Walking southwards from Ben Greggan the First Slate is crossed, and then about 150 feet of grits lead up to the horizon of T.B.6. At first sight the tuff bed appears to be absent, but investigation shows that it is partially represented by a breccia of angular tuff fragments, up to 2 feet in diameter, set in an unbedded matrix of grit (Plate 19). The breccia ends suddenly to the east, where it is replaced by the complete tuff bed. A thin band of bedded slate rests directly on the breccia, and ends at the same place.

The breccia can only be accounted for by postulating an extensive slump, taking place at a time when the welded T.B.6, already solid, rested on unconsolidated sand. Most of the tuff was carried away, but a few broken fragments remained. Immediately afterwards, finer-grained material collected in the area of deeper water left by the slump, and continued to accumulate for a short while until the basin was once more invaded by coarse sediments.

Here the deposition of slate followed directly after large-scale slumping, which was probably the result of local subsidence. Evidence is adduced in section f. that there was movement along or near the Maam Fault zone during sedimentation, and the subsidence and slumping probably resulted from this, as the slate is not represented elsewhere.

Plate 19.

Brecciated fragments of T.B.5, Ben Creggan.

Angular fragments of tuff (weathered white), set in a matrix of unbedded grit.

Plate 20.

A cliff in the basal Mweelrea Grits, Doolough.

Flaggy grits.

Plate 19.



Plate 20.



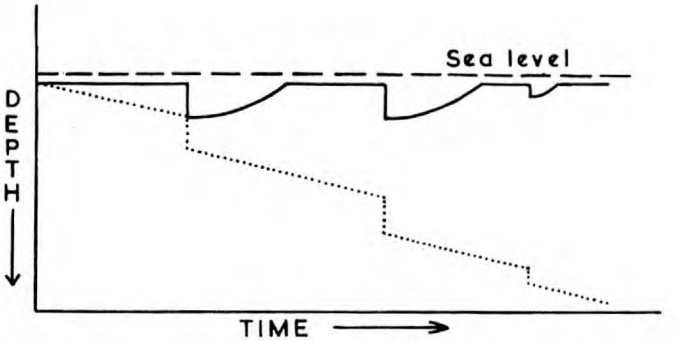
Figure 13 summarises the depositional rhythm of slate and grit. The area must have been subsiding gently all the time, to allow the accumulation of grits under continuously shallow-water conditions. At intervals the rate of subsidence suddenly increased, the shoreline receded, and only fine-grained material was laid down in the deeper water. Gradually the coarse sediments spread out from the coast, and shallow-water conditions were restored.

The upward transition from the Glenummera Slates through flags into the Mweelrea Grits is probably due, not to regional uplift alone, but also to the gradual advance of coarse sediments into the area at the onset of the new cycle of erosion. The water of the Glenummera Slate sea was of considerable depth, and thus the advance of the grits was slow, and the passage through the flags very gentle. Plate 20 illustrates the flags just below T.B.1 south of Doolough.

Some indication of the actual depth of water during the grit-depositing stages of the Mweelrea Grit sea may be gained by considering the effect of the tuff beds on sedimentation. In north-west Doogahtry T.B.1, 35 feet thick, rests on flaggy slate (the first stage in the passage of the Glenummera Slates into the Mweelrea Grits), and underlies normal false-bedded grit with thin pebble bands. The tuff bed was deposited in an exceedingly short time, perhaps in

Fig. 13

Diagram illustrating subsidence during the sedimentation of the Mweelrea Grit.



only a few hours (Chapter Seven), and it is apparent that the sudden aggradation of the sea bottom by 35 feet replaced a neritic marine environment by a littoral one. Indeed at other localities the sea must have withdrawn completely, as the upper surface of T.B.1 is often eroded into pockets and irregularities, and coarse conglomerates containing tuff pebbles rest on it.

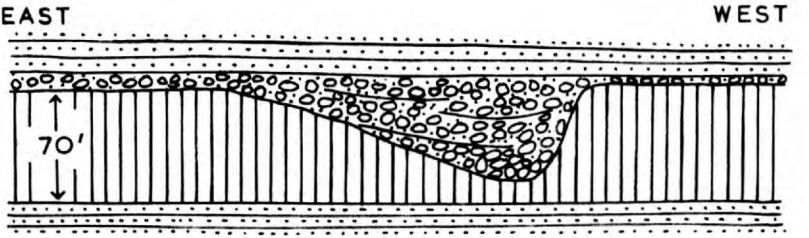
The laying down of the higher tuff beds, especially T.B's 2 and 3, whose average thicknesses are 40 feet and 80 feet respectively, must have caused withdrawal of the sea over a wide area. Shallow-water grit deposition was replaced by intense erosion of the upper surfaces of these tuff beds, on which were left pockets of coarse conglomerates full of tuff pebbles.

A quarter of a mile east of Oughty Craggy, at the point marked E on the general geological map, the thickness of T.B.3 is suddenly reduced from 80 to 20 feet, while that of the overlying conglomerate swells from 8 to 60 feet. (Fig.14).

The pebbles in the swollen conglomerate reach a diameter of 2 feet. Evidently this is an erosion channel recording the downcutting of a powerful stream.

It is unlikely that downcutting would have taken place more than a few feet below sea level, and so it may be concluded that the deposition of 80 feet of tuff built up the sea floor until it reached a height of about 60 feet

Fig. 14 Section of the erosion channel in Tuff Bed 3 500 yards west of Oughty Craggy



above sea level. In other words, the grit-depositing sea into which it fell can have been little more than 20 feet deep.

It is necessary to postulate sub-aerial erosion for this particular channel, since the welded tuff in which it was excavated was already a hard rock (Chapter Seven). At Bunaglass, Dooaghtry, and east of Bundorragha transgressive lenticular conglomerates mark the sites of other erosion channels, but since they were cut in unconsolidated sediments - sands - they were not necessarily subaerial. Nevertheless, they indicate shallow water. Plate 14 illustrates such a channel, cut in flags and filled with coarse grit.

The welding of the tuffs is direct evidence that the water into which they fell was shallow, for they could hardly have become welded if they were completely submerged. In fact, the welding of T.B.1 is less intense between Oughty Craggy and Dooaghtry, and it is probable that the water was deeper in this region than elsewhere, at the time.

The erosion of the upper surface is characteristic of T.B's 1, 2, 3, 4, and 5. It is therefore very likely that such erosion is the result of accumulation of the tuff bed until it is above sea level, and not due to incidental uplift.

To sum up, the evidence of the sediments and sedimentary structures indicates continuous gentle regional subsidence, during which coarse sands and gravels were laid down in a very shallow sea that seldom exceeded a depth of about 30 feet, and was subject to strong currents. At three stages in the accumulation of the Mweelrea Grits there was sudden regional subsidence, which caused a recession of the shoreline and the deposition of clay and silt in deep water, until coarse sediments again spread out over the area from the land.

(f) Stratigraphy.

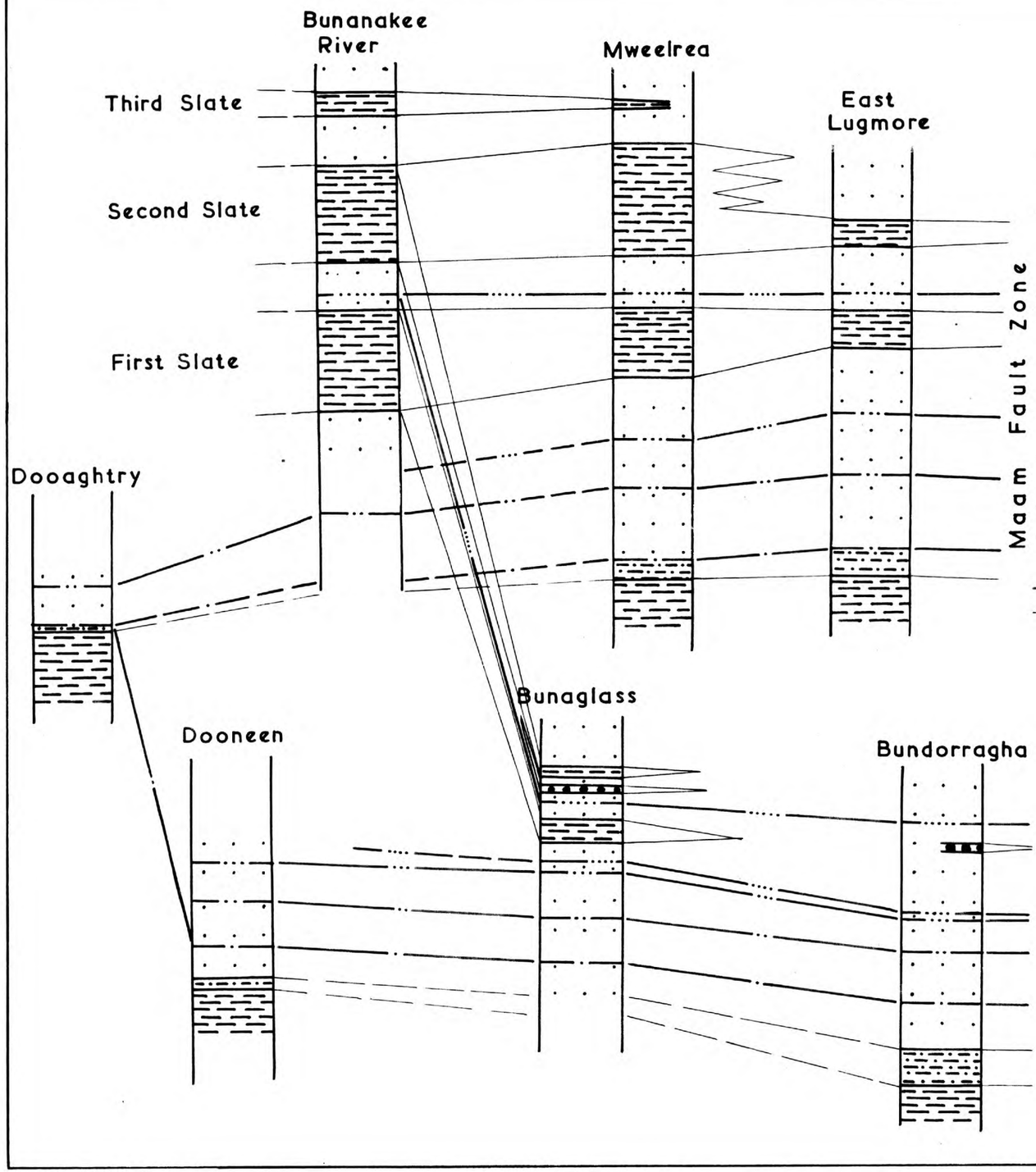
The essential stratigraphy of the Mweelrea Grits is summarised in Fig.15, and in a more detailed diagram, Fig.16, which shows the changes in the thicknesses of grits, slates and conglomerates along their outcrops. It must be emphasised that the interpretation given in the following pages is based on the recognition of T.B's 1, 2, 3, and 5 as time planes that are continuous throughout the area that was mapped. Without them the correlation of the slate horizons would have been well-nigh impossible.

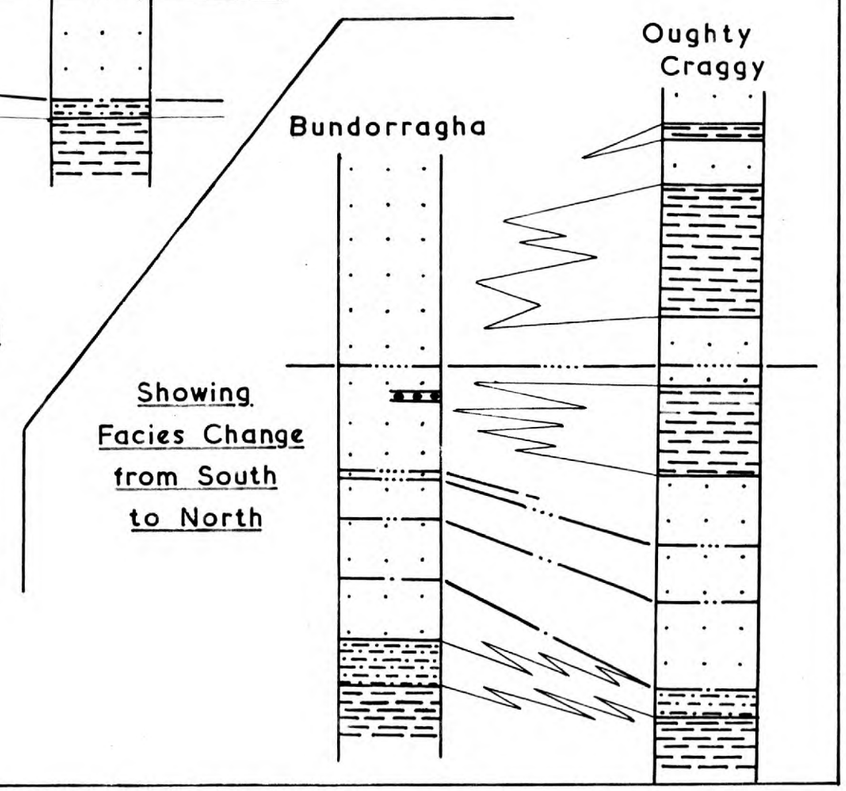
Reference to the inset in Fig.15 will show that the most obvious facies change is in the slates, which are absent from the Bundorragha region on the south, but reach a combined thickness of 1,500 feet near Oughty Craggy and

Fig. 15

THE FACIES CHANGES IN THE MWEELREA GRIT FORMATION

For key refer to Fig. 16





Mweelrea on the north.

In the south the First Slate appears as a thin wedge lying conformably between coarse grits west of Bundorragha. It thickens rapidly westwards, and also northwards, where it is repeated by a strike fault. At Bunaglass it is nearly 200 feet thick, but, a short way beyond, it is truncated by the tear fault of lower Killary Harbour, and is not seen again on the south of the Mweelrea syncline.

Two miles to the north-west the First Slate reappears beside the Bunanakee River, north of Uggool, where (although one boundary is faulted) it is at least 700 feet thick. Eastwards it thins slightly to a point north of Ben Lugmore, where it is suddenly reduced to a thickness of 200 feet by the lateral passage of its upper portion into grits. This diminished thickness is maintained as far as the eastern Maam Fault. Suddenly, on crossing the fault, the First Slate thickens to 900 feet, after which it thins gently eastwards to the boundary of the area.

The outcrop and thickness of the Second Slate are closely similar to those of the First; however, its upper portion is typically more gritty. The Third Slate is only foundin the north-west of the area, and it probably consists of a series of lenses at about the same horizon.

In summary, the Slates are only slightly developed on the south, but are important on the north, of the syncline.

Fig.16.

In the diagram the strata have been upturned to the vertical, so that their true thicknesses are presented. Their horizontal layout is therefore greatly distorted, but for convenient reference it has been made to conform as closely as possible to the geological maps.

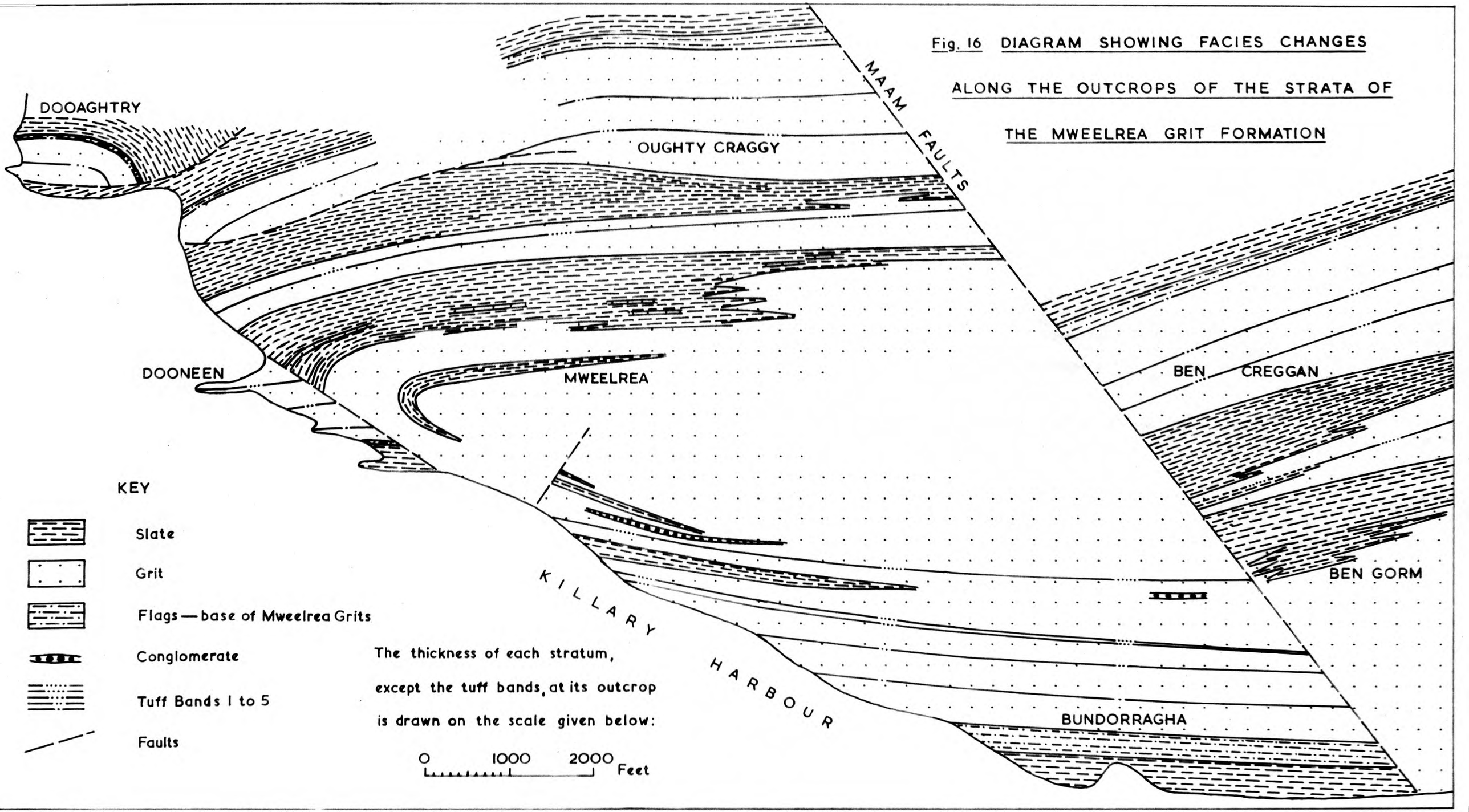


Fig. 16 DIAGRAM SHOWING FACIES CHANGES ALONG THE OUTCROPS OF THE STRATA OF THE MWEELREA GRIT FORMATION

They reach a maximum in the north-west, and are entirely absent in the south-east. They pass laterally into grits; in fact, the slates of the north limb of the syncline are equivalent to a smaller thickness of grit on the south.

This facies variation is in itself enough to suggest that the sediments were derived from a land mass to the south or south-east, the coarse materials having been deposited near the shore. Furthermore, the strata near Oughty Craggy are half as thick again as their equivalents at Bundorragha. Below Oughty Craggy T.B.5 is separated from T.B.1 by 2,200 feet of strata, whilst at Bundorragha the same tuff beds are only 1,400 feet apart. Since both T.B.1 and T.B.5 fell into shallow water, it follows that the extra thickness on the north represents a greater subsidence there.

If in fact a shoreline lay to the south-east of the area, and subsidence increased north-westwards, all the sediments should change their character when followed from south to north. The strata underlying T.B.1 provide useful evidence. At Bundorragha, T.B.1 rests on 400 feet of grits and 300 feet of flags, which intervene between it and the Glenummera Slates. At Oughty Craggy T.B.1 and the Slates are separated by only 200 feet of flags, while at Doogahtry their place is taken by about 30 feet of flaggy slate. But T.B.1 is a time plane, and it follows that when grit-

depositing conditions prevailed at Bundorragha, silts were being laid down at Oughty Craggy, and silty mud at Dooaghtry. (Fig.15). This is direct evidence that these sediments were derived from a land mass to the south or south-east. Also, the lower boundary of the Mweelrea Grits is shown to be diachronous, and lithological only.

On tracing the conglomerates (excluding the massive erosion channel deposits) northwards, they are found to decrease in abundance and coarseness. The change is especially noticeable in the pebble beds which characteristically overlie the tuff beds.

In the coastal region of Dooaghtry flaggy beds exist between T.B's 1 and 2; a condition not seen elsewhere (Plate 14).

The variation in the lithology of the tuff beds (Chapter 7) sheds further light on the matter. In the north T.B.1 presents a curious nodular appearance on weathering (Plate 21), a condition that does not obtain in the south. On the north, too, T.B.1 is sometimes present complete and un-eroded, with green sheared material at top and bottom. The upper surface is always eroded in the south. Many pebbles of tuff are found in the conglomerates overlying the northern nodular T.B.1, but none of the pebbles are themselves nodular, resembling rather the uniformly welded tuff on the south of the syncline. It is probable that they have

been transported northwards for some distance.

It is significant that the thinnest tuff bed, T.B.4, is present on the south of the syncline, but it is absent on the north. In the extreme south-east, near Bundorragha, it appears to merge with T.B.3, probably because in this direction subsidence was slight and no sediments were deposited inthe interval between the accomulation of the two tuff beds.

If we look to the south, beyond Killary Harbour, for a possible source of these Middle Ordovician Sediments, we find in the Connemara Schists a high-grade metamorphic region, separated from the Mweelrea Grits by the Arenigian grits of Leenane and Rosroe. As stated in section d., the metamorphic pebbles in the Mweelrea Grits can all be matched with the rocks of Connemara, while the sandstone, black shale, and jasper pebbles are similar to the cherts and other sediments of Arenigian age south of Killary Harbour.

The conclusion to be drawn from the foregoing evidence is that the Mweelrea Grits consist of the sediments derived from the erosion of the Connemara Schists and the nearby Arenigian rocks, during a prolonged period of crustal warping in which the Connemara Schists were uplifted and the country to the north subsided. A roughly E.N.E. - W.S.W. coastline lay to the south of the present line of Killary Harbour, receding southwards in slate - depositing times and advancing northwards after the accumulation of each tuff bed.

Denudation was rapid, and sediments were supplied to the sea in sufficient quantity to cover a large area while keeping pace with the subsidence. Thus the sea remained shallow, and waves and currents distributed the coarse material evenly, and carried away the finer fractions to deep water.

An attempt was made to plot the general direction of the sea-currents as shown by the current-bedding (or false-bedding) in the grit. Where a false-bed is exposed on two vertical surfaces, or on one vertical and one bedding surface, the direction of the current which produced it can be determined. Measurements were made eastwards from Oughty Craggy in the north limb of the syncline, and from Bunaglass to the Maam Faults in the south. The current directions are tabulated below :-

Northern area.

From N.E. quadrant	approx.	250
" S.E. "	"	70
" S.W. "		7
" N.W. "	approx	30

Southern area.

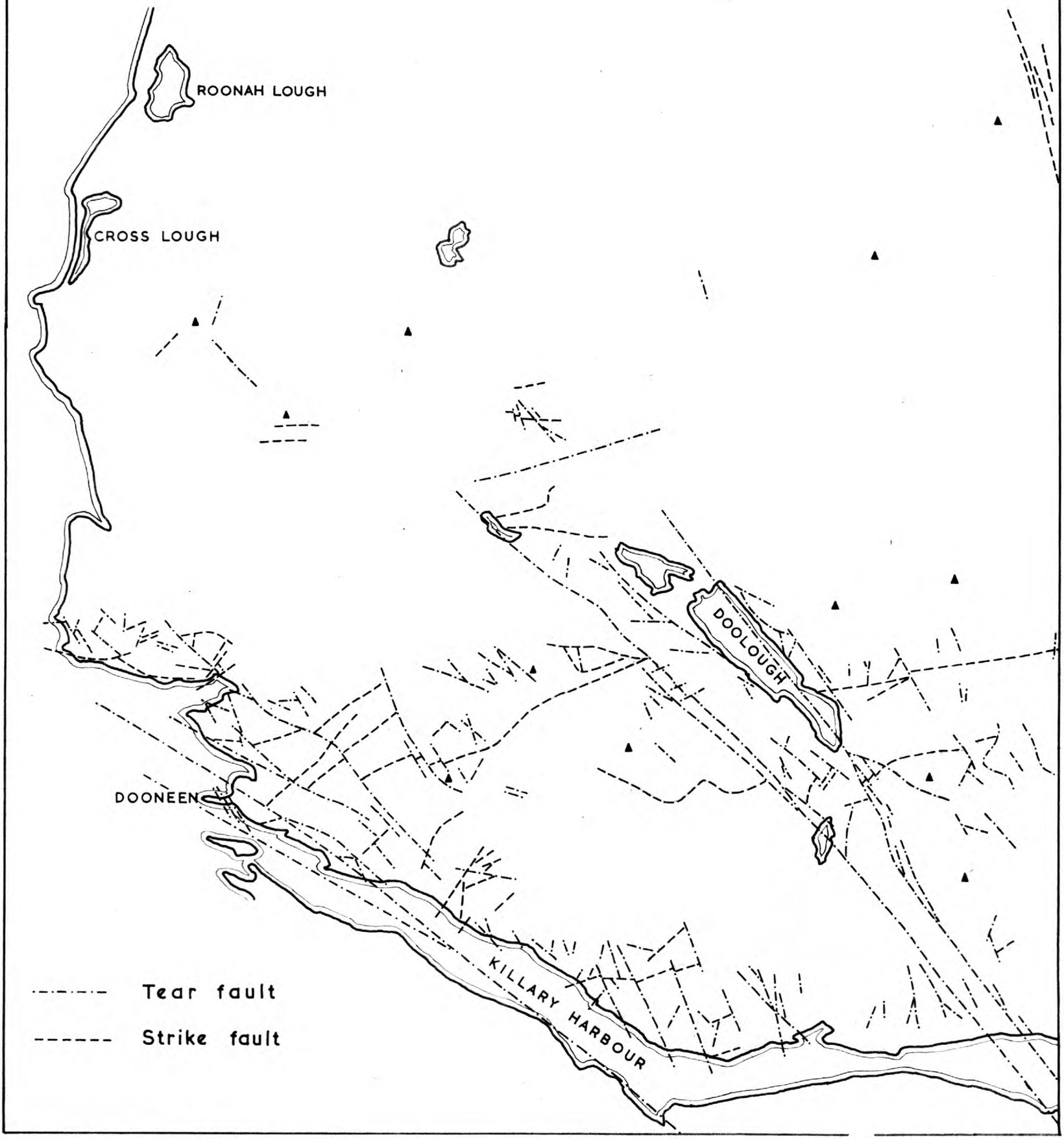
From N.E. quadrant	approx	50
" S.E. "	"	180
" S.W. "	"	12
" N.W. "		2

In the north the prevailing currents came from the east and north-east; in the south from the east and south-east. Probably the main current was a long-shore one from the E.N.E., which towards the land was increasingly affected by the influx of material from the south-east. The only important occurrence of ripple-marks, that in the Glendavock valley shown in Plate 18, was also produced by a current from the east.

The sudden facies change in slates and grits as the Maam Faults are crossed has already been mentioned in this section. The change, (well shown in Figs.15 and 16, and in the general geological map), actually takes place at the eastern of the two main faults. On the west the First and Second Slates are only a third of their normal thickness, but on the east they are slightly swollen close to the fault, regaining their normal thickness in the Glendavock valley. In fact, the zone of facies-change extends as far to the west as Ben Lugmore, where the slates suddenly diminish in thickness by passing laterally into grits. In both Slates it is the upper portion that is replaced by grit.

There is no unconformity, and the apparent explanation is that grit-depositing conditions reached the area west of the east Maam Fault before extending over the rest of the region. Perhaps a submarine ridge, widening to the south, existed there, and the sea bottom was early raised to the

Fig.17 The Fault Pattern of S. W. Murrisk



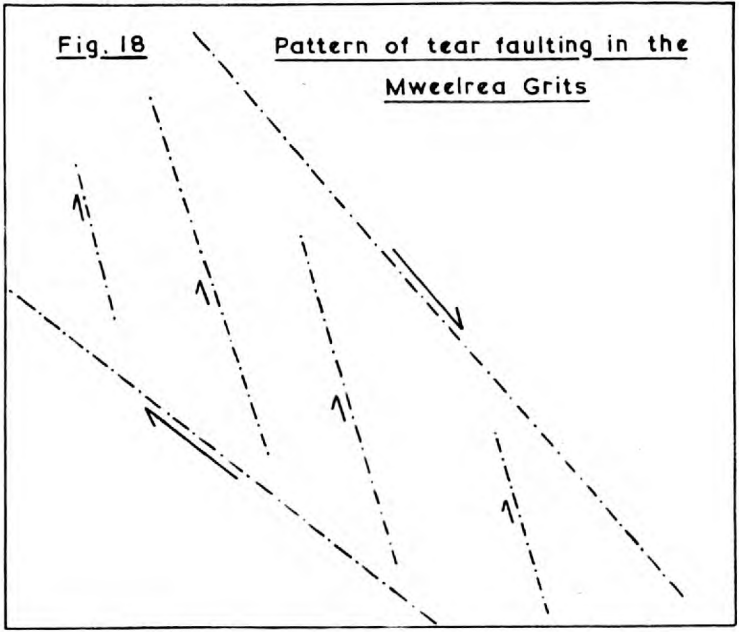
level at which waves and currents carried away the fine-grained material. The deeper water on either side took longer to silt up.

Since the eastern boundary of the postulated ridge is sharp, and coincides with a large known fault, it is not improbable that this boundary was the scarp of a small contemporary fault, with a downthrow to the east. The scarp would be no more than a steep slope, as the faulted sediments were unconsolidated. To the east of the eastern Maam Fault, fingers of grit penetrate a short distance into the Second Slate; these may represent temporary advances of grit from the ridge into deeper water.

An alternative explanation is that the area between Ben Lugmore and Ben Creggan received a plentiful supply of coarse sediments from an important and persistent river to the south-east. Thus, after a sudden subsidence, coarse grits might invade this area more rapidly than they would enter the surrounding region.

(g) Structure.

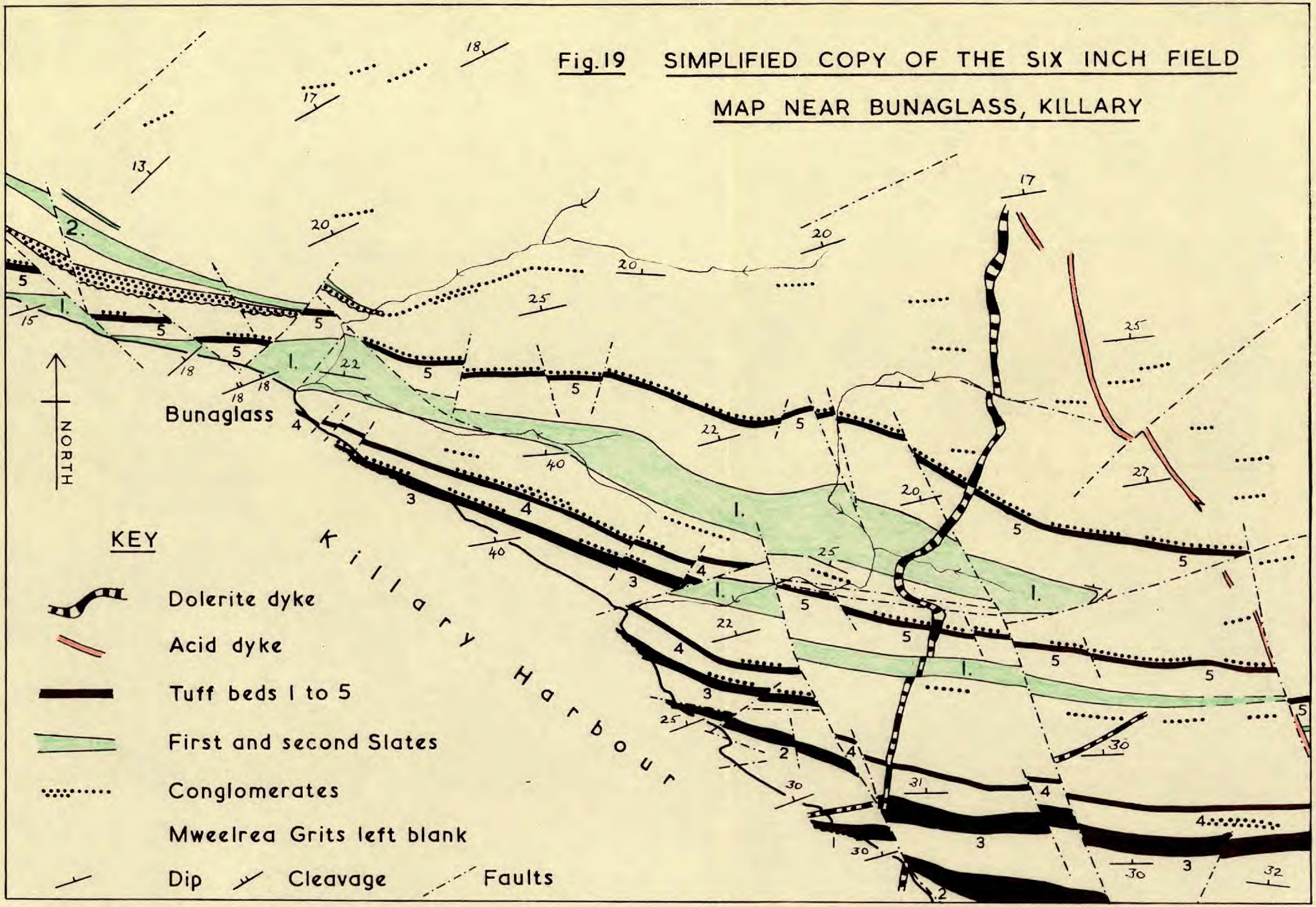
The Mweelrea Grits are folded into an east - west syncline, that pitches at less than 10 degrees to the E.N.E. The steepest dip, of 60 degrees, was recorded near Bundorragha. In the older rocks of S.W. Murrisk the strata are often nearly vertical, with isoclinal folds, but it seems


Fig. 18
Pattern of tear faulting in the
Mweelrea Grits

that this massive grit formation has resisted such intense folding by riding up over the incompetent Glenummera Slates, whose junction with the Grits is frequently sheared and violently contorted (Fig.11).

The massive Grits have responded to tectonic stress by fracturing, and hence a large number of faults have been mapped (Fig.17). In the field they are easily distinguished where they displace prominent marker beds - tuffs, slates, and conglomerates - and the fault zones are often eroded into a steep gully. (One such, just south of Mweelrea, is a chasm 10 feet wide and 100 feet deep). Many of the fault planes are little more than a crack between the opposing walls of rock. At the point where the western Maam Fault enters Killary Harbour, there is only a 4- foot zone of brecciation to record the one-and-a-quarter mile displacement. Slickensides are strangely absent from the older fault planes, but are present on the plane of a more recent normal fault that cuts across all the structures north-east of Uggool. Quartz is sometimes found in the fault planes, but other types of mineralisation are absent.

Reference to Fig.17 will show that there exists a well-defined system of left-handed tear faults running N.N.W. - S.S.E., with a complementary development of strike-faulting at right angles to them. The tear faults often displace the strike faults, and may have been initiated rather later in the folding.


Fig.19 SIMPLIFIED COPY OF THE SIX INCH FIELD MAP NEAR BUNAGLASS, KILLARY
Bunaglass
NORTH
Killary Harbour
KEY
Dolerite dyke
Acid dyke
Tuff beds 1 to 5
First and second Slates
Conglomerates
Mweelrea Grits left blank
Dip
Cleavage
Faults

There are 3 major left-handed tear faults, 2 of which lie roughly parallel to each other between Doolough and Leenane, and continue S.S.E. into the Maam Valley. They were named the Maam Faults by the Geological Survey of Ireland (1876). Between them they cause a displacement of nearly 1.7 miles, of which the western fault provides 1.2 miles. At one point near Killary Harbour, horizontal slickensides were observed on the vertical fault plane.

The other major tear fault runs up the lower part of Killary Harbour, and cuts across the peninsula south of Uggool. Another branch lies just south of Dooneen. The total displacement is more than 2 miles.

Of the numerous small tear faults, it may be said that the majority run in a more northerly direction than the 3 large faults already described. They may, perhaps, be interpreted as the fracture cleavage associated with the large faults, such as would be expected in inflexible strata (Fig.18).

East of the Maam Faults several of the small tear faults have a right-handed displacement, while yet maintaining the N.N.W. trend. The tear fault planes are all more or less vertical.

The strike faults dip steeply in most cases, and may be either normal or reversed, with a downthrow to south or north. Their shatter zones are generally narrow. In the east of the area strike faulting is negligible, but westwards

Fig.20 SECTIONS THROUGH THE MWEELREA GRITS

a. Centre of syncline

Killary Harbour

S.18E.

Bundorragha Hill

Owenaglogh

Oughty Craggy

N.18W.

Sea level

Dolerite Dykes

b. Western end of syncline

S.51E.

Bellaglanna

Third Slate

Sea level

Second Slate

First Slate

Bunanakee River

Dolerite

N.51W.

S.27E.

Trawleckackoolia

Dooaghtry

N.27W.

Slates

Conglomer–ate

Grit

Flags

Tuff Bands 1 to 5

Faults

0 2000 4000 Feet

Vertical and horizontal scale

it increases in importance. A large steep normal fault, with a downthrow to the south of 800 feet (decreasing westwards), runs from Lugmore past Mweelrea until it dies out in the Second Slate near Uggool. Near Lough Bellawaum the adjoining strata are bent in a manner that indicates vertical movement. The fault is several times displaced by tear faults.

A similar but vertical fault, downthrowing 500 feet to the south, enters Killary Harbour south-east of Bunaglass. (Figs.19 and 20a). At Funshoge there is another, with a downthrow to the north. In the district around Uggool the strike faults are numerous and complicated (Fig.20b), downthrowing to both north and south and entirely concealing T.B.3, except at Dooneen.

The small outlier of Grit at Dooaghtry is bounded on the south by a strike fault, and is cut by numerous smaller strike and tear faults. The strata are mainly flat-lying, and it may be that the abundant faults represent the reaction of the Grit to crumpling in the Glenummera Slates beneath. The relative abundance of faults in the north-western district may be a reflection of the presence of thick slates, allowing increased flexing of the formation as a whole, and readier fracturing of the diminished grits.

Thrust faults are very rare. North of Ben Creggan T.B.1 is repeated by a small thrust which dips south at 60 degrees, and is directly related to the synclinal folding

and over-riding of the Grits. The long "thrust" south-east of Ben Lugmore dips northwards at about 20 degrees, but can only be mapped by its topographical expression. Small slickensides on the plane of the "thrust" demonstrate over-riding from the north.

Chapter Seven. THE LOWER ORDOVICIAN VOLCANIC ROCKS.

(a) Introduction.

Deposits of tuff have been found in each of the 3 Ordovician formations of S.W.Murrisk. Those in the Sheefry Grits were first recorded by the Officers of the Geological Survey of Ireland, who believed that they were intrusive dykes of unusual composition. Wilkinson, in the Memoir of 1876, several times describes one or another of them as : "a massive intrusive rib, in places like a felstone, in others like a grit." Evidently he could not reconcile the fine-grained top and the coarse -grained bottom of the tuff bed.

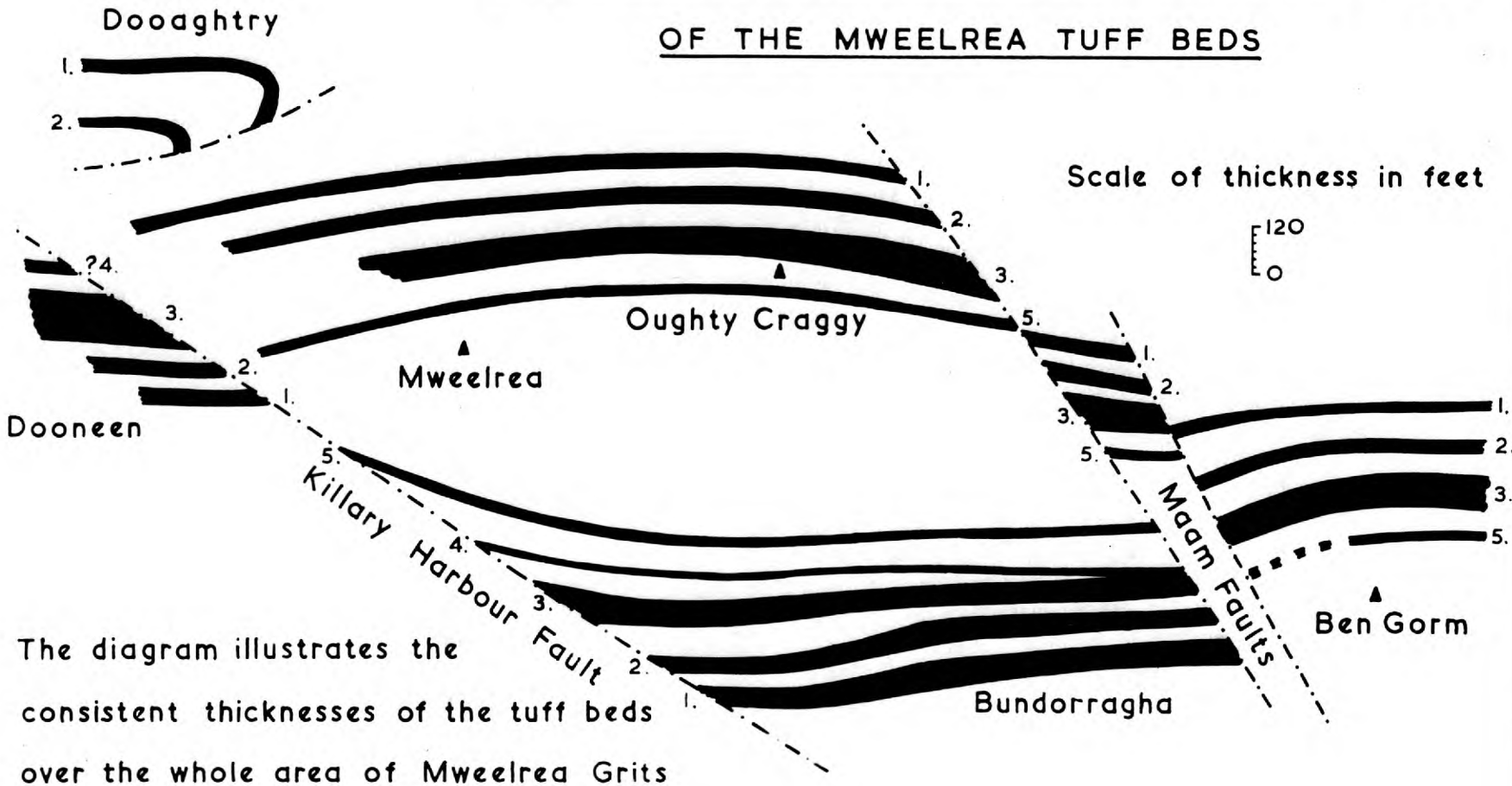
The 3 tuff beds in the Glenummera Slates were first discovered in 1951-52. They closely resemble those in the Sheefry Grits. The appearance of the 5 Mweelrea tuff beds is totally different. Kelly (1860) described them as quartz-porphyry dykes. Hull (1874) suggested they were lava flows, capped with volcanic ash, and it was not till 1951-52 that they were recognised as tuffs.

The Silurian Strata do not appear to contain tuffs.

The abundant exposures of tuff in the Sheefry Grits cannot be correlated with certainty, but it is probable that they belong to 8 distinct tuff beds. Each of these,

Fig. 21

DIAGRAM SHEWING THE VARIATIONS IN THICKNESS OF THE MWEELREA TUFF BEDS



The diagram illustrates the consistent thicknesses of the tuff beds over the whole area of Mweelrea Grits

(and T.B.'s 4, 5, 6, and 7 in particular), must have originally covered a very large area. The thickest tuff bed (T.B.7) attains a maximum of 120 feet; the thinnest (T.B.1) a maximum of 10 feet. Besides the 8 graded tuffs, several impersistent beds of flinty fine-grained tuff have been mapped. The coarse-grained bottom of the graded tuff beds is generally a greenish-brown or yellowish-brown colour, while the banded and fine-grained top can be pale yellow, grey, or nearly white (Plate 22). The Sheefry tuffs suffered no contemporary subaerial erosion.

Of the tuff beds in the Glenummera Slates, 2 are thin dust tuffs, but the bed on the shore east of Bundorragha is 4 feet thick and well graded, with a green coarse base and a greenish-grey fine-grained top.

Four of the fine Mweelrea tuff beds are continuous throughout S.W. Murrisk. Reference to the 1-inch map of the Geological Survey of Ireland (Sheet 84) shows that they extend at least four or five miles to the south and south-east, so that the uneroded portions must cover in all about 100 square miles. The thickest bed, T.B.3, attains a maximum of 120 feet; the thinnest, T.B.4, a maximum of 15 feet (Fig.21). The particles of tuff are sorted inasmuch as porphyritic crystals of quartz and felspar become rather less abundant at the top of the bed, which, (where it did not undergo contemporaneous erosion), may be capped with a layer

Plate 21.

Nodular weathering of T.B.1, Oughty Craggy.

Plate 22.

Sheefry T.B.3, west of Lough Alisheen.

The tuff bed is graded, and youngs to the right. In the photograph the dark coarse-grained base, the banded middle, and the white fine-grained top, can be distinguished.

Plate 21.



Plate 22.



of green pumice and volcanic dust.

Over much of S.W. Murrisk the Kweelrea tuffs are welded; that is, the material was deposited at such a high temperature that the individual particles at once adhered to form a coherent rock. In the north and north-west T.B.'s 1 and 2 are less completely welded than elsewhere. The tuff beds are reddish-purple or brown in colour, with a flinty appearance, where they are welded; in other areas they are greenish or greyish-white, with a more lithic appearance. Weathering gives them a pinkish-white patina. They are traversed by widely spaced vertical joints, and the resulting massive blocky appearance is easily recognisable in the field.

(b) Petrology.

1. Tuffs in the Sheafry Grits and Glenummera Slates.

The graded tuff beds in these two formations were accumulated under marine conditions, and are in consequence very similar in appearance, as well as in mineralogical composition. The particles at the base of a bed may reach a diameter of 0.2 of an inch; upwards the average size decreases slowly and then more rapidly until a zone of banded rock, (Plate 22) composed of small crystals and shards of pumice, is reached. Above this there are a few feet of flint-like rock consisting of shards and dust, and the tuff bed finally passes up into normal sediments through a zone of

thin-bedded slate and volcanic dust.

Under the microscope the lower portion of the tuff bed is seen to consist mainly of crystals, which constitute about 75% of the rock. The matrix is composed of secondary minerals and alteration products. The following table summarises the composition of the coarse tuff.

Crystals.	Per cent.
Felspars	40 - 70
Quartz	0 - 30
Magnetite	1 - 10
Mica	0.- 5
Rock Fragments	0 - 3
Rutile, zircon, apatite, sphene	0 - 1
Matrix	
Chlorite	0 - 20
Secondary albite	5 - 20
Carbonate	0 - 30

The porphyritic felspar crystals include orthoclase and albite-oligoclase, the latter being rather more common. Microcline and sanidine occur, but very sparingly. The plagioclases are sometimes zoned. The felspars are never quite fresh, and may be seen inall stages of alteration to scapolite, sericite, and clay minerals.

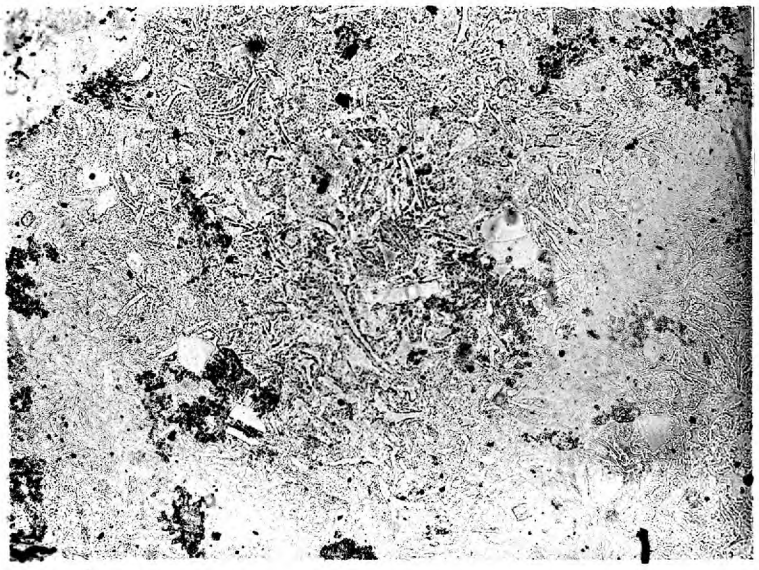
Plate 23. Photo-micrographs of the Sheefry tuffs.

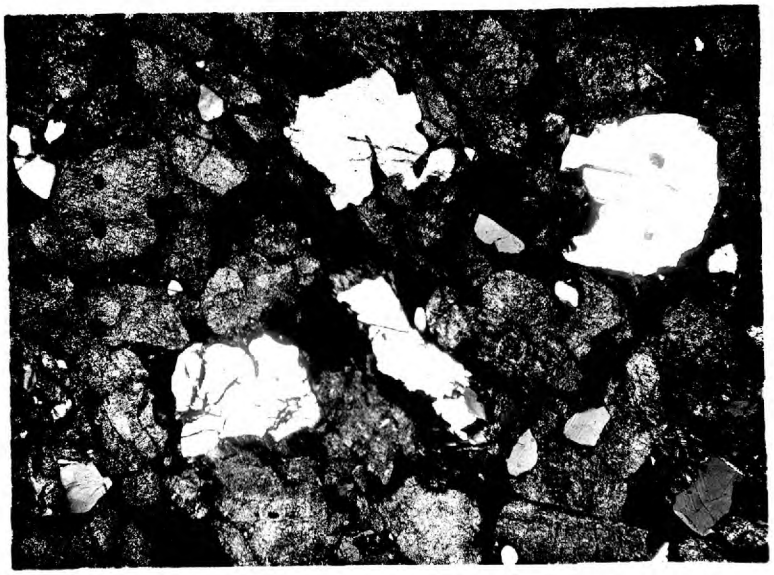
(a) Glass shards from the fine-grained top of a tuff bed (x 55).

The shards are seen under ordinary light.

(b) Crystals from the coarse-grained base of a tuff bed (crossed nicols, x 15).

Note the decaying felspars, and the large corroded crystals of quartz.





The large quartz crystals generally occur in the lowest few feet of the bed. They are characteristically corroded, the outline of each crystal being smoothed and rounded, and broken now and then by resorbtion embayments and hollows.

Magnetite is always present in small quantities, often as idiomorphic crystals. In some thin sections it is partially altered to chlorite. The muscovite and biotite have generally suffered extensive alteration. Pumiceous glass and pieces of fine-grained quartzite make up the bulk of the included rock fragments.

Chlorite is patchily distributed through the matrix, of which it is sometimes the principal constituent. The small twinned crystals of secondary albite are always fresh, and sometimes fill cracks that cut across crystals and matrix alike. At other places the felspar appears to be filling cavities between the crystals, or even replacing other crystals. In the latter case it is usually accompanied by chlorite.

The carbonate, which appears to be mostly calcite, is present in variable quantity in the matrix and in decaying felspars.

The fine-grained upper part of the tuff beds often contains small glassy lumps which weather white in the field. The banding (Plate 22) is caused by the weathering of thin layers of slightly different grain-size. It is only noticeable

in T.B's 3 and 4. The bulk of the fine-grained material is composed of shards and dust, with small crystals of quartz and felspar. The shards are seldom distinguishable under crossed Nicols, as the whole groundmass is usually re-crystallised into small granular crystals of felspar (fig.23a). The shards have not been flattened to any appreciable extent.

2. Tuffs in the Mweelrea Grits.

In the field the 5 Mweelrea tuff beds could easily be mistaken for remarkably uniform flows of rhyolite, containing porphyritic crystals of quartz and felspar. At some localities they are apparently flow-banded. In the south limb of the Mweelrea Syncline their upper surfaces must have been eroded shortly after deposition, since the surfaces are irregular and overlain by coarse conglomerates containing pebbles of precisely similar material. It is therefore necessary to establish that they are in fact tuffs, and not flows of lava.

Samples were taken at 5 - foot intervals across T.B.2 near Bundorragha, and across T.B.3 below Oughty Craggy. Under the microscope the rock was found to consist of crystals of quartz and felspar, set in a matrix of shards of volcanic glass (which constituted up to 40% of the rock). The rest of the matrix was volcanic dust. In T.B.2,

Fig. 22 SECTIONS THROUGH T.B.1, MWEELREA GRITS

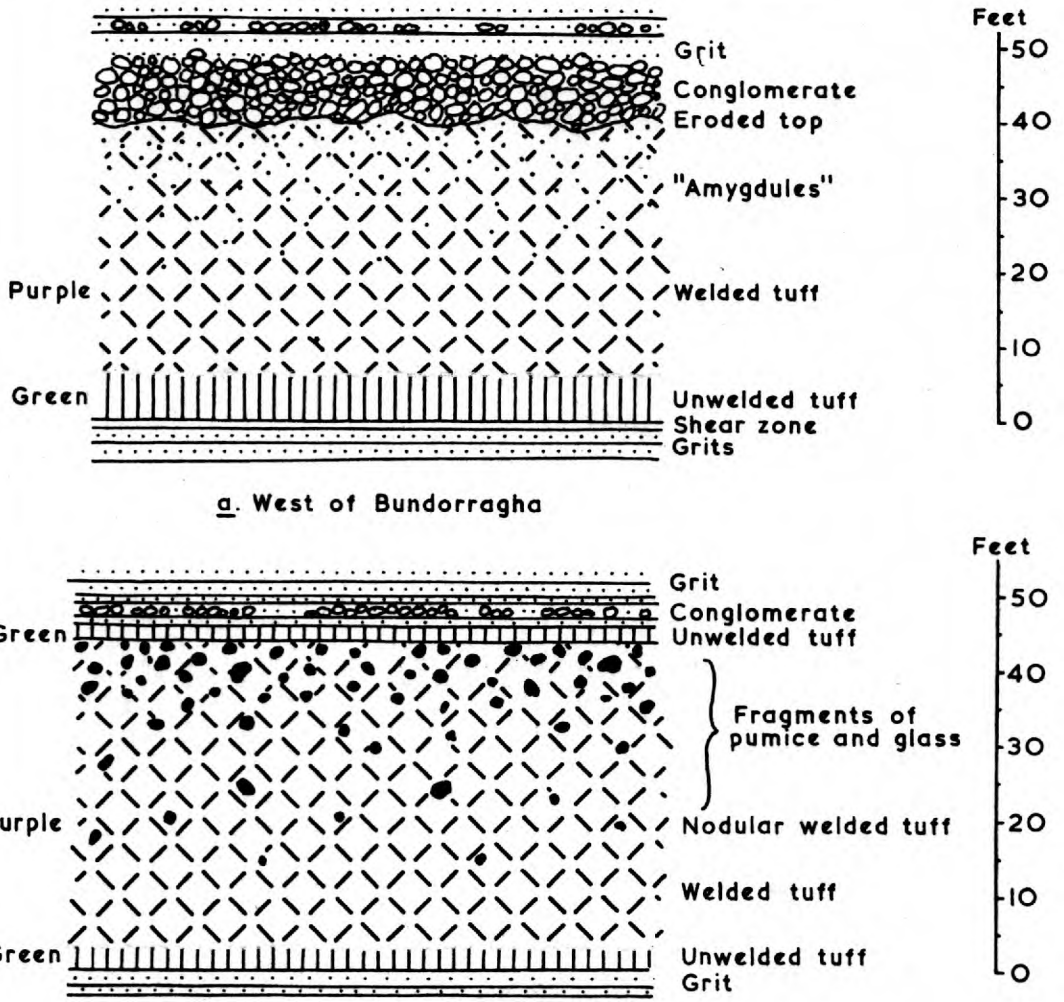
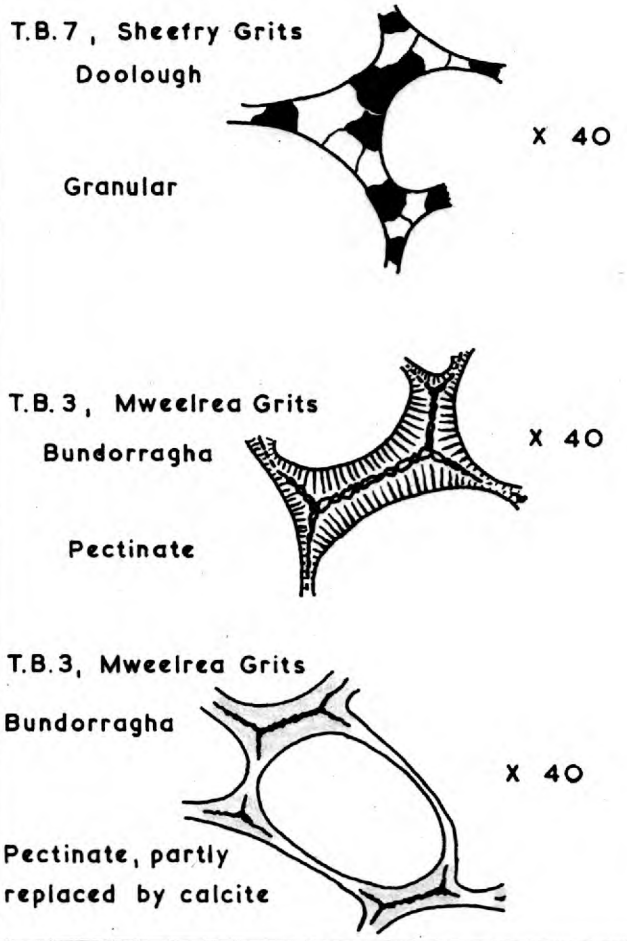


Fig. 23 RECRYSTALLISATION IN SHARDS OF VOLCANIC GLASS



(40 feet thick) the lowest 30 feet of the bed contained recognisable shards, which became more recrystallised upwards until in the topmost 10 feet they were indistinguishable. In T.B.3 (90 feet thick) shards made up at least 20% of the rock from top to bottom. Numerous specimens were collected from the other tuff beds, and in all cases where the matrix was not recrystallised, or wholly composed of dust, shards were abundant.

Such a deposit~~ion~~ of shards (the broken walls of bubbles in volcanic glass) can hardly represent a consolidated lava flow, but must be an accumulation of particles that fell to the ground in a solid or semi-solid state. It follows that the crystals were deposited in a similar manner, and that the whole is a deposit of tuff.

The Mweelrea tuffs in the south limb of the syncline differ in certain lithological characters from those in the north. The southern outcrops are described first.

Between Dooneen and Bundorragha all 5 tuff beds are exposed. There is little change in the lithology of individual beds from end to end of this outcrop, but any single tuff bed can often be recognised immediately in the field by certain characteristics of composition and appearance which persist over great distances.

The thickness of each tuff bed fluctuates slightly in the south (Fig.21). T.B.'s 1, 2, and 3 have at their bases

a zone of soft greenish material, which sometimes attains a thickness of 10 feet. (The bases of T.B.'s 4 and 5 are not seen). Porphyritic crystals of felspar, quartz, and muscovite, with occasional hornblends, are embedded in a fine-grained matrix of volcanic dust and shards. Grains of sand and small pebbles are common, and it would seem that some of the underlying sediment was caught up and incorporated in this part of the tuff bed. Under the microscope the felspars are seen to be altering to scapolite, and the hornblende to chlorite and magnetite. The crystals of quartz sometimes exceed 0.1 of an inch in diameter, and possess the rounded, pocketed outline that results from corrosion. The shards have recrystallised in a rather indefinite pattern, half-way between pectinate (or comb-shaped, Marshall 1935) (Fig.23b) and granular (Fig.23a). This soft green tuff is readily sheared, and has often been affected by bedding-plane slip between the massive tuff bed and the underlying grits.

Upwards, the green tuff becomes intermixed with patches of purplish material, and within a foot the purple flint-like rock that forms the bulk of the tuff bed is reached. The rock is not glassy, but has a very fine-grained lithic appearance. The fracture is often sub-conchoidal. In the field the porphyritic quartzes and felspars are prominently displayed, especially on weathered surfaces, together with small blebs of bright reddish

material that are often elongated or flattened parallel to the bedding. There are in all the tuff beds spherical cavities filled with carbonate, which have the appearance of amygdules and are especially abundant towards the top of the bed.

When the purple rock is examined under a microscope, the porphyritic crystals and the matrix are seen to be present in roughly equal quantities. The mineralogical composition is summarised in the following table:

Crystals.	Per Cent.
Felspar	8 - 40
Quartz	5 - 20
Magnetite	2 - 10
Mica	0 - 5
Rock fragments	0 - 5
Green Hornblende	0 - 2
Epidote, zircon, apatite, rutile	0 - 1
Matrix.	
Glass shards	0 - 40
Dust	0 - 40
Recrystallised dust and shards	0 - 80
Carbonate	0 - 10
Chlorite	0 - 5
Sericite	0 - 5
Secondary felspar	0 - 2

Plate 24. Photo-micrographs of the Mweelrea tuffs.

(a) A recrystallised glass shard in welded tuff, T.B.3, Ben Creggan. (Ordinary light, x 55).

The pectinate structure of the shard is clearly visible. The remainder of the rock is composed of dust and smaller shards.

(b) Welded tuff, T.B.2, Bunderragha. (Crossed Nicols, x 20).

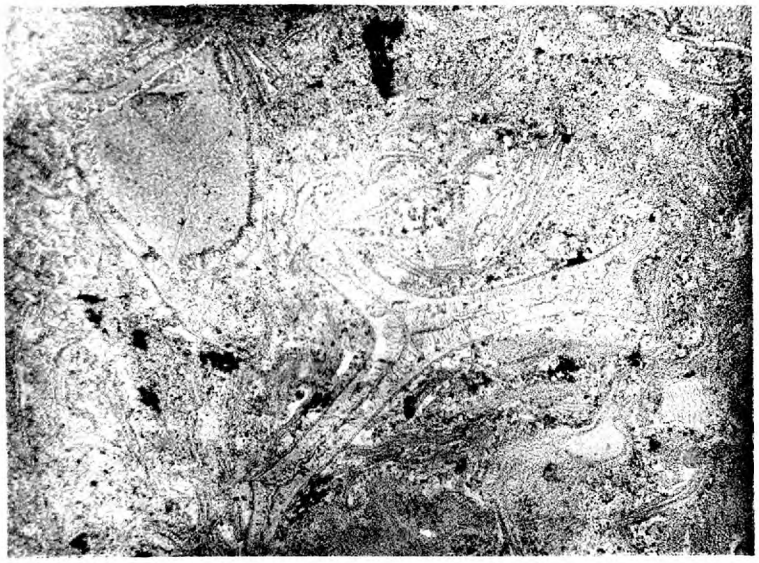
Crystals of twinned albite-oligoclase and corroded quartz, with magnetite, are set in a fine grained matrix of recrystallised dust and shards.

(c) A fragment of pumice in welded tuff, Oughty Craggy. (crossed Nicols, x 20).

The upper part of the photograph is of normal welded tuff, containing crystals of quartz, plagioclase, hornblende, and magnetite, in a fine-grained matrix. The lower part is coarsely re-crystallised glass, containing a large crystal of hornblende.

Plate 24

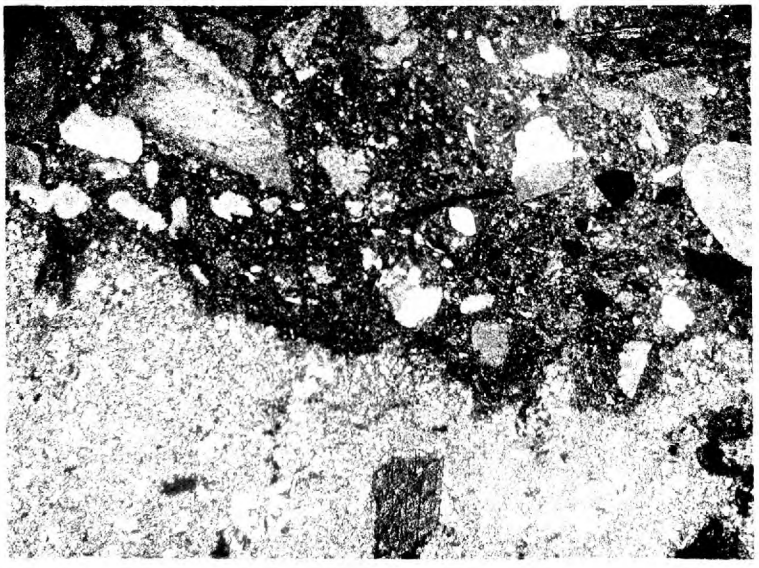
a.



b.



c.



The felspar crystals consist of albite-oligoclase and orthoclase, the plagioclase being the more plentiful. Microcline occurs sparingly. All the felspars have altered in some degree to sericite, clay minerals, and scapolite.

The quartz crystals are highly corroded. The magnetite is usually present as idiomorphic crystals, which, in contradistinction to the others, become slightly more abundant towards the top of the bed.

Muscovite and biotite are rarely found in the tuff, except at the top and bottom of the bed. The crystals are often distorted, and encrusted with magnetite and chlorite. Hornblende is of local occurrence, but 8- sided pseudomorphs in chlorite and magnetite are occasionally seen. The rock fragments include small grains of quartz, quartzite, and occasionally slate.

Glass shards and dust are present through_out the matrix. In some places they are so recrystallised as to be unrecognisable, but, since all stages in the recrystallisation can be seen in the various slides, it is safe to assume that such areas of uniformly microcrystalline material were originally dust and glass. Recognisable shards are usually composed of perfectly clear material, but the dust contains innumerable minute particles of iron ore, (probably hematite) that appear red by reflected light, and impart the red colour to the rock.

In the purple flinty part of the tuff bed the shards have always recrystallised in the pectinate pattern (Fig.23b, Plate 24). The fibres, normal to the length of the shard, are probably of felspar, but this is uncertain. The dust, where it is un-recrystallised, is so fine-grained as to appear almost glassy.

In thin section the boundaries of the calcite-filled "amygdules" can be seen to be irregular, and it is possible, but unlikely, that they are replacement segregations of calcite. This mineral sometimes wholly replaces the glass of a shard (Fig.23c, ~~Plate 24~~).

The blebs of red material, often aligned, are more coarsely recrystallised than the rest of the tuff. Sometimes the crystallisation is spherulitic, resembling chalcedony. The bleb frequently has a banded appearance, and is usually sharply delimited from the surrounding tuff. At Dooneen the red lumps in the upper part of T.B.2 reach a diameter of a foot, and are coarsely recrystallised. The rock is banded, and contains very large corroded crystals of quartz, exceeding 0.4 of an inch in diameter (twice as big as any in the tuff). The crystals are fractured, as if they were breaking up. It is suggested that these red lumps are fragments of pumice that did not disintegrate into tuff, so that the quartz crystals were preserved at their original size.

The upper surfaces of the tuff beds are always eroded in the southern outcrops.

Plate 25.

Pumiceous inclusions in T.B.1, Oughty Craggy.

Plate 26.

Un-eroded top of T.B.1, Oughty Craggy.

The hammer handle crosses a thin bed of green unwelded tuff, which caps the nodular welded tuff and underlies massive grits.

Plate 25.



Plate 26.



In the north limb of the syncline the same tuff beds (with the exception of T.B.4) are exposed. They are of essentially the same composition as their equivalents in the south, but possess a number of new features. The differences are especially apparent in T.B.1, and, in the north-west, T.B.2.

Along the whole of the northern outcrop, the weathered surface of T.B.1 has a nodular appearance (Plate 21). It is only seldom that the individual nodules consist of a lump of foreign material, and they appear rather to reflect a discontinuous structure in the tuff itself. In section it is found that the nodules are made of purple tuff, whereas the less resistant tuff between them is green. Under the microscope the minute particles of hematite that give the purple tuff its colour are seen to be absent from the green material; instead, their place is taken by finely-divided green chlorite, which is more readily weathered. It is believed that the nodular structure reflects in some way the rather deeper water into which, on this side of the syncline, the tuff undoubtedly fell, but no suggestion is here offered as to the actual process that operated.

In many places, especially near Oughty Craggy, T.B.1 contains lumps of hard uniform fine-grained greenish material, weathering white (Fig.22b, Plates 25, 26). They are rare at the bottom of the bed, but become abundant at the top,

and attain a diameter of nearly a foot. They occasionally contain very large fractured quartz crystals, similar to those in T.B.2 at Dooneen, and small twinned crystals of idiomorphic hornblende, as well as the usual large felspars. The matrix is uniformly recrystallised, somewhat more coarsely than is the enclosing tuff. The presence of exceptionally large quartz crystals, as at Dooneen, that the lumps never disintegrated into tuff, but are fragments of the original pumice with the approximate composition of the parent magma.

A layer of soft green tuff is present at the base of all the 4 tuff beds in the north limb of the syncline, but it is usually thinner than it is in the south. Below Oughty Craggy T.B.1 is virtually complete and uneroded (Fig.22b), and is capped by a two-foot bed of soft green material, devoid of pumiceous lumps but containing approximately 5% of hornblende, as well as quartz and felspar. Apparently the last tuff to settle was at a temperature insufficiently high to allow welding. Near Oughty Craggy the green colour of this upper bed of tuff is due to the presence of secondary granular epidote in the dusty matrix.

Near Doocghtry, in the extreme north-west, the whole of T.B.1 is dark green in colour, with a stony appearance, and is softer than elsewhere. It seems to be incompletely welded. At one locality east of Trawleckackoolia the lowest 10 feet

is a hard green rock, comparable to T.B.8 in the Sheefry Grits south of Tievummera.

Between Doogahtry and the Bunanakee River, T.B.2 is greyish-white, and frequently contains glassy lumps like those in T.B.1 below Oughty Craggy. Under the microscope the white tuff is found to consist of the usual crystals of quartz, felspar, and magnetite; but the matrix is made up of clearly distinguishable shards and dust, the shards recrystallised in the granular pattern that is characteristic of the Sheefry tuff beds and the other unwelded tuffs (Fig. 23a). The white tuff is fairly soft, and often sheared. In the extreme west of the Doogahtry outlier T.B.2 seems to be thinning rapidly.

T.B's 1 and 2 sometimes include in their mass fragments of foreign material, such as grains of sand, and pebbles, that have obviously been derived from the underlying grits. Often, when the rest of the fine-grained tuff is recrystallised, shards are preserved in the matrix adjoining a large fragment, as though the hot tuffaceous material had been chilled at the contact, thereby escaping recrystallisation.

Certain lithological characters allow of the direct identification of each tuff bed in the field. Thus, T.B.2 invariably contains larger and more abundant quartz crystals than the other tuffs. T.B.'s 1, 3, 4, and 5 can usually be recognised by less tangible features, involving small

peculiarities of colour and texture which persist over considerable distances.

(c) Stratigraphy.

Figure 21 summarises the occurrence and thicknesses of the Mweelrea tuff beds. The variations in lithology, northwards and westwards, have already been discussed in section b. There can be no doubt that these tuffs were laid down as continuous and uniform sheets over the whole area under discussion. T.B.4 is the only exception, and it is unfortunate that its original termination is not exposed. In the south, where all the tuff beds suffered contemporaneous erosion, they must have originally been a little thicker than they are now.

The tuff beds in the Glenummera Slates are of small lateral extent, and only that east of Bundorragha, in the extreme south, is graded into coarse and fine fractions.

The Sheefry tuffs are exposed over a wide area, and are often very thick. Since each tuff bed is a deep-water deposit, contemporaneous erosion could only occur as a result of slumping, and a bed is usually complete where it is present.

The following table lists the observed thicknesses of each of the Sheefry tuff beds:

T.B.1	10 feet	T.B.5	30 - 60 feet.
T.B.2	20 feet	T.B.6	nil - 45 feet.
T.B.3	15 - 25 feet	T.B.7	50 - 120 feet.
T.B.4	15 - 30 feet	T.B.8	10 - 50 feet.

Except for T.B.7, it is not certain that the Sheefry tuffs are continuous sheets. T.B.8, for example, appears in the field as 3 lenses at approximately the same horizon. T.B.'s 1 to 6 are not continuously exposed, and, since they are not lithologically distinctive, their correlation can beno more than the most probable of several alternatives.

The puzzling manner in which some of the tuff beds suddenly terminate has been discussed (Chapter Four, section g). In five places at least, less abrupt terminations can definitely be ascribed to non-deposition. Thus T.B.6, when traced E.S.E. for 250 yards through a chain of small exposures on the north shore of Glencullin Lough, passes from a graded bed 30 feet thick into 12 feet of fine-grained tuff, and then vanishes altogether. Similar but less well exposed transitions exist in T.B.8 south of Glencullin Lough, in T.B.5 north-west of Clashcame, and in T.B.3 at both ends of the small exposure south of Cregganbaun.

The tuff beds are concentrated in the southern exposures of the Sheefry Grits, especially between Cregganbaun and Doolough. None are exposed north of the Feenune - Corvock anticline, and in general the exposures of tuff

become patchy and incomplete northwards. It is significant that the great T.B.7, which is continuous from east to west across the whole area, is 120 feet thick at Legha More, 50 feet thick a mile to the north east near Six Noggins, and completely absent half a mile north of that. T.B.8, 50 feet thick near Legha More, is similarly absent further north.

It is interesting that no volcanic rocks have been recorded in the Leenane and Rosroe Grits, the equivalents of the Sheefry Grits south of Killary Harbour.

(d) Conditions of deposition.

Until 1951 - 52 the Mweelrea tuffs were believed to be intrusions, or lava flows. In the field there isno indication that they are tuffs, except insofar that rhyolite flows of such extent and uniformity would be most unusual. However, there are several phenomena which demonstrate that the Mweelrea tuffs acquired the properties of coherent rock very shortly after their deposition.

In all areas, the conglomerates between T.B.1 and T.B.6 contain pebbles of tuff, pebbles which are especially common in the thick conglomerates that rest on the eroded tuff beds in the south. Their distribution (in the horizon of the tuff beds only) indicates that they are derived from the contemporaneous erosion of the tuffs, and this surmise is confirmed by the presence of pebbles of the distinctive T.B.2 resting on

Plate 27.

Mweelrea T.B.5, near Bunaglass.

Note the prominent coarse jointing and the overlying conglomerate.

Plate 28.

Mweelrea T.B.2, south-west of Bundorragha.

The coarse jointing is very conspicuous.

Plate 29.

Mweelrea T.B.1, near Dooaghtry.

The flags beneath the massive tuff bed are undisturbed.

Plate 27.



Plate 28.



Plate 29.



the surface of that tuff bed.

The brecciated T.B.5 on the ridge south of Ben Creggan has already been mentioned (Chapter Six, section e.). The surface and edges of the fragments of tuff are as smooth and sharp as if they had only just been broken. Yet the slumping must have occurred very soon after deposition, and the tuff must have been a coherent rock at the time.

The west wall of the erosion channel in T.B.3, on Oughty Craggy, is quite precipitous, and exhibits traces of a white patina, presumably a weathering effect. Evidently the walls of the erosion channel were stable, and were exposed to the elements for some time.

It is now established that in all areas except, possibly, the extreme north-west, the tuff consolidated shortly after it settled on the ground.

Marshall (1935) and Gilbert (1938) have described recent deposits of welded tuff in New Zealand and the United States. The following table illustrates their similarity to the Mweelrea tuffs.

Mweelrea Tuffs.	Bishop Tuff (U.S.)	New Zealand Tuffs.
1. Area 100 sq.miles.	Area 400 sq.mi.	Area 10,000 sq. mi.
2. Thickness 12 to 130 feet.	Thickness 500 feet.	Thickness 60 to 500 feet.
3. Not composite.	Composed of several members.	
4. Each T.B. is partly a Shallow water deposit.	Entirely continental deposits.	

(Cont'd)

	Mweelrea Tuffs.	Bishop Tuff (U.S)	New Zealand Tuffs.
5.	Unwelded base 2 to ~~10~~ feet.	Unwelded base a few inches thick.	
6.	Unwelded pumiceous top (where uneroded)	Becomes less welded upwards.	
7.	Contain lumps of pumice.	Contain large pumice lumps and blocks.	
8.	Non-porous.	Porosity 3% at bottom, 40% at top.	
9.	Widely spaced vertical joints.	Widely spaced vertical joints.	
10.	Top originally level.	Top level.	
11.	Underlying strata are undisturbed.	Underlying strata are undisturbed.	
12.	Middle Ordovician.	Pleistocene	Late Tertiary and Recent.

A fundamental cause of difference between the Mweelrea tuffs and the Bishop and New Zealand tuffs, was the environments in which they accumulated. Had the Mweelrea tuffs been deposited on a land surface, instead of a subsiding deltaic area, or shallow sea, they would have formed a composite sheet of tuff 150-250 feet thick from top to bottom, without the thick layer of unwelded material at the base of each bed. It is thought that this green unwelded layer consists of tuff that was rapidly cooled as it fell into the shallow water. Welding commenced as soon as the deposit of tuff was built up above water level.

No evidence can be found, in the field or under the microscope, to indicate that the Mweelrea tuffs were once porous. However, compaction since the Ordovician could

hardly fail to reduce the porosity of a glassy rock to a negligible amount.

Under the microscope, the Mweelrea tuffs compare very closely with the photo-micrographs that illustrate the descriptions of the Bishop and New Zealand tuffs. The recrystallisation of the shards is characteristically pectinate, except in the unwelded base. In the field the tuff beds are similar in appearance to some of the photographs of the New Zealand tuffs (Marshall 1935).

Welded tuffs are believed to be the deposits formed by Nuées ardentes, or "glowing avalanches", such as have been described by Lacroix (1930), Perret (1936), and Fenner (1925). A nuée ardente is supposed to originate in the sudden eruption of acidic magma very highly charged with gas. As the pressure is released, the gas, (mainly steam) escapes, and the magma at this stage has been likened by Lacroix to milk boiling over. Gas is evolved violently and continuously, and the magma is at once converted into a mass of incandescent glass particles suspended in an ever-expanding gas cloud, the particles themselves emitting gas freely. Such a cloud is dense and exceedingly fluid, and will spread out and flow at a great speed down the gentlest of slopes. In country of low relief it will cover a considerable area. Lacroix believed that the Nuées ardentes of Mont.Pelee travelled at more than 300 miles per hour. The temperature of the cloud is supposed to be in the region of 1,200 °C.

When the gases are exhausted, the material of the nuées will settle to the ground in a layer which, in flat country, will be very uniform. If the glassy shards and pumice are still hot, they will adhere, to an extent depending on their temperature and on the pressure of the overlying material.

Such, in brief, is the suggested origin of the Mweelrea tuff beds. It is curious, that in none of the great sheets of welded tuff that have been described, have any of the feeders or pipes that supplied the tuff been discovered. (The welded tuffs of Mont Pelée are on a comparatively small scale). The same must be said of the Mweelrea tuffs. Only 2 isolated exposures of tuffaceous material have been found, both of them in the north-west of the outcrop. One is a small hummock, near Doogahtry, of material that closely resembles T.B.1, and is apparently a portion of this tuff bed that has been brought up by a quadrilateral pattern of faults. The other adjoins the 80-foot thick dolerite dyke half a mile south-east of Trawleckackoolia. The ground is not faulted, and as the tuff resembles T.B.1 (even to the nodular weathering), it is suggested that this fragment of tuff was carried up from a lower level during the intrusion of the dolerite.

Fenner (1925), describing the welded tuff in the Valley of Ten Thousand Smokes, Alaska, suggested that the tuff was

derived from a sill of magma that was intruded beneath the whole district. The thin crust under the valley fractured in many places, and the gas-laden magma poured up the fractures into the valley. Gilbert (1933) and Marshall (1935) also suggest that the material of the nuées ardentes had its source in numerous separate vents.

There is no indication that a sill, large or small, underlay the Mweelrea Grits in S.W.Murrisk. A great area of strata below the tuff beds is exposed, and the apparent absence of even a single feeder pipe suggests that such pipes were not common.

The nearest known centre of vulcanicity is at Lough Nafooey, some seven miles south-east of Bundorragha, and the spilites there are of Arenigian age. At Tourmakeady, 12 miles east of Bundorragha, the Arenigian strata contain tuffs and "contemporary rhyolites", and are intruded by a large boss of felsite containing porphyritic felspars and corroded quartzes. A similar felsite intrusion occurs on the Kilbride peninsula, south of Tourmakeady. They were described by Gardiner and Reynolds (1909, 1912), who considered that they were intruded shortly after the surrounding Arenigian sediments were laid down. Their mineralogical composition appears to be quite like that of the Mweelrea tuffs.

It would be unwise to speculate further on the source of the Mweelrea tuffs, until they have been examined in east and south-east Murrisk. Nevertheless, it is likely

that the nuees ardentes moved from land to sea, rather than vice-versa, and it is therefore probable that the source lay to the south or south east.

It has already been established (Chapter Four, section e) that the tuffs in the Sheefry Grits settled to the sea bottom through deep water, the larger particles sinking more rapidly, so that the resulting bed of tuff was graded. There is only one grading in the thickness of each bed, indicating that the supply of tuff was copious, and that the whole operation was completed in a very short time.

The mineralogical composition of the Sheefry tuffs is almost identical with that of the Mweelrea tuffs (section b). Both were deposited extremely rapidly over great areas, and the two series of tuff beds are of comparable thicknesses. It is suggested that they had a common origin in nuées ardentes. If so, it is necessary to assume that the speed and momentum of a nuée ardente is such that it can carry out to sea for 4 or 5 miles (since it could hardly originate in deep water, and the Arenigian shoreline lay just south of Killary Harbour). If one considers the 120 feet of sediment contained in T.B.7, it seems clear that the postulated nuée ardente must have been a rushing, towering cloud, more than 1,000 feet high. Such a cloud would surely travel a great distance seawards before all its suspended particles could sink into the sea. However, the supply of sediment

would diminish seawards, and in S.W. Murrisk the tuff beds thin out, become patchy, and then vanish, as they are traced northwards (the seaward direction in Arenigian times).

Part of the fine-grained top of each tuff bed must be formed from the immense clouds of volcanic ash which rise miles into the air during the eruption of a nuée ardente (Fenner 1925, Lacroix 1930). The thin beds of dust tuff occasionally found in the Sheefry Grits probably result from the settling of smaller airborne clouds of dust and pumice.

It is interesting that no references could be found to welded tuffs or nuées ardentes in strata older than the Cretaceous. The early Ordovician occurrences in S.W. Murrisk, therefore, are probably the first pre-Cretaceous ones to be discovered and described.

Chapter Eight. THE SILURIAN STRATA.

(a) Introduction.

Silurian rocks are only found in the northern part of S.W. Murrisk, near Cregganbaun and near Boheh. They are more completely exposed at the former place, hence their collective name: "the Cregganbaun Series". Between the two hamlets the rocks are buried beneath glacial drift, but in all probability the sediments have been lost through the intrusion of the Corvock and Knockaskeheen granite. West of Lough Nahaltora drift again conceals the Silurian strata.

The Silurian rocks rest discordantly upon Arenigian strata, but the unconformity is seldom exposed in the district mapped. The lowest Silurian bed is a remarkable conglomerate, formed of large rounded pebbles and reaching 30 feet in thickness. Above it is a grey and white impure quartzite, which passes up into a series of calcareous silty slates, that locally contain fossils.

These strata form the southern limb of an east-west syncline. The northern limb is exposed several miles further north, where the quartzite, much thickened, makes a high mountain ridge that culminates in Croagh Patrick (2,510 feet).

Although the rocks are comperatively hard, they form low hummocky ground about Cregganbaun and Boheh. Glacial striae are often well-preserved on the smooth surfaces of quartzite.

(b) Age.

Fossils occur in abundance in thin calcareous bands in the Cregganbaun Slate Series, just west of the Carrownisky River. Corals, brachiopods, and trilobites are preserved in calcite. The Officers of the Geological Survey of Ireland found enough species in 1874 to assign a "probable Wenlock" age to the Series. Kilroe (1907) referred to it as Wenlock, solely on the evidence of the 1876 Memoir.

Gardiner and Reynolds (1912) assigned similar strata near Lough Nafooey to the Llandovery. No extensive collecting has since been undertaken, and in the present work the Cregganbaun Series is assumed to be of Llandoverian age.

(c) Field Description.

The Silurian strata are not exposed west of the small roadside quarry a mile W.N.W. of Lough Nahaltora. In the quarry the basal conglomerate is seen, together with sheared sills of appinite, but the unconformity is concealed by quarry spoil. The conglomerate pebbles are very much flattened parallel to the bedding.

Between the quarry and Lough Nahaltora there are scattered outcrops of conglomerate and appinite. On the lake shore the quartzite and slate of the Cregganbaun Series are exposed for the first time. The beds are vertical or overturned, younging to the north-east. Subsequent exposures are

good. The conglomerate is particularly well seen in a cliff a hundred yards east of the small lake called Derrygarvebeg Lough. (Plate 30). Acid dykes and sills abound, often differing little in appearance from the quartzite. Intrusions of appinite are not infrequent, one sill in the slates north of Derrygarvebeg Lough being 500 yards long. Fossils are to be found in most of the small quarries in the slates.

South of Cregganbaun the strata twist round through almost a right angle to adopt the typical Caledonid strike of north-east and south-west, and the dip decreases to 60° North. The conglomerate pebbles are only slightly flattened. The quartzite thickens to 1,300 feet, and the slate series reaches its maximum observed thickness of 2,600 feet. Granitic and dioritic dykes cut the sediments, and the slates are hornfelsed, losing their cleavage. Near Cregganbaun School the main mass of granite is encountered, and immediately all the rocks are lost beneath a mantle of alluvium which persists unbroken to near Boheh, a distance of 4 miles.

Exposures are scanty near Boheh, but the quartzite appears to have increased to a thickness of more than 2,000 feet, and its upper boundary with the slate series (here very silty) is difficult to define. There is one minute outcrop of conglomerate. The sedimentary rocks are somewhat hornfelsed by the nearby granite, and acid dykes

Plate 30.

The Cregganbaun conglomerate, Derrygarve.

A small cliff facing north. The view is at right angles to the strike, so the flattening of the pebbles cannot be seen.

Plate 31.

The Cregganbaun conglomerate, Cregganbaun.

View along the strike. The pebbles are only slightly flattened.

Plate 32.

The Cregganbaun conglomerate, Derrygarve.

View along the strike. The outcrop is in the Maam Flexure, and the pebbles are very strongly flattened.

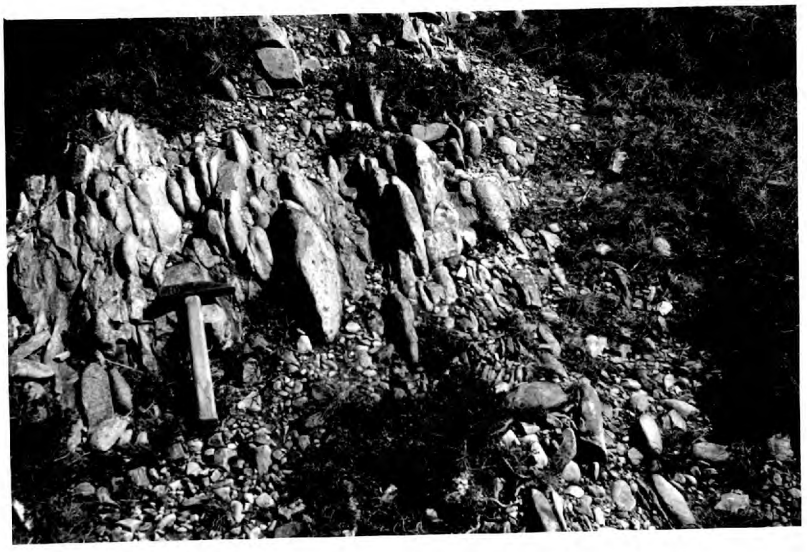
Plate 30.



Plate 31.



Plate 32.



are common. An appinite intrusion exists at the base of the quartzite. In the extreme east the strike begins to swing round into the N.W. - S.E. direction. A long narrow tongue of granite cuts across the Silurian strata at right angles to the strike.

(d) Lithology.

The basal conglomerate of the Cregganbaun Series consists of smooth rounded pebbles of igneous, metamorphic, and sedimentary rocks, set in a sandy or gravelly matrix which makes up only a small part (about 15%) of the whole. This matrix is always greatly sheared. In the district under discussion the pebbles attain a maximum diameter of 2 feet, but a diameter of 6 inches to 1 foot is most usual. Pebbles less than 3 inches across are rare. In some localities, tectonic forces have flattened the pebbles parallel to the strike.

The great majority of the pebbles consist of white and pink quartzite, of varying grain size, the interlocking particles, mainly quartz, being set in up to 30% of fine-grained matrix. Patches of sericite and epidote may represent decayed felspars.

Among the other pebbles a bright red jasper is not uncommon; under the microscope it is seen to be chalcedonic. Fragments of slate occur, cleaved parallel to the regional

cleavage; they resemble the underlying Arenigian slates. There are occasional pebbles of quartz-porphyry, Spilite(?), a coarsely crystalline epidote-zoisite-quartz rock, a possible dust-tuff, and a much-altered felsite. Notable by their absence are the schist, gneiss, and granite pebbles, derived from Connemara, that are so common in the Mweelrea Grits.

Near Gregganbaun the conglomerate has been much altered by the Corvock granite. In thin sections a net of green calcic hornblende crystals, with or without biotite, is seen to pervade the matrix and pebbles (other than quartzite and jasper). Granular epidote, zoisite (sometimes euhedral), and euhedral sphene and apatite, together with rare tourmaline and epidote, are scattered at random through the mass.

Directly above the conglomerate is a sheared gritty band of schistose appearance, which contains scattered pebbles in its lower half. It varies in thickness from 20 - 100 feet. Grains of quartz, quartzite, and altered felspar are present, embedded in about twice the quantity of fine-grained matrix, which is mostly altered to chlorite. On the general geological map this band is included in the quartzite.

Upwards again the rock becomes more quartzose, and passes rapidly into the Cregganbaun quartzite. Fifty to

seventy per cent of this rock consists of partially interlocking grains of quartz, with rare plagioclase and quartzite, set in a fine-grained quartzose and sericitic matrix. Metamorphism at Cregganbaun and Boheh has produced euhedral sphene, biotite, and tourmaline, accompanied by granular epidote and zoisite. At one point south-east of Cregganbaun the matrix is calcareous. The quartz grains are strained, and near Lough Nahaltora they are flattened in a similar manner to the conglomerate pebbles.

The passage into the Slate series near Cregganbaun is gradual but occurs over a small vertical distance, due to a decrease in the proportion of quartz grains to fine silt and clay. The strata are always silty, never providing a pure slate, and occasionally containing coarse quartzite bands, especially near Boheh. Between Cregganbaun and Lough Nahaltora, there exist in the slates impure limestone bands less than a foot thick, which contain abundant fossils. Thermal metamorphism near Cregganbaun and Boheh has destroyed the cleavage (or prevented its formation), and the slaty silts have a massive hornfelsed appearance, somewhat similar to a dark fine-grained limestone. The fossils in this area are preserved as chlorite and recrystallised calcite.

(e) Sedimentary Structures.

Current-bedding is rarely seen in the quartzite, which is generally massive in its centre and thin - bedded on its margins. However, there are two occurrences of false beds, about a foot thick, by the roadside at Cregganbaun, which prove the quartzite to young northwards. A third exposure shows northward-younging quartzite near Boheh.

The slates contain many thin silty beds, but graded bedding is surprisingly rare. In a few poorly-graded beds the direction of younging is northwards. Imperfectly graded beds are also found at the base of the quartzite.

No ripple-marks were observed in the Series.

(f) Structure.

The structure of the Cregganbaun Series is comparatively simple. In plan, the quartzite and conglomerate are bent into a great V - shaped curve, in which the strata are vertical or overturned in the west, and dip at 50° north in the east. There is no evidence of intraformational folding in the area examined. One fault is postulated south of Cregganbaun, because of an apparent shift in the conglomerate outcrop.

On the general geological map it appears that the quartzite thins westwards. This is in fact the case, but

the apparent thinning is structurally exaggerated. In the first place, the dip in the west is steeper, which results in an apparent diminution, but the principal cause is a thinning where the strata enter the zone of the Maam Flexure (Chapter Four, Section g). South of Cregganbaun, where the strike is north-easterly, the conglomerate pebbles are only slightly deformed (Plate 31) but near Lough Mahaltora, in the attenuated limb of the flexure, they are so flattened as to be only half their original thickness (Plate 32). A similar flattening is noticeable in the individual grains of the quartzite, as well as in the underlying Sheefry Grits. It is therefore safe to assume that in the limb of the Maam Flexure the true thickness of the quartzite has been reduced, perhaps by as much as half.

(g) Stratigraphy, and conditions of deposition.

Only a small part of the total exposure of the Cregganbaun Series has been mapped in the present work. Of the three component formations, the conglomerate shows no important change along its outcrop, and the slates are insufficiently exposed for any conclusions to be drawn from them. The quartzite alone undergoes a visible change in S.W. Murrisk, for in the east, near Boheh, it is 2,500 feet thick; at Cregganbaun, 1,300 feet, and near Lough Mahaltora

the thickness has diminished to about 1,000 feet (allowing for the tectonic thinning). Two miles north-east of Boheh the quartzite reaches its greatest development in the magnificent conical peak of Croagh Patrick. The slate series is siltier near Boheh than at Cregganbaun.

Whilst the exposures are inconclusive, it is quite probable that there is a lateral facies change; that the upper quartzite at Boheh is the equivalent of the lower slate series at Cregganbaun.

The Cregganbaun slates are undoubtedly a marine deposit, since they contain corals, brachiopods, and trilobites. Fine mud and silt must have accumulated in a comparatively shallow sea, in which calcium carbonate was precipitated at intervals. Coarse detritus occasionally reached the area, but the paucity of sedimentary structures suggests that sedimentation took place under generally tranquil conditions. There is no trace of volcanic material in any of the Silurian strata.

The rare current-bedding in the quartzite indicates that this lithological unit is an aqueous deposit. The rock is badly sorted, the fine-grained matrix providing up to 40% of the whole, and the inference is that bottom currents were not strong. There was some precipitation of calcium carbonate.

A great unconformity exists between the basal conglomerate and the underlying Ordovician rocks. The conglomerate is exposed again north of Croagh Patrick, and must underlie at

least 25 square miles, for it is reported (Kilroe 1907) to occur on Clare Island. Such a widespread thin sheet is hard to explain. To suggest that the pebbles have dropped from melting icebergs is clearly erroneous, since they are all smoothly rounded, sorted to a degree, and must have undergone violent water-abrasion during the formation of the conglomerate. Moreover, the conglomerate forms an integral part of a well-defined cycle of sedimentation :-

3, Slate.
2. Quartzite.
1. Conglomerate.
(Unconformity).

To postulate a simple marine transgression is not enough, for any explanation must account for the mass of finer-grained sediments in the cycle, which must have been derived from outside areas, since they are quite different from the underlying Sheefry Grits. It is not unlikely that a gentle subsidence in the area now occupied by the conglomerate was accompanied by a sharp uplift and erosion elsewhere. If such was the case, the conglomerate is, perhaps, best interpreted as a diachronous shallow-water or littoral deposit, the finer material of the original sediment having been carried further away.

The lithological differences between this conglomerate, and those of the Mweelrea Grits, have already been noted. During Llandoverian times, deposition was taking place over the northern part, at least, of the Connemara Schists. Thus it is unlikely that the materials of the Cregganbaun conglomerate were derived from the south. Pebbles of schist, granite, and Mweelrea Grit and tuff are characteristically absent. Moreover, the quartzite thickens to the north. The abundant white quartzite pebbles closely resemble the quartzites of North Mayo. Hence it is tentatively suggested that the Silurian strata may be the products of uplift and erosion in the district north of Clew Bay.

Chapter Nine. THE INTRUSIVE IGNEOUS ROCKS.

(a) Introduction.

The outcrops of igneous rocks in S.W.Murrisk were carefully entered on the field maps, but the specimens have not been subjected to an extensive petrological examination. This chapter, therefore, is devoted to a general description of the various intrusive rocks, with only brief comments on their petrology. Only a limited number of the acidic dykes and doleritesare marked on the general geological map, but all the outcrops of hornblendic rocks (appinites) and lamprophyres are shown.

(b) The Corvock Granite.

1. Field Description.

The Corvock Granite extends five miles in an east - west direction, and is probably about three miles wide from north to south. It is very well exposed in the hills of Corvock (Plate 33) and Knockaskeheen, but, with the exception of one small exposure of granite in the bed of the lower Bunowen River, the rocks north and north-west of these hills are concealed by drift. A narrow tongue of granite 1.5 miles long cuts across the Silurian strata north-west of Knockaskeheen.

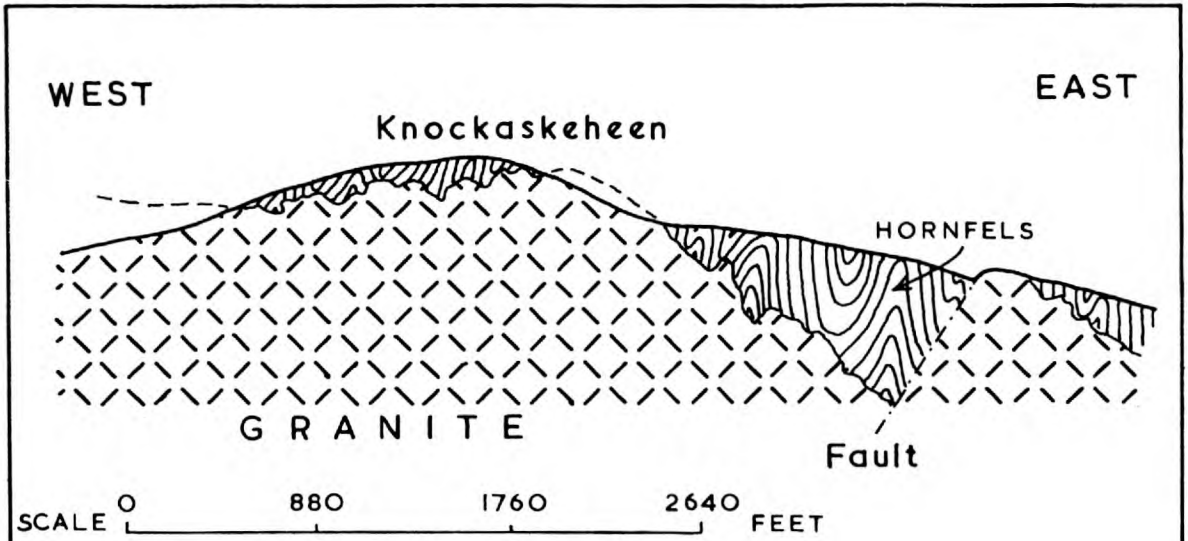


Fig. 24 Section (natural scale) through the granite

On the summit of Knockaskeheen there is an area of hornfelsed country rock seamed with granitic dykes, that appears to form a thin capping to the granite (Fig.24). At many points around the periphery of the granite, the contact dips gently outwards. It seems likely that the present exposure of granite is close below the original roof of the pluton, and that a relatively small amount of granite has been lost through erosion.

North-east of Knockaskeheen the granite is crossed by a zone of normal faults that dip west at 70 degrees. The fault planes are thickly coated with quartz, and the adjoining granite is breciated. Elsewhere the granite is a massive coarsely-jointed rock. There is well developed layer-jointing parallel to the steep hill slopes (Plate 33).

The main mass of the granite is a uniform coarsely crystalline rock. Quartz, felspar, muscovite and biotite can be distinguished in hand-specimens. Close to the margin of the pluton dark xenoliths of country rock are common, and the composition of the rock changes. Biotite is more abundant, and the rock is finer-grained and darker in colour. This alteration is believed to be due to the marginal assimilation of the country rock by the granite magma. Alteration of the country rock in situ has occurred at a point west of Knockaskeheen, where large biotites and felspars have grown in hornfels, which still shows traces of bedding.

Plate 33.

Layer joints in the Corvock Granite.

Knockaskeheen, the hill in the background, is also composed of granite.

Plate34.

Spotted rock in the hornfels, Laghta Oughter.

The spots, of cordierite, are best developed in the pelitic bands, which are darker in colour.

Plate 35.

A transgressive acidic dyke, Cregganbaun.

The dyke occupies the upper right half of the picture, and is lighter in colour than the slates. Cleavage cuts dyke and slate alike. The lower boundary of the dyke is very irregular.

Plate 33.



Plate 34.



Plate 35.



2. Mode of emplacement.

The granite boundary is highly transgressive, since it cuts across the strike of both the Silurian and the Archaean strata, as well as the core of the Feemane anticline. There can be little doubt that much of the country rock has been replaced, and not merely pushed aside. The hornfels surrounding and overlying the granite is veined with countless dykes, and it is to be inferred that blocks of country rock, isolated by the intrusion around them of granitic dykes and sills, subsided into the magma and were assimilated. In other words, the granite was emplaced by the process of stoping.

3. Petrology.

The main mass of the granite is composed of a coarsely crystalline, mutually interfering, aggregate of quartz, felspar, and mica. The crystals may attain a diameter of 0.1 of an inch. The average composition is :-

Microcline	10%
Oligoclase	35%
Biotite	5%
Quartz	43%
Muscovite, apatite, pyrite, zircon ..	2%

In the marginal areas, where the granite is contaminated by country rock, biotite-rich xenoliths are common, and the rock contains more muscovite than is usual. The grain-size is smaller, the proportion of quartz is reduced, and plagioclase (and very occasionally biotite) crystals are porphyritic in a groundmass of small lath-like felspar and biotite and granular quartz.

There is no trace of lineation or flow structure in the granite.

4. Age.

The granite is undoubtedly post-Llandovery, since it intrudes Llandoverian sediments. On the other hand, many but not all of the acidic dykes (which can be traced back into the granite) have been cleaved and sheared by the same forces that brought about the regional folding (Plate 35). It would seem, therefore, that the granite was intruded at a late stage in the Caledonian orogeny. It is cut by a dolerite dyke that is probably Tertiary.

5. The metamorphic aureole.

The granite is everywhere surrounded by a zone of hornfels and spotted rock (Plate 34) that extends up to 0.5 of a mile outside the boundary. Beyond the spotted rock is a zone in which the slate is uncleaved.and somewhat resembles

a dark fine-grained limestone. Under the microscope this rock exhibits a network of minute crystals of biotite and chlorite, while the siliceous fraction of the rock shows partial recrystallisation. Actinolite may be present instead of biotite.

The spots in the spotted rock consist of crystals of cordierite, which often show sector-twinning, and may reach a diameter of 0.2 of an inch. The remainder of the rock contains small crystals of biotite, hornblende, and chlorite, together with the recrystallised quartz and felspar of the original sediment. Fibrous radiating sillimanite is occasionally present, but the rock is in the main a biotite-cordierite - hornfels.

(c) The Acidic Dykes.

1. Field Description.

Several different types of acidic dykes can be recognised in the field. They range from a dirty white fine-grained rock, which is often cleaved, to a massive grey one full of porphyritic crystals of quartz, felspar, biotite, or hornblende. The intrusions are usually sills a few feet thick and several hundred feet in length, but cross-cutting horizontal sheets (Plate 35) sometimes occur which, on the map, seem to cover a considerable area (Fig.5).

On reference to the general geological map it becomes evident that the acidic dykes are closely associated with the granite. The great majority occur along the strike of the rocks intruded by the granite; that is, in the Sheefry Grits and Cregganbaun Series between Cross Point and Knockaskeheen. On the shore at Cross Point only 3 dykes outcrop, but the numbers increase towards Lough Nahaltora, until in the region south of Cregganbaun there are acidic intrusions every few yards. In the metamorphic aureole innumerable acidic and granitic dykes seam the hornfels in every direction, and can often be traced back into the main mass of the granite.

South of Glenkeen there are fewer dykes, but they occur at intervals nearly as far south as Glencullin Lough and Clashcame. On the hill a few hundred yards north of Lough Cunnel is a large intrusion of a striking white rock, which reaches a thickness of more than 100 feet at one point. Under the microscope it is seen to be a strongly-sheared quartz-plagioclase rock.

Only one acidic dyke is known from the Mweelrea Grits and Glenummera Slates. This is a long intrusion of flow-banded, fine-grained felsite, with porphyritic quartz and felspar crystals, that cuts across the strike for more than a mile north of Gubnamona, west of Bundorragha. The material of this intrusion is similar in some ways to the Mweelrea tuffs, but it cannot have been a vent for the known tuff beds, as it intrudes strata above T.B.5.

2. Petrology.

The fine-grained acidic dykes have a micro crystalline quartz - felspar matrix. In the zone of the Maam flexure, where they are generally sheared, chlorite crystals are developed along the foliation planes. Some of these fine - grained dykes contain large porphyritic crystals of corroded quartz, which reach a diameter of 0.1 of an inch.

The porphyritic crystals in other dykes are usually plagioclase felspar, often zoned, but on occasion they consist of biotite or hornblende. The groundmass in such cases is composed of smaller laths and granules of biotite, felspar, hornblende, and quartz. Some of the dykes contain so much biotite or hornblende that they might be termed dioritic.

It is believed that the variation of the composition of these dykes is due to the varying degree of contamination of the granite magma by the country rock.

3. Age.

The acidic dykes can be traced back into the granite, from which they sprang. They are therefore of Caledonian age.

(d). The Hornblendic rocks (Appinites).

1. Field Description.

The dykes and sills of hornblendic rock, which may

properly be termed appinite, are closely associated in space with the acidic dykes, and are not found outside the area intruded by them. They are fewer in number than the acidic dykes, and it has been possible to enter nearly all of them on the general geological map. The two biggest dykes, each more than 100 feet thick, occur south of Killeen and south of Knockaskeheen. They are most plentiful near Cregganbaun, and are concentrated in the Silurian quartzite and conglomerate. The conglomerate especially is rarely seen without one or more appinite sills.

In the field the appinites appear to be composed largely of crystals of dark green hornblende set in a variable proportion of pink and white felspar. They are exceedingly hard rocks. However, gently sloping surfaces are often channeled, in a manner similar to the solution channeling of pavements of Carboniferous Limestone.

The intrusion north of Lough Alisheen is sheared, and has been partly converted into talc. Elsewhere, small veins of chrysotile asbestos are not uncommon. In the zone of the Maam Flexure the appinites are often sheared.

2. Petrology.

The appinites consist in the main of large euhedral crystals of hornblende, closely set in a matrix of crystalline sodic plagioclase. The hornblende is light green, and pleochroic, and is sometimes altering to chlorite.

The plagioclase is albite-oligoclase. Hornblende is usually dominant over felspar, and may make up 80% of the whole rock. In the intrusion of Cloghaun, light brown euhedral pyroxenes are present. Crystals of apatite and iron ore are scattered through the rock.

3. Age.

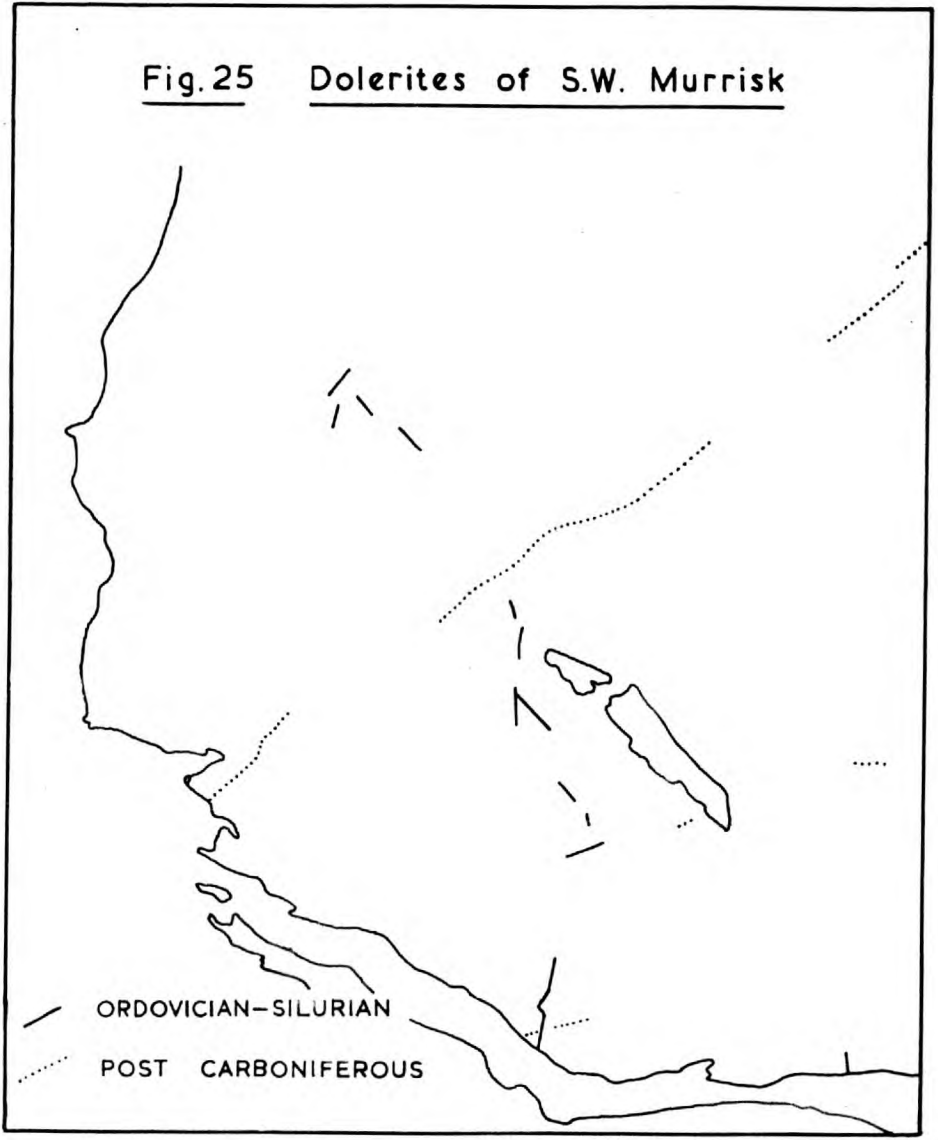
The appinites can be found to be intersected by acidic dykes at two places : near Cregganbaun, and south of Knockaskeheen. They were therefore intruded at a time before the intrusion of the granite was completed, but after the deposition of the Llandoverian sediments, into which they are intruded. They are associated in space (as far as can be seen in S.W. Murrisk) with the acidic dykes, which themselves are centred on the granite.

It is suggested that the appinites were intruded at an early stage in the emplacement of the granite, with which they were genetically connected.

(e) The Lamprophyres.

A number of lamprophyric dykes outcrop in the Sheefry Hills, and have not been met with elsewhere. The rock is purple and very hard, and weathers spheroidally to a pinkish-white colour. It is fairly coarsely crystalline, and the minerals present include reddish-brown biotite, and large

Fig. 25 Dolerites of S.W. Murrisk



idiomorphic crystals of apatite up to 0.1 of an inch long, set in a matrix of mutually-interfering quartz and orthoclase felspar. Small crystals of zoisite are generally present, and the rock locally contains much calcite. It is the only potash-rich rock in S.W. Murrisk.

No evidence concerning the age of the lamprophyres is available.

(f) The Dolerites.

A number of dolerite dykes have been mapped in S.W. Murrisk. Only the largest are entered on the general geological map, but Fig.25 illustrates the complete suite.

In the field the dolerites often outcrop at the bottom of a shallow gully, showing that they are easily weathered. They are black crystalline rocks.

There are 2 sets of dykes (Fig.25). The Palaeozoic dolerites are never quite fresh, and may be considerably altered. In 2 places, west of Lough Nahaltora, they are cut by acidic dykes of Caledonian age. Their texture is ophitic, and their average composition is :

Andesine - labradorite	60%
Clino - pyroxene (augite)	30%
Iron ore	10%

Oligoclase is occasionally present, and segregations of zeolites fill small amygdules. The rock is more or less altered to serpentine, chlorite, and clay minerals.

The post-Carboniferous dolerites are readily recognised in the field and under the microscope by their fresh, unaltered appearance. Mineralogically they differ from the earlier dolerites in containing up to 20% of fresh olivine.

One very large post - Carboniferous dolerite dyke is exposed at intervals right across S.W. Murrisk, from Uggool north-eastwards to Boheh. In the exposures it maintains a nearly constant thickness of 20 feet. On the map it appears to be faulted in the granite near Boheh, but it is not shattered at the fault plane, and the probability is that it was intruded in its present position. The Officers of the Geological Survey of Ireland, in their Memoir of 1876, assumed that this same dolerite was intrusive into the Carboniferous Limestone north-east of Westport. In thin section it closely resembles a Tertiary dolerite. The post - Carboniferous dolerites are undoubtedly the newest rocks in S.W. Murrisk.

Chapter Ten. THE STRUCTURE OF THE AREA.

(a) Introduction.

The geological structure of the individual formations has been described in detail in Chapters Four, Five, Six, and Eight. It only remains to summarise the structure of the district as a whole, to correlate it with the regional structure, and to give some idea of the succession of earth movements in this part of Connaught.

(b) Folding and Faulting.

In S.W. Murrisk a number of simple E. - W. folds are displaced in 2 zones of left-handed vertical shearing, which run N.W. - S.E. The more easterly of these shear zones finds expression as the Maam Faults in the competent Mweelrea Grits, and as the Maam Flexure in the less competent Sheefry Grits and the incompetent Glenummera Slates. The western (and larger) shear zone lies beneath lower Killary Harbour, and bounds the area on the S.W.

The competent Mweelrea Grits have been folded into a simple E. -W. syncline, with a zone of bedding-plane slip and drag-folding at their base, where they have over-ridden the Glenummera Slates. The Slates are exposed north and south of the Mweelrea syncline, so that their general structure must be synclinal, but, sandwiched between the Mweelrea Grits

(dipping south at 40°), and the Sheefry Grits (dipping south at 80°), they have suffered complex internal folding. The minor folds run more or less parallel to the regional trend.

The Sheefry Grits (bedded grits and slates) are grittiest and most competent in the Sheefry Hills, and there they are least folded. Elsewhere they lie in a series of roughly E. -W. folds, except in the Maam Flexure. Most of the folds pitch westwards at 10° - 30°, and are tight, but they are only isoclinal in the Maam Flexure. The flanks of the larger folds are themselves folded, giving the impression of extreme complication in the field.

The lower beds of the Sheefry Grits are exposed in the core of the Feenune - Corvock anticline, which is the largest in the formation. The strata young northwards from it until the great unconformity at the base of the Silurian formation is reached.

The Silurian Cregganbaun Series rests on the Sheefry Grits with no apparent angular discordancy. The rocks dip northwards at 50° - 60°, except where they are twisted round to the vertical in the limb of the vertical Maam Flexure.

The Maam Flexure and Faults, and the Killary Harbour Faults, are the expression of left-handed shearing in vertical planes running N.W. - S.E. There is evidence, especially in the small faults of the Mweelrea Grits, that the whole area was affected by shearing in the same direction.

This regional shearing stress alone may account for the swing in the Caledonian strike from its normal N.E. - S.W. direction, to an overall E. - W. one in S.W. Murrisk. A similar bending of the Caledonian strike is seen at several other localities on the N.W. coast of Ireland.

In the Mweelrea Grits the Maam Faults consist of 2 major vertical planes nearly parallel to one another, with several minor parallel faults, as well as others branching off at small angles. The grits on either side of the faults are almost undisturbed. As the zone is traced north-westwards into the Glenummera Slates, the small faults die out. The 2 major faults persist, albeit with a reduced throw due to the bending of the strata in the direction of movement. This flexure increases north-westwards at the expense of the faults, until, a short distance inside the Sheefry Grits, the faults die out altogether, to be replaced by the Maam Flexure. The bending of the incompetent strata has produced large left-handed drag folds, with vertical axes, on the Sheefry Hills (Fig.8).

The lower Killary Harbour Fault is not well exposed. At Dooneen it is evidently a double fault, for the island just south of Dooneen is composed of the Arenigian Roscoe Grits. The total horizontal throw on the fault must be in the region of 3 miles, as compared to the displacement of nearly 2 miles along the Maam Faults.

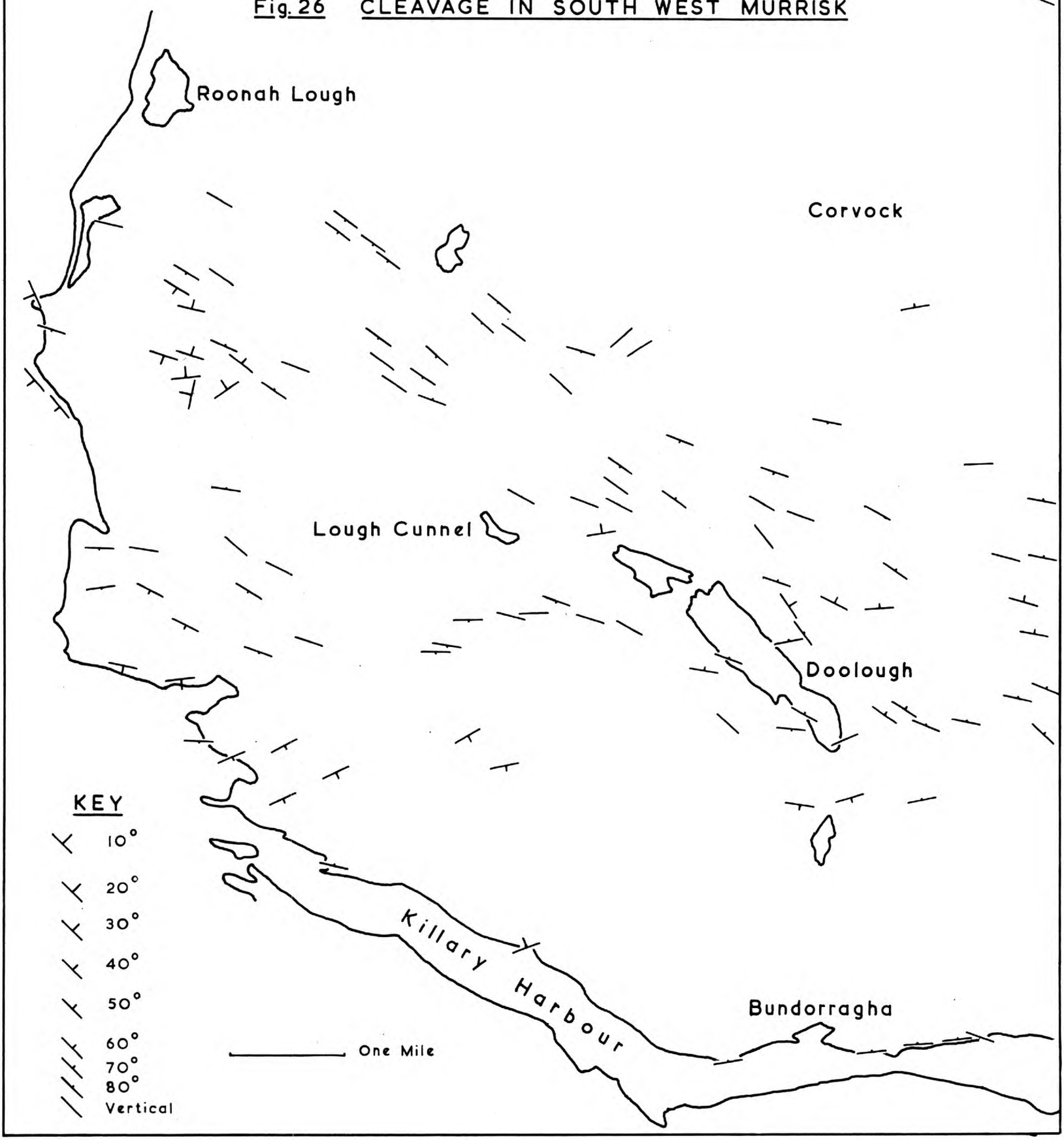
These 2 major fault zones are the most important in S.W. Murrisk. Almost all the other faults in the Mweelrea Grits are tear faults roughly parallel, or strike faults roughly at right angles, to them. The tear faults make an angle of about 70° with the axis of the Mweelrea syncline.

Faults are hard to detect in the Sheefry Grits, and where they can be seen they follow no set pattern. Most of them may be best described as "accommodation structures", which relieved local stresses set up during the folding. Thus, the limbs of folds may be sheared out, and hard tuff beds fractured in the process of adjustment to the more easily folded slates and grits.

The faults in the Mweelrea and Sheefry Grits are typically tight, and quartz is seldom developed on the fault planes. Evidently fracturing occurred under conditions of great stress. The N. - S. fault that cuts the granite differs from them in that it is a normal fault, with a downthrow of several hundred feet to the west, and a coating of quartz several feet thick on the fault plane. These indications of tension, and the fact that it is later than the granite, suggest that this fault is not connected with the others.

The present structure of S.W. Murrisk apparently results from a combination of pressure in the normal

Fig. 26 CLEAVAGE IN SOUTH WEST MURRISK



Caledonian direction with a regional left-handed shearing stress. The pressure resulted in a system of parallel folds, while the shearing stress found expression in 2 major tear faults, a large number of minor tear faults, and a swing of the regional strike into an east - west direction.

(c) Age of the earth - movements.

In S.W. Murrisk the Llandoverian and older strata are intensely folded, while further to the east the same strata pass beneath undisturbed Carboniferous Limestone. The main folding therefore occurred between the Middle Silurian and the Carboniferous. In E.Murrisk the strike adopts the normal Caledonian trend, and there can be no doubt that the folding was in fact Caledonian. Five miles north of Cregganbaun, on the southern shores of Clew Bay, a formation believed to be Old Red Sandstone is thrown into tight E. - W. folds. This would seem to indicate that folding continued well into the Devonian, but such a conclusion would be unreliable, as the structure of the Clew Bay region is not well known. It has been suggested (Bailey 1928) that the continuation of the North Highland Boundary Fault lies close to the southern shore of Clew Bay, and if this is the case the Old Red Sandstone might

well be contorted. On the north side of Clew Bay the Old Red Sandstone is relatively undisturbed.

Earth-movements must have occurred at other periods in or near S.W. Murrisk (Fig.27). The deposition of the Mweelrea Grits, following the tranquility of the Glenummera Slate sea, took place during an important uplift of the Connemara Schists area south of Killary Harbour, and a complementary subsidence in Murrisk. This movement took place during the Middle Ordovician. There is no evidence that it was anything but a simple crustal tilting (Fig.27c).

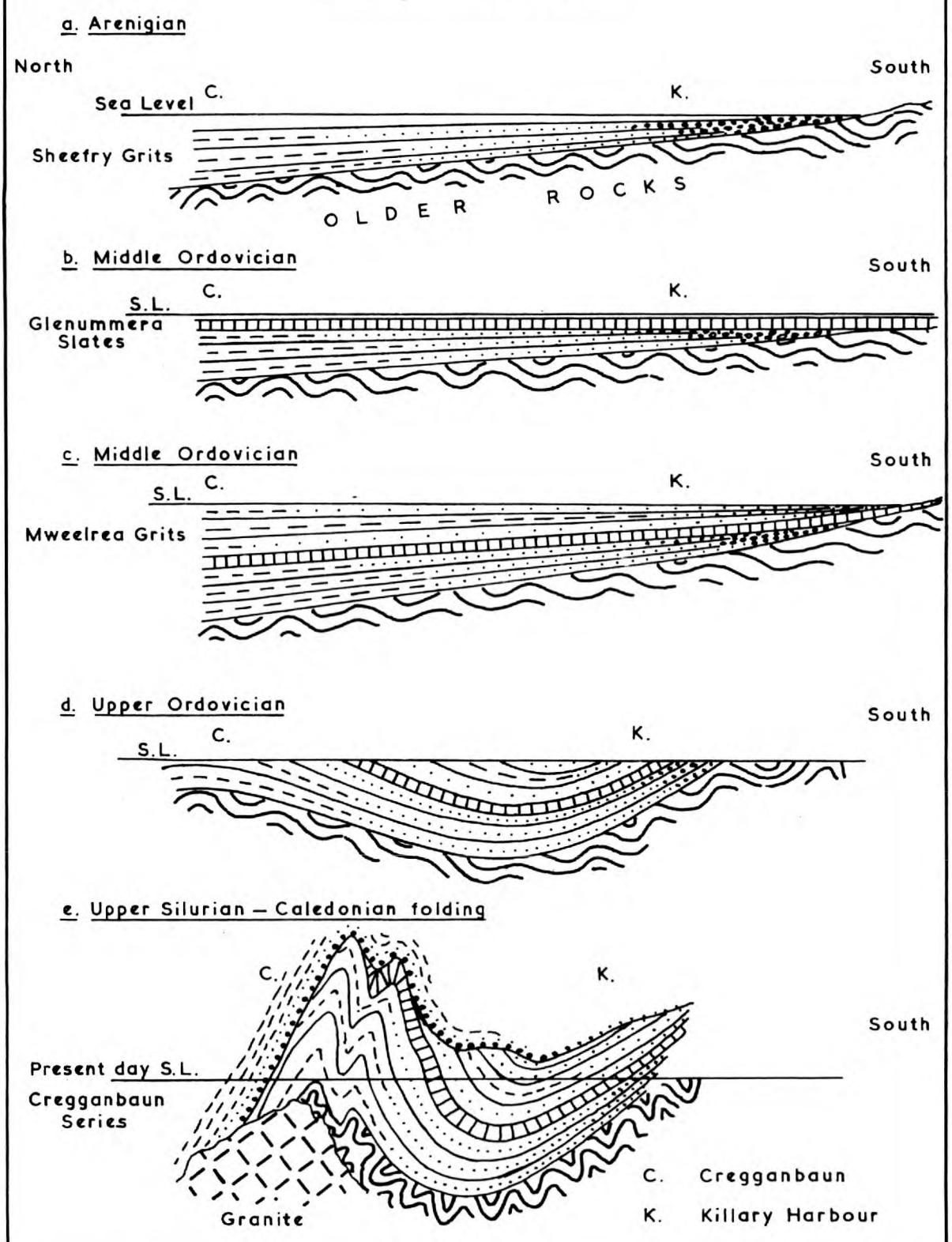
It is likely that the Arenigian strata were deposited during a similar episode. The tilting in this case was more intense, as the Sheefry Grits were laid down in deep water only 4 or 5 miles from the shore (Fig.27a).

After the deposition of the Mweelrea Grits a certain amount of folding must have occurred, for the Silurian unconformity is apparently transgressive over at least 11,000 feet of strata. At Cregganbaun the basal Silurian conglomerate rests on the Sheefry Grits 5,000 feet below the Glenummera Slates; and it is not exposed on the topmost strata of the Mweelrea Grits, 6,000 feet above the Slates, and only 4 miles south of Cregganbaun. Such a result can only have been achieved through a considerable uplift on the north during the Upper Ordovician. Since there seems to be no angular discrepancy between the Sheefry Grits and the

Silurian rocks at Cregganbaun, it appears that a certain amount of gentle folding was associated with this uplift (Fig.27d).

Fig. 27 HYPOTHETICAL SECTIONS (TRUE SCALE)

ACROSS S.W. MURRISK



Chapter Eleven. PALAEONTOLOGY.

This brief chapter deals with the fossils that were discovered during 1951 and 1952. An extensive faunal examination was not attempted, since such an examination must await a more detailed knowledge of the Lower Palaeozoic geology of Connaught. No large collections were made, except from Locality 1. The more important fossil localities are enumerated in Appendix A.

The fauna of the oldest strata is described first :

Sheefry Grits.

Locality 1.

This locality is in the lower strata of the Sheefry Grits, about 5,000 feet below the Glenummera Slates. The rock is a dark silty slate, which has been strongly sheared due to its position in the limb of the Maam Flexure. No fossils other than graptolites were found.

Dr. O.M.B.Bulman, who kindly examined the graptolites, identified the following species :

Trigonograptus ensiformis.
Cryptograptus c.f. *hopkinsoni*
Glossograptus c.f. *acanthus* (abundant)
Dichograptid stipes (very abundant)

Certain other graptolite species, insufficiently well preserved for identification, were found. Dr. Bulman states that the faunal assemblage is in no way unlike that of the zone of Didymograptus extensus.

A small number of graptolites were collected from a band of silt on the south shoulder of Clashcame. They were too badly preserved for identification. The graptolite-bearing beds on the shores of Doolough (M.G.S.I. 1876; Carruthers and Muff 1909) could not be discovered.

Glenummera Slates.

Locality 2.

Locality 2 is in grey cleaved slates, sheared by the movement on the West Maam Fault, a few yards away. The fossils are abundant, gastropods being exceptionally numerous, but they are generally badly preserved and difficult to extract due to the cleavage in the slate. They represent a normal shelly fauna.

Graptolites:

One Diplograptid.

Trilobites:

Phacops ? bissetti

Asaphid pygidia, c.f. Ogygiocaris corndensis.

Ostracods:

Several spp. c.f. Aparchites canadensis.

Brachiopods:

Lingula sp.

Strophomenids.

Orthids.

Lamellibranchs:

Several spp.

Gastropods:

Ecculiomphalus ? bucklandi.

Lophospira sp.

Orthoceratids:

Several spp.

Ecculiomphalus is very common, and closely resembles the genotype of E. bucklandi, except that the external ribbed ornament is rather coarser.

Locality 3.

It is remarkable that only one species, a small trilobite, was found in the grey cleaved slates at Locality 3, and that 54 specimens of this one species were collected.

The trilobites are moderately well preserved as calcite, and occur in nodular calcite segregations in the slates. They resemble Nileus armadillo Dalman in every observable respect,

except that Nileus is believed (Lake 1906 - 1946) to possess 8 thoracic segments, whereas the number of thoracic segments in the 23 complete specimens from Murrisk is 7. Lake (1906-46). in discussing the number of thoracic segments in Nileus and Platypeltis, points out that very few complete specimens of either genus have been discovered, and that other authors have described Platypeltis with either 7 or 8 segments. He writes (p.310) "it is unsafe to assume that it (the number of thoracic segments in Nileus) is always 8."

At other localities in the Glenummera Slates, poorly preserved brachiopods, lamellibranchs, ostracods, and orthoceratids, were found.

Mweelrea Grits.

Localities 4, 5. (Second Slate).

The Second Slate is the most fossiliferous of the 3 slate bands in the Mweelrea Grits. The rock is greenish-grey and cleaved, though not to such an extent as the Glenummera Slates. Fossils are exceptionally abundant at Locality 5.

Trilobites:

Pygidia and fragmentary cephala of Asaphids.

Brachiopods:

Orthids (well preserved moulds at Locality 4).

Gastropods:

? Sinuopea sp.

Lophospira sp.

Orthoceratids:

Two spp.

Corals:

? Favosites sp.

Fossils occur at many places in the Second Slate, but they are most prolific in localities 4 and 5. In the First and Third Slates they are less common, but the faunas appear to show no significant differences from that of the Second Slate.

Cregganbaun Series.

Locality 6. (Cregganbaun Slates).

At Locality 6, fossils are exceedingly abundant in brown leached calcareous slates. The organic remains were originally preserved as calcite, but now only the moulds remain. Tabulate corals are especially common.

Trilobites:

Encrinurus (2 spp.)

Brachiopods:

Leptaena sp.
Strophomenids.

Corals:

Heliolites sp.

Favosites spp.

Halysites catenularia.

Porpites porpita.

Rhabdocyclus sp.

"Cyathophyllids".

Similar fossils can be found at many localities in the Cregganbaun Slates, but not in such abundance.

Chapter Twelve. THE GEOLOGICAL HISTORY OF S.W.MURRISK.

The oldest known strata of S.W.Murrisk are of Middle Arenigian age. The nature of the foundation that underlies these rocks is unknown. No proved Cambrian strata have yet been found in Connaught, but the Connemara Schists are known to be of Pre-Cambrian age (Wager and Andrew 1930). The Middle Arenigian conglomerates of Mount Partry, near Tourmakeady, contain abundant pebbles of "grit" (Gardiner and Reynolds 1909), and it therefore appears that unmetamorphosed sedimentary rocks were present in Connaught at the end of the Lower Arenigian.

The Middle Arenigian period, the first of which we have any definite knowledge in Murrisk, saw the area completely covered by water, which supported graptolites, brachiopods, and cephalopods. This sea was deep enough to allow the formation of graded beds of silt and fine-grained grit. The predominant sediments were clay and silt, but occasionally a submarine slump or landslip initiated a turbidity current that carried coarser-grained material into the area. The sources of sediments probably lay to the east and south.

Near Lough Nafooey, 10 miles away to the east (for this was before the formation of the Maam and Killary Harbour Faults) there was great volcanic activity, and deposits of spilitic pillow lavas were being formed. It is probable

that some of the lower Sheefry tuff beds belong to the Middle Arenigian, but these products of nuées ardentes are rhyolitic rather than spilitic in composition.

The shoreline lay near Tourmakeady, where there are thick beds of conglomerate. No other evidence of the position of the Middle Arenigian shoreline in West Connaught has yet been discovered. Graptolitic cherts, limestones, and "felsites" of Middle Arenigian age have been reported from Bencraff, 2 miles south of Bundorragha (Theokritoff 1950) and it would appear that this area was some way from land.

The beginning of the Upper Arenigian was marked by the commencement of an important tilting of S.W.Murrisk, in which the northern area subsided and the southern area was uplifted. The shoreline lay roughly north-east and south-west, a short distance south of Killary Harbour. The tilting was a pronounced one, since the sea was deep (probably more than 1,000 feet) at a distance of only 4 or 5 miles from the shore.

A great quantity of sediment was transported into the area from the south. Gravel and pebbles accumulated near the shore, and subsequently consolidated into the Grits of Leenane, Rosroe, and Rinavore. The grain size of the deposits rapidly decreased northwards, and the depth of the water increased. The sea floor sloped northwards at more

than 3 degrees, an unusually steep angle. As a result, the sediments were unstable, and large-scale slumping frequently occurred. The slumping initiated turbidity currents, which transported the material further northwards into the deeper water, where it settled onto the sea bed and produced the graded strata of the Upper Sheefry Grits.

Upper Arenigian vulcanicity was limited, so far as is known, to intermittent outpourings of enormous quantities of tuff as nuées ardentes. These "burning clouds" swept far out over the sea in a northerly direction, and the tuffaceous particles accumulated on the sea floor in thick graded beds. Occasionally less violent eruptions deposited thin layers of dust tuff.

Towards the end of the Arenigian the tilting ceased, and erosion lowered the mountains on the south. The sea, which already covered S.W. Murrisk, transgressed southwards until only the finest sediments (clays and silts) reached the area. Subsequently they consolidated to form the Glenummera Slates. The water was probably shallower than in the preceding period, since a shelly fauna replaced the graptolitic one.

Evidence of occasional vulcanicity is afforded by the 3 tuff beds of the Glenummera Slates. Of these, the one near Bundorragha is graded, and was probably derived from a nuée ardente. The coarse sediments, small lenses of which

are sometimes present, may have reached the area in turbidity currents from the south.

The comparative tranquility of the Glenummera Slate sea was brought to an end by a further tilting, similar to that which occurred in Upper Arenigian times. This second tilting resulted in the formation of the Mweelrea Grits. The Connemara Schists on the south were uplifted, and a complementary subsidence took place in S.W.Murrisk. The subsidence was less pronounced than before, as the supply of sediment more than kept pace with the sinking of the sea floor, so that the water was always very shallow. At this time, the mean position of the shoreline probably lay between a point a few miles south of Booneen, and a point near Tourmakeady. Allowing for the subsequent displacement along the Maam and Killary Harbour faults, this direction was nearly N.E. - S.W.

A number of streams brought coarse sediments down to the sea and the material was evenly distributed along the coast. The attitude of the current-bedding suggests that there was a prevailing long-shore current from the north-east.

At three stages in the deposition of the Mweelrea Grits a sudden increase in the rate of subsidence caused a recession of the shoreline, and slates were deposited in rather deeper water. However, it was not long before the deeper

water silted up, and coarse sediments were once more laid down. Four or five miles from the shore, the stratigraphical column of the Mweelrea Grits contains nearly equal thicknesses of grits and slates. A few miles further north, the proportion of grit must have been negligible.

On 5 occasions during the deposition of the Mweelrea Grits, S.W. Murrisk was overwhelmed by nuees ardentes, composed of incandescent tuffaceous material. These enormous "burning clouds", or "glowing avalanches", swept northwards over the sea (which was only a few feet deep) and aggraded the sea floor until it was 20 to 70 feet above water level. The material of the nuees ardentes was so hot that, on settling, the tuffaceous particles became welded together, and immediately formed a coherent rock. The lowest part of the tuff bed was not welded, as the particles were cooled on entering the water.

The upper surface of the tuff bed was subjected to subaerial erosion, until the continuous regional subsidence caused the sea to transgress over the area once again. The erosion was less pronounced in the north and north-west of the Mweelrea Grit outcrop, since there the sea was rather deeper. Near Doogahtry the water was so deep during the deposition of T.B.2 that this bed of tuff was not welded at all. However, the bed is not graded, so the sea must have been much shallower than it was during the laying down of the

Sheefry tuff beds.

The deposition of the Mweelrea Grits ceased at some time in the Middle or Upper Ordovician, when earth movements resulted in gentle folding and a regional uplift, which was greatest in the north. There followed a prolonged period of erosion, that continued into the early Silurian. At this stage the topography of S.W.Murrisk approached that of a peneplain.

During the Llandoverian, S.W.Murrisk was once more submerged beneath a shallow sea, which received sediments from the north. The sea transgressed northwards, and a diachronous conglomerate was deposited in the migrating littoral zone. The materials of a quartzite were laid down above the conglomerate, and later, as the shoreline retreated northwards from Murrisk, only silt and mud reached the area. The conglomerate, quartzite, and silty slates together form the Cregganbaun Series. There was no vulcanicity during this episode. Corals, brachiopods, and trilobites abounded in the sea.

Late in the Silurian, and during the early part at least of the Devonian, the sedimentary rocks of S.W.Murrisk were tightly folded by the earth-pressures of the Caledonian orogeny. Due to the left-handed stress which affected the area, (Chapter Ten) the general trend of the folds was east - west instead of the normal Caledonian direction of

N.E. - S.W. It is interesting to note that this shearing stress was not effective before the late Silurian, since the shorelines of Arenigian and Middle Ordovician times were parallel to the Caledonian trend.

At some stage late in the folding, a granite body with associated acidic and appinitic dykes was intruded by stoping into the core of the Feenune - Corvock anticline, which contains the oldest strata exposed in S.W.Murrisk.

It is probable that erosion had levelled the Caledonian mountains of Connaught by the end of the Devonian period. Flat-lying Old Red Sandstone rests on the present 2,600 foot peneplain 4 miles east of Leenane, (Bishopp 1950) and it is not impossible that this peneplain, which determines the summit levels of most of the present-day mountains of West Connaught, is of Devonian age.

The whole of West Connaught was, in all probability, covered by Carboniferous rocks. However, some uplift and erosion must have taken place early in the Carboniferous, since a shallow valley between the hills in East Murrisk is filled with Carboniferous deposits.

Nothing is known of events in Murrisk between the Carboniferous and Pleistocene periods. If the area was covered by Mesozoic and later rocks they have all been eroded away. During the Glacial Period the ice moved radially outwards from the mountains of Connemara, weaving deep

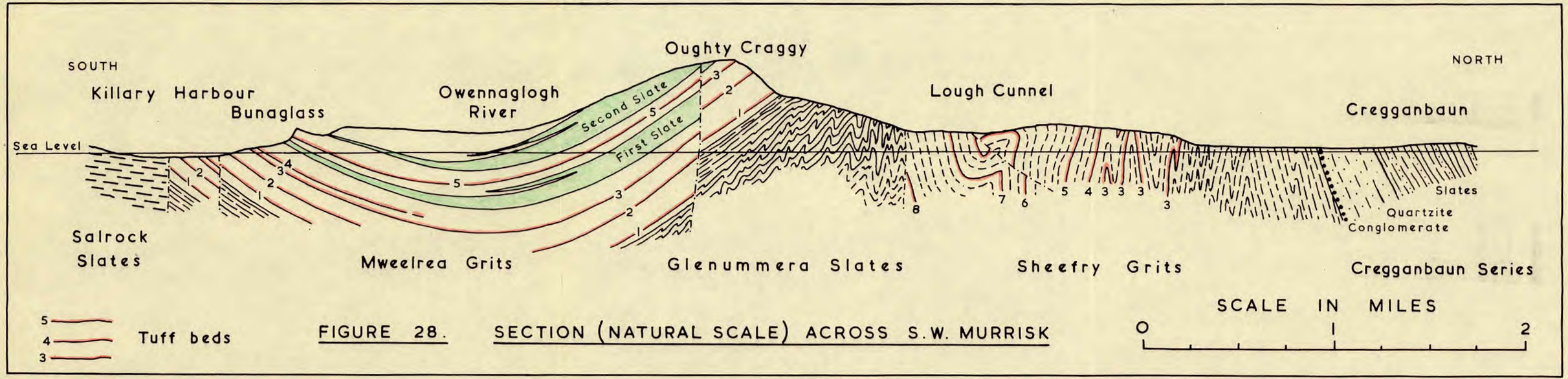


FIGURE 28. SECTION (NATURAL SCALE) ACROSS S.W. MURRISK

valleys in bands of slate (the Glenummera valley, middle Killary Harbour) and in fault zones (Doolough, lower Killary Harbour). Frost weathering, and coast and river erosion, are active at the present day.

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Appendix A. Positions of Fossil Localities.

The descriptions refer to the six-inch maps of the Ordnance Survey of Ireland, and for the purpose the edges of the sheets are assumed to run N - S and E - W.

Locality 1. Sheefry Grits.

About 0.4 of a mile S.W. of Lough Mahaltora.

2,255 feet at 213° from B.M. 221.4 on the Killeen - Cregganbaun road.

A very small stream flows northwards, and crosses a lane at a point 450 feet N.W. of the townland boundary. 275 feet upstream of the lane there is a basalt dyke. Graptolites can be found in dark sheared slates a yard north of the dyke, for a few feet on either side of the stream.

Locality 2. Glennammera Slates.

At water level on the north shore of Killary Harbour, 1.5 miles east of Bundorragha.

A small stream flows under the coast road 450 feet west of B.M. 51·6. The stream follows the western Maam Fault. Fossils are abundant in grey slates 50 to 100 feet west of the point where the stream enters Killary Harbour.

Locality 3. Glenummera Shales.

At water level on the north shore of Killary Harbour, about 0·8 of a mile W.S.W. of Bunadorragha.

The fossils are preserved in hard flinty nodules up to an inch in diameter, that weather out of the grey slates on the coast between Gubnamona and Pollnagower. Only about half the nodules contain fossils.

Locality 4. Mweelrea Grits, Second Slate.

On the hillside near Funshoge, close to the north shore of Killary Harbour.

In a band of green slate, 400 feet east of B.M. 202.9, which is 200 yards N.W. of the ruined house at Funshoge.

Locality 5. Mweelrea Grits, Second Slate.

In the small north-facing cliff known as Uggool Rock, 250 feet north of B.M. 36·1 at Uggool.

Locality 6. Cregganbaun Slates.

About 0.5 of a mile W.S.W. of Cregganbaun Post Office.

1,100 feet at 133° from Srahwee Bridge, where the Killeen - Cregganbaun road crosses the Carrownisky River.

A track (not marked on the six-inch map) leads eastwards from the nearby group of cottages. Fossils are extremely abundant in two small quarries on the south side of the track.

Appendix B. Positions of Type Exposures.

The descriptions are based on the six-inch maps of the Ordnance Survey of Ireland.

Sheefry Grits.

This formation is especially well exposed along the coast between Bunlough Point and Legha More, and on the north and east shores of Doolough.

Sheefry Tuffs.

T.B.7, the largest of the Sheefry tuff beds, is completely exposed in cross section on the coast at Legha More. The two outcrops beside the road on the east shore of Doolough are faulted, but the essential features are clear. T.B.'s 3 and 4 outcrop at several points beside the road to Cregganbaun, north of Glencullin Lough.

Glenummera Slates.

The Slates are very well exposed at several places, but the most accessible outcrops are on the north shore of Killary Harbour, east of Bundorragha. The graded tuff bed is exposed on the coast near Gubgar.

Mweelrea Grits.

The Mweelrea Grits are well exposed at many places. The most readily accessible outcrops occur beside the road east of Bundorragha, and by walking 0.3 of a mile up the

stream called Sruhaungarve, the pebbles in a 20-foot thick conglomerate band can be examined. Other accessible localities are on the west side of the river between Doolough and Fin Lough, and at the picturesque beach called Trawleck-ackoolia. The First Slate outcrops beside the road just north of Fin Lough.

Mweelrea Tuffs.

Exposures of T.B.'s 1, 2, and 3 are conveniently accessible at many places near Bundorragha, where they consist of normal welded tuff. The same tuff beds are better exposed south of Uggool, where their upper and lower boundaries can be seen.

Incomparably the best exposures of T.B.'s 1, 2, and 3 on the north of the syncline occur in the cliffs north-east of Oughty Craggy, but they are relatively inaccessible. The same tuff beds are well seen on the hillside west of the river between Doolough and Fin Lough, S.W. of Doolough.

On the low ground S.E. of Trawleckackoolia there are outcrops of the incompletely welded T.B.1 and the unwelded T.B.2.

Cregganbaun Series.

The Cregganbaun conglomerate is exceptionally well exposed in a small cliff 100 yards east of Derrygarvebeg Lough. It also outcrops beside the road near B.M.204.2, south of Cregganbaun.

The quartzite is seldom well exposed, but by following the lane southwards from Srahwee Bridge into Cregganawoddy townland a large glaciated pavement of quartzite can be reached. The Cregganbaun slates outcrop in many places around Cregganbaun village.

Intrusive Rocks.

A track runs alongside the Bunowen River north of Corvock, and the main mass of the granite can be reached from it. There is a small exposure of granite beside the road at Cregganbaun School.

The acidic dykes outcrop at very many places around Cregganbaun.

There is a typical exposure of appinite at the roadside near spot height 193, between Cregganbaun and Glenkeen Bridge.

The lamprophyre dykes are only exposed high on the Sheefry Hills, an hours walk from the nearest road.

The 80-foot thick dolerite dyke outcrops in many places south of Trawleckackoolia.

THE GEOLOGY OF S.W. MURRISK

EXPLANATION

INTRUSIVE ROCKS

- Granite
- Acidic Dykes
- Hornblendic Dykes
- Lamprophyres
- Dolerites

SEDIMENTARY ROCKS

LLANDOVERIAN

Cregganbaun Series — Slate; Quartzite; Conglomerate

UNCONFORMITY

MIDDLE ORDOVICIAN

Mweelrea Grit — Conglomerates; 3rd Slate; 2nd Slate; 1st Slate; T.B. 5; T.B. 4; T.B. 3; T.B. 2; T.B. 1

Glenummera Slate — T.B. 1; T.B. 8

Sheefry Grit — T.B. 7; T.B. 6; T.B. 5; T.B. 4; T.B. 3; T.B. 2; T.B. 1

ARENIGIAN

- 45 Direction of younging, with dip in degrees
- \+ Horizontal strata
- Vertical strata
- Faults

SCALE IN MILES

0 1 2 3 4 5

TRUE NORTH

ROONAH LOUGH
CARROWNISKY RIVER
BOG
KILLEEN
Cloghaun
Cross Point
CROSS LOUGH
LOUGH NAMUCKA
BUNOWEN RIVER
BOHEH
Knockaskeheen
LOUGH NAHALTORA
CREGGANBAUN
Corvock
Bunlough Point
Barnabaun Point
DRIFT
Legha more
Six Noggins
Doogan Hill
GLENKEEN
CARROWNISKY
D. R I F T
OWENNADORNAUN RIVER
LOUGH CUNNEL
CORRAGAUN LOUGH
GLENCULLIN LOUGH
LOUGH ALISHEEN
LOUGH BRAWN
Tievummera
Clashcame
DOOLOUGH LAKE
DOOAGHTY
Trawleckackoolia
Oughty Craggy
GLENUMMERA RIVER
Ben Lugmore
Mweelrea
Ben Creggan
JUGGOOL
Dooneen
FIN LOUGH
Carricklea
Funshoge Hill
OWENAGLOGH RIVER
Ben Gorm
Funshoge
ROSROE
Bunaglass
Bundorragha Hill
BUNDORRAGHA RIVER
SALROCK
KILLARY HARBOUR
Gubnamona
Gubgar
Cooneen
LEENANE