THE DALRADIAN STRATIGRAPHY AND STRUCTURE OF SOUTHERN ISLAY, ARGYLL.

B Y

A H M E D   N A S I R   B A S A H E L

A thesis submitted in accordance with the requirements of the University of Liverpool for the Degree of Doctor of Philosophy

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SECTION 1

INTRODUCTION

Introduction

1.1 Location: The Island of Islay is situated on the south coast of Scotland, and forms part of the County of Argyllshire. It occupies an area of about three hundred and eighty four square K.M. and is of great scenic beauty.

1.2 Geographology: On a geographical basis Islay is divided into two distinct areas which are separated by Loch Indaal and Loch Gruinart. The western area known, as the Rhinns of Islay, extends as a peninsula from Ardmore point in the north to Rhinns point in the south. The land rises gradually inland the highest point being Beinn Tart a' Mhill, at 735 feet above sea level.

The second area of the island extends from Rhuvaal point in a south-south easterly direction, to the Mull of Oa and is bounded on the east by the Sound of Islay and on the south by the Atlantic Ocean. The maximum, elevation, of 1500 feet above sea level, is found in two places Beinn Bheigeir along the Sound of Islay and Beinn Bhann about 2.5 miles to the west of Beinn Bheigeir. The elevation decreases gradually in the southern region along a line going from the Sound of Islay to Port Eilen (50 feet) passing through Beinn Bheigeir (1500 feet) and Beinn Uraraidh (1490 feet) it rises again in the Oa at Beinn Mhoor (600 feet).

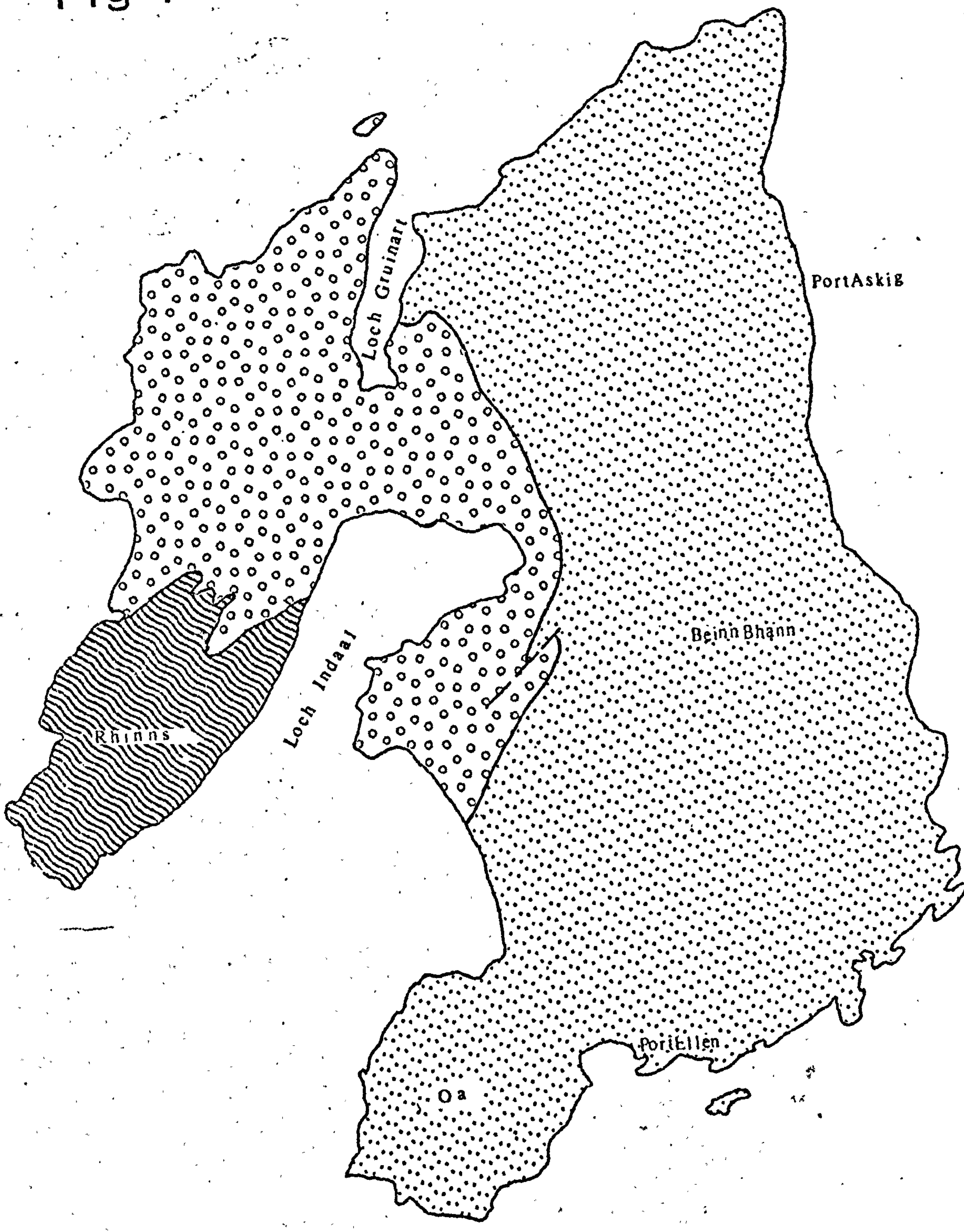
The above-mentioned area forms the water shed of the southern part of Islay. The many streams running down the slopes feed the rivers to the west and south-west. These rivers, and their tributaries, are of great importance in the geological study for they cut through the rock, exposing good cross sections particularly in the south and south-west of the island. The longest of these rivers are: The Laggan and its tributary, the Kilennan, the Duich, the Torra and the Machrie; the latter flows out from Loch Uigeadail and Loch Leathann on Sgorra.

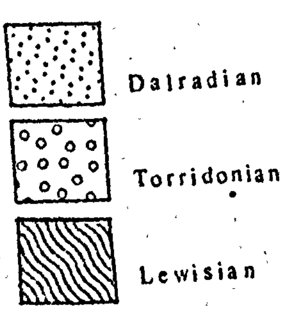
1.3 Terrain: The terrain in the northern part of Islay consists usually of alluvial land, where as in the south-west peaty area, together with smaller pockets of agricultural land are found. To the west, the slopes of Beinn Bhann area, boggy and have been recently drained by the Forestry Commission and planted with trees, in Kildalton the forest covers the southern-most part of the Island.

1.4 Geology of Islay:

General setting: The island of Islay may be divided into two portions, the Rhinns (western area) and the eastern area. The western area comprises the whole of the portion of the island known as the Rhinns of Islay together with the belt west of Loch Skerrol's thrust lying round the head of Loch Indaal. It is separated geologically from the eastern area by the Skerrol's Thrust, which follows a sinuous southwards course from Banan Uillt, on the east shore of Loch Gruinart, it crosses Loch Skerrol's, and then passes to the east of Bridgend by Tallent farm, which it is folded and faulted by a normal fault. Beyond this point its course is concealed under superficial deposits, but probably continuous to the shore of Laggan Bay (fig 1).

Fig 1





Geological map of Islay Showing the position of the formations

The western area is entirely occupied by rocks of pre-cambrian age, the Lewsian Gneises occupy the western portion of the Rhinns, which lies south of Kilchearen bay and Bruichladdich. The rocks consist of acid and basic gneises of probably igneous origin. The Torridonian Conglomerate, slate and grits from the northern and largest portion of the western part.

The whole of the eastern section of Islay is composed of metamorphosed Dalradian rocks. These consist essentially, of pre-cambrian metasediments, namely quartzike, limestone, slates and phyllite and showing varying degrees of metamorphism. The Dalradian rocks of Islay tectonically overlies Moinian Quartzite (Bowmore Sandstone) (fig 1).

Previous Work

As far back as 1790 Mr. Abraham Mills recognized the intrusive character and basaltic nature of the Dolerite dykes of Islay. He also refers to the high level beaches, and considers them to indicate a recession of the sea.

MacCulloch (1809), as a result of an examination of the western islands, refers to the conglomerate of Portaskai on Lossit Hill as a primary conglomerate, correlating it with the Garvellach Isle Conglomerate and on the Schichallion Conglomerate. He also pointed out that, in addition it contains pebbles of granite, foreign to the island, and it also contains fragments of the limestone upon which it lies. MacCulloch correlated the dark limestone of Islay and Lismore.

J. Nicoll (1844) confirmed the observation of MacCullach as to the content and position of the conglomerates of Portaskaig (Boulder Beds) and Lossit Hill.

Murchison and Geikie (1861) make the following references to the geology of Islay.

The grits and schists (Torridonian) of the north west part of the island are regarded as equivalents of the lower quartzite rock (Cambrian) of Southernland. The Islay limestones refer to the horizon of the Assynt Limestone, and the overlying quartzite to that of the "upper quartzite" of west southern land. They further pointed out that the Islay limestone extends north-east through the Garvellach Isles to Lismore and Shuna, and that the overlying quartzite and "upper sediments, as a series", after traversing Jura and Scarba, reappear to the north of Oban.

Thomson (1875) has suggested that the Mull of Oa, Port Ellen and Kildalton rocks belong to the Silurian period, the Islay quartzite to the Upper Cambrian, and the rocks of north and north-west Islay to the Lower Cambrian. He also noted the occurence of a breccia conglomerate on either side of the central belt of the quartzite, but regarded that on the east as the base of an overlying schists series. He further recognized the granite fragments of the Portaskaig Conglomerate (Boulder Beds) as foreign to the island and attributes their presence to glacial transport.

At the beginning of this century the officers of the Geological Survey of Scotland covered Islay on sheet 27

(Rhinns and north Islay) Sheet 19 (Bowmore, Kildalton and the Oa) and Sheet 20 (The south-east part of Kildalton). The report can be found in the Geological Survey Memoirs by Wilkinson (1907). The area was mapped by Wilkinson and Peach, but no consistent structural pattern emerged. They succeeded in establishing for the first time a stratigraphical sequence in Islay. Their interpretation is as follows:-

They regard the Dolomitic Group as the latest member of the succession. The Moal an Fhithich Quartzite is considered to be a downfaulted portion of the main quartzite (Islay Quartzite). The phyllite and the limestone of Central Islay correlated with Port Ellen Phyllite, and Jura Slates are explained as an upfold of the Port Ellen Phyllite. The Portaskaig Boulder Bed is the equivalent of the Scarba Conglomerate Group. Also they interbent the structures as a syncline with the Islay Quartzite in its core.

In (1916) Bailey introduced his theory of "the Islay Anticline" and the stratigraphical section was established (table 1). The anticline pitching north-east ward, with a core of Moal an Fhithich Quartzite (fig 3b) and Mull of Oa Phyllite, flanked by successively higher members of the sequence, upto the main quartzite (Islay Quartzite) to the north and up to the still higher Ardmore and Laphroaig Quartzite in the south.

Green (1924) contradicted Bailey's theory and suggested a synclinal structure with a complicated isoclinal folding (fig 3c). He correlated the Portaskaig Conglomerate with the Bowmore Sandstone (Torridonian). He converted Bailey's

ailey and Allison 1916) (1933)	Gregory (1927)
dmore & Laphroaig Quartzite	Bonahaven Quartzite
rt Ellen Phyllite	Dolomitic bed of North Islay
arba Conglomerate	Lower Quartzite of North Islay
ra Slate	Moal an Fhithich Quartzite
in Quartzite	Portaskaig Conglomerate & Bowmore Grits
lomitic Group of North Islay	Mull of Oa Phyllite
wer fine-grained Quartzite	Jura Quartzite
rtaskaig Boulder Bed	Jura Slate
lay Limestone	Port Ellen Phyllite
ll of Oa Phyllite	Laphroaig Quartzite
al an Fhithich Quartzite	Schistoze Grits of North Western Islay

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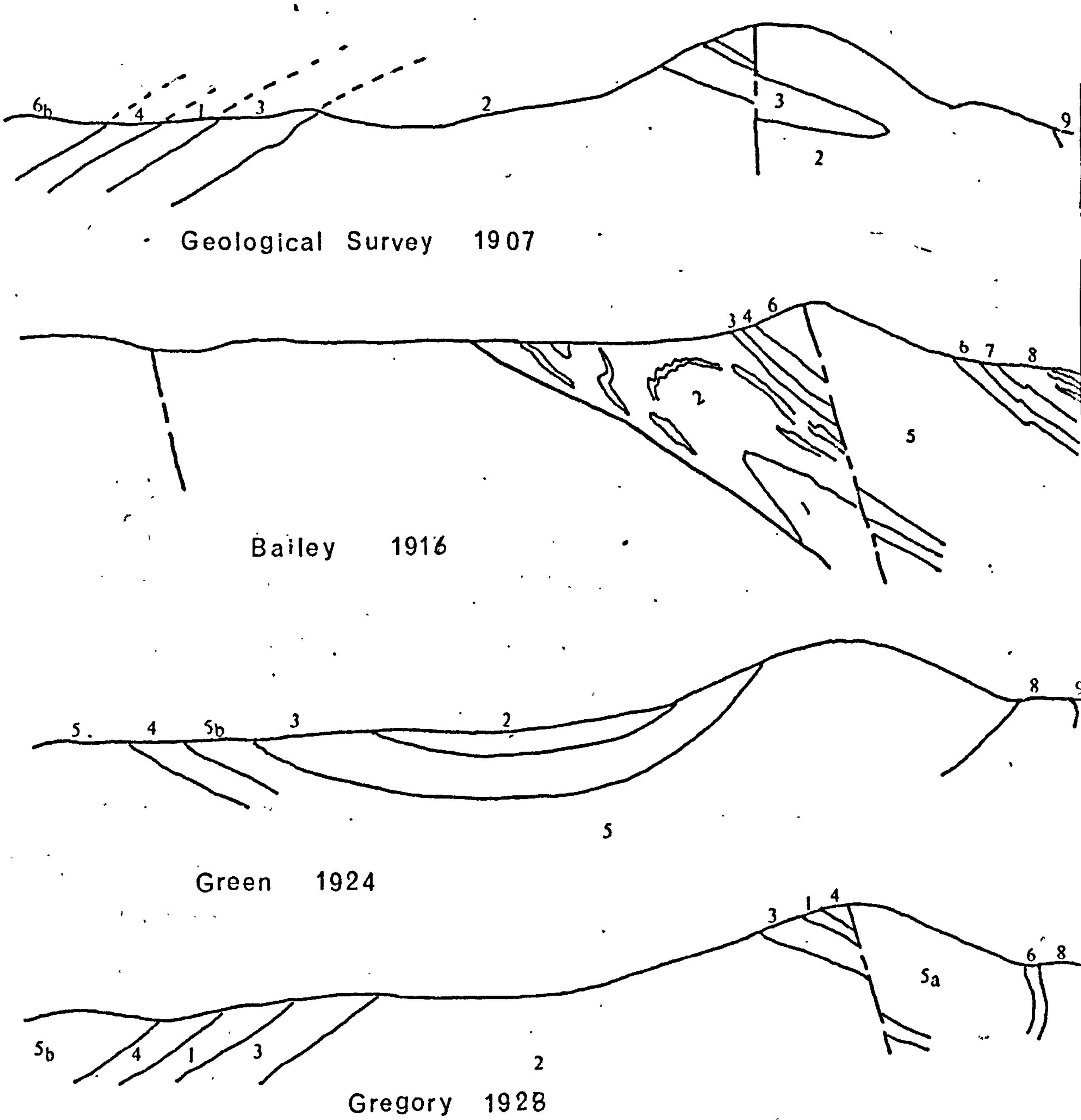
sequence and introduced a large unconformity below the Portaskaig Conglomerate in its new position. His views were based partly on the fact that the Portaskaig Conglomerate contains numerous fragments of dolomite but none are of the Islay Limestone type, and partly on the significance of Nordmarkite pebbles in several members of the sequence.

Gregory (1928) accepted most of Bailey's interpretation of the structure and sequence of that part of Islay which lies between the Loch Skerrol's thrust and the Beinn Bhann Fault. He rejected the Moal an Fhithich Quartzite as an independent formation, but regarded it as a down-faulted outline of the lower Quartzite, and in this followed (Wilkinson et al.). He refers to the succession east of the Beinn Bhann Fault (thrust) as the main quartzite (Islay Quartzite). This is distinct from the main quartzite of north Islay, in that it is older than the Mull of Oa Phyllite and it is followed east ward by an inverted outcrop of still older formations, Jura Slate, Port Ellen Phyllite etc. (fig 3d).

Elles and Tilley (1930) accepted the succession of Bailey and agreed with him that the structure of Islay is anticlinal. They, however, separated the Moal an Fhithich Quartzite from the Mull of Oa Phyllite by the alleged continuation of the Loch Skerrols Thrust.

Peach and Horne (1930) also accepted the greater part of Bailey's theory of the structure of the islands. Peach still held, however, that the Jura Slates were an upfold of the Port Ellen Phyllite, and that the Scarba Conglomeratic Group in downfold of the Laphroaig Quartzite.

Fig 3



Sections across Islay by the above authors

9 Laphroaig Qtz.
8 Portellen Phyllite
7 Scarba Conglomerate
6 Jura Slate
5 { Northern Islay Qtz. 5_b } Islay Qtz.
  { East Beinn Bhann Qtz. 5_a }
4 Dolomitic group
3 Portaskaig Boulder Bed
2 Islay Limestone & Mull of Phyllite
1 Moal an Fhithich Qtz,

The Moal an Fhithich Quartzite he considers, is a down-faulted portion of the main quartzite (Islay Quartzite).

The work of Bailey has been summarized by Allison in (1933), using the suggestion by Bailey and Green (1924) that graded bedding and false bedding indicated way-up criteria. Allison has used the way-up evidence and demonstrated to Green and Gregory that the Islay Quartzite is younger than the Portaskaig Boulder Beds, and Islay quartzite is younger up into Jura Slate and Scarba Conglomerate (fig 2).

THE AIM OF THE RESEARCH

Previous work on Islay by the above workers resulted in widely differing conclusions. There is complete disagreement in stratigraphic succession and structural setting of Islay. Further more the lack of detailed maps and sections render all interpretations hypothetical.

Nowhere is lack of stratigraphic and structural detail more marked than in the area labelled "Mull of Oa Phyllite" which covers a large tract of ground occupying the central part of Islay and the Oa. This lack of detail mapping results in a conflicting stratigraphical correlation across the Dalradian succession on the Scottish MainLand and in Ireland. This subject will be dealt with later, in Section 2 of this thesis.

The writer's task, therefore, was to reach firm conclusions regarding the stratigraphic succession on Islay, and try to resolve the conflicting ideas reached by the previous workers, necessitated the mapping of the southern part of Islay (Sheets 19 and 20 of the Geological Survey) where these ideas can be solved. The area is ideal for the work as it contains the core of the anticlines.

The aim of mapping was to:-

(a) arrange the order of stratigraphy;

(b) elucidate a structural history;

(c) reinterpret the geology of Islay; and

(d) draw regional conclusions

The aims necessitated the restriction of geological observations to stratigraphic and structural phenomena and the visiting of other localities outside the mapping area.

The Field Mapping

Three local terms have been introduced for the area mapped (Geological Survey Sheets 19 and 20).

i Central Islay to the ground between south of Bridgend, Bowmore and North of Beinn Bhann.

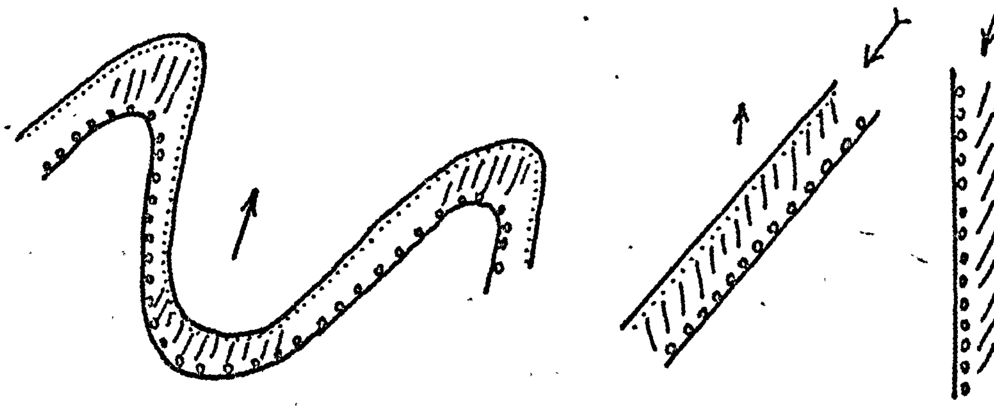
ii The Oa which is the ground south most part of Islay

iii Keldalton the ground south of Beinn Bhann and stretches from Port Ellen in the south to the Moal ard-fLalla in the south-east.

Work in the field occupied about eleven months during the years (1969, 1970, 1971), during which time about 100 square miles of ground was mapped. The mapping was on a scale of (6" to one mile). The maps are nineteenth century second edition and their accuracy tends to diminish with increasing elevation. Aerial photography (1964 edition) was used in the Kildalton area, where sills of epidiorites cut the country rocks throughout the area, and the information transferred to the base map.

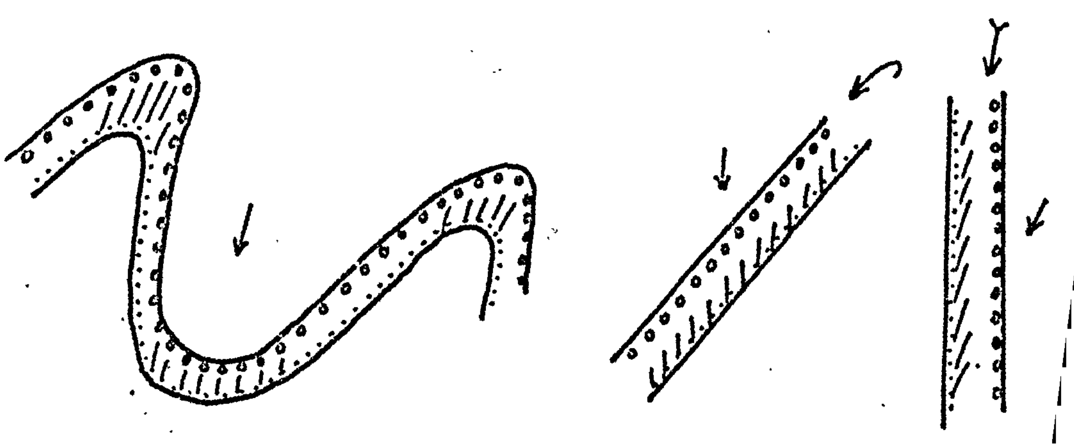
Fig 4

A



upward facing structure

B



Downward facing structure

Method of Investigation

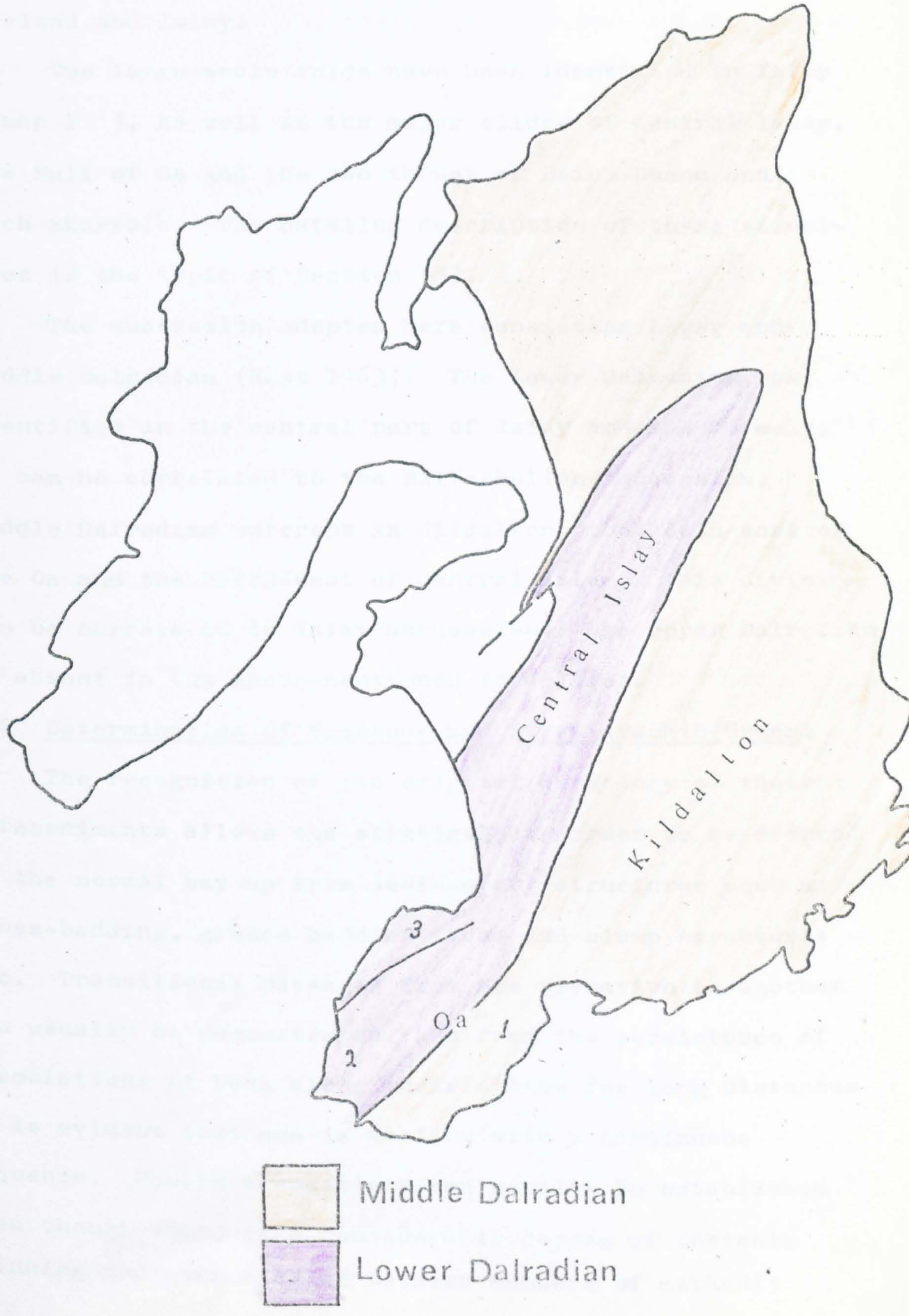
The purpose of this work is to establish the Dalradian succession in Islay and its structure, by means of primary structures. That is by determination of younging by means of current and gradding etc., and from cleavage-bedding relationship of Shackleton (1957). He has found that if, when considering limb of a fold, the schistosity-stratification relationship accords with the sequence shown by sedimentary structures, the fold faces upwards (fig 4a). If the sedimentary structures and the schistosity-stratification relationships are non-accordant, then the folded structure faces downwards (fig 4b). These two methods were applied together on perfect field evidence to decide, from the cleavage-bedding relation (plate 56) on which side of the stucture a certain outcrop is situated; similarly top and bottom of a limb can be determined from the sedimentary structures.

SECTION 2

STRATIGRAPHY

Fig 5

Sketch map show the three districts



STRATIGRAPHY

2.1 Introduction:

The Dalradian succession in Islay is part of the north-east, south-west trending Caledonian fold-belt, and most of its stratigraphic groups and many of its large structures can be easily recognized in the Highlands of Scotland, Ireland and Islay.

Two large-scale folds have been identified in Islay (map 1), as well as the major slides of Central Islay, the Mull of Oa and the two thrust of Beinn Bhann and Loch Skerrol's. The detailed description of these structures is the topic of Section (5).

The succession adopted here consisting Lower and Middle Dalradian (Rast 1963). The Lower Dalradian was identified in the central part of Islay and the Oa only; it can be correlated to the Ballachulish succession. Middle Dalradian outcrops in Kildalton, the south-east of the Oa and the north-west of Central Islay; this division can be correlated to Islay succession. The Upper Dalradian is absent in the above-mentioned localities.

2.2 Determination of Sequence and Stratigraphic Order:

The recognition of the original lithology of these metasediments allows the stratigraphic order to be deduced in the normal way up from sedimentary structures such as cross-bedding, graded bedding, load and slump structures etc. Transitional passages from one formation to another can usually be demonstrated, and from the persistence of associations of beds along their strike for long distances it is evident that one is dealing with a continuous sequence. Upward transitions can usually be established even though there is a considerable degree of tectonic thinning and even sliding between members of markedly differing competencies. For examples there is a tectonic break the Loch Skerrol's thrust in the north-west which cuts out the part of the Middle Dalradian in north Islay and the whole Middle Dalradian, and part of the Lower Dalradian in the north-west of Southern Islay; similarly the Central Islay Slide which separates the Islay Antcline and the Mull of Oa Anticline, cuts out part of the south-east limb of the Islay Anticline. The Mull of Oa Slide cuts part of the middle Lower Dalradian in the Oa. The Beinn Bhann Thrust cuts the whole Dolomitic succession of northern Islay except for the outcrop just north of Beinn Bhann, and is responsible for a dramatic thinning of the Boulder Beds and the top of the Lower Dalradian to the south-west. Other stratigraphic units have been thickened by complex folding. As it is therefore impossible to predict the real thickness of stratigraphic units, only apparent thicknesses are referred to in this work.

2.3 Lower Dalradian:

This will be described in the areas of Central Islay and the Oa. Twelve units of the Lower Dalradian were recognised. These form the following succession, which was corroborated on the whole by Rast and Litherland (1970).

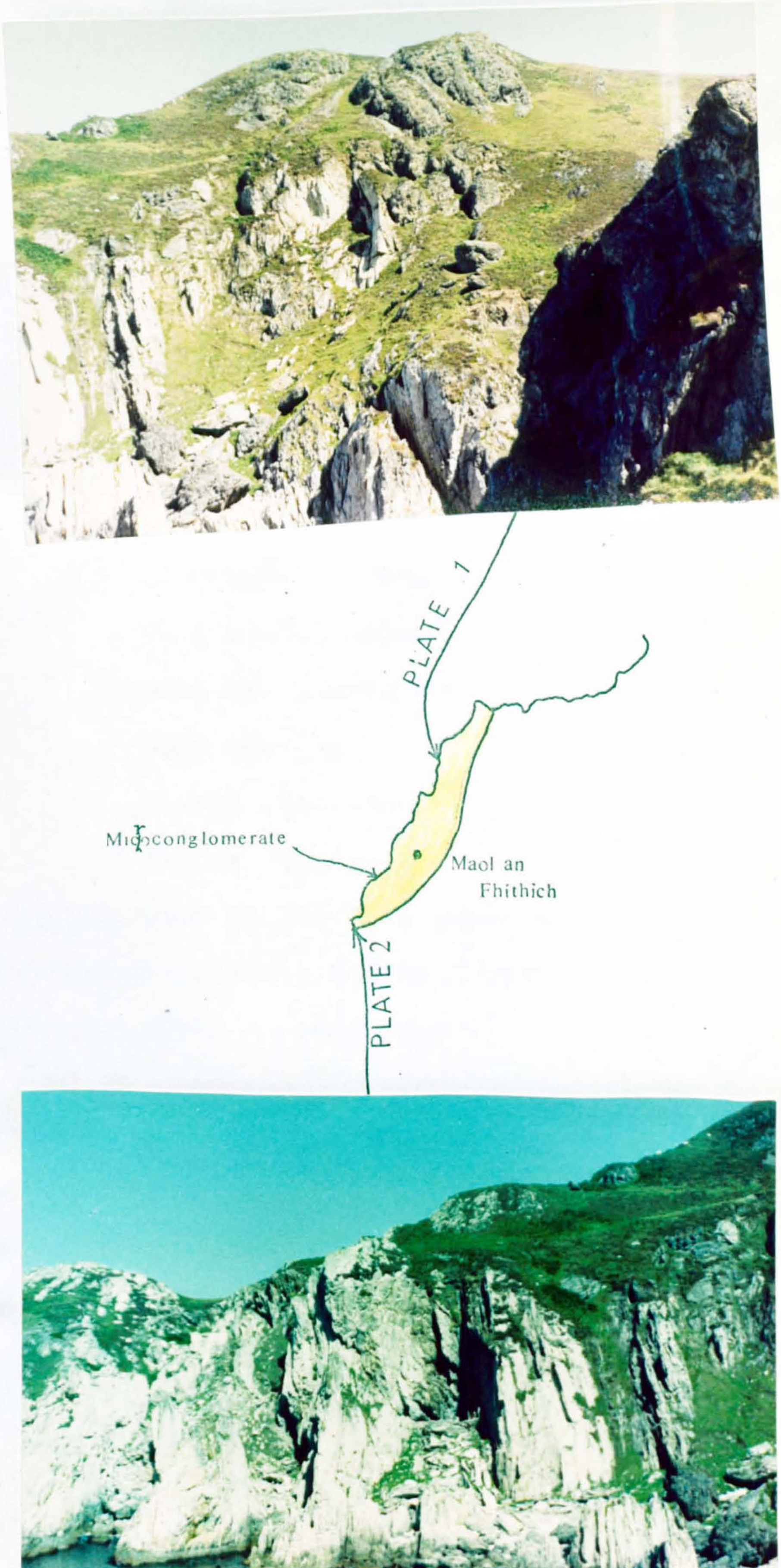
Top	Port nan Gallan Limestone		
	Port nan Gallan Phyllite		
	Ballygrant Limestone		
	Baharradail Phyllite		
Cnoc Don group		(a)	Phyllite
		(b)	Quartzite
		(c)	Limestone
	Cnoc Don Quartzite		
	Cnoc Don Transition		

Plate 1. Typical white crystalline quartzite of Moal an Fhithich. Occupying the north west cliffs of the Oa.

Plate 2. Note the vertical dip of the Quartzite, also the flagginess of the quartzite at the right corner of the photograph i.e. toward the east.

Maol an Fhithich Quartzite

Fig 6



Cnoc Don Slate

Kintra Limestone

Kintra Phyllite

<u>Bottom</u> Moal an Fhithich Quartzite

2.4 <u>Description of the Lower Dalradian:</u>

A - The Lower Dalradian in the Oa

The Lower Dalradian in the Oa is tectonically disturbed and some of its above-mentioned units are missing. The succession is as follows:-

<u>Top</u> Port nan Gallan Limestone

Port nan Gallan Phyllite

Ballygrant Limestone

Baharradail Phyllite

Cnoc Don Limestone

Cnoc Don Quartzite

Cnoc Don Slate

Kintra Limestone

Kintra Phyllite

<u>Bottom</u> Moal an Fhithich Quartzite

Immediately following is a description of each unit forming the above succession:-

1. <u>Moal an Fhithich Quartzite</u> (fig 6)

The Moal and Fhithich Quartzite is the oldest rock of the area; however older rocks have been recognized in the Ballachulish succession. Bailey (1916), has recognised the quartzite as the oldest unit, occupying the core of the Islay Anticline; the axis of the later passes through the quartzite. Allison (1933) came to the same conclusion.

Plate 3. Typical laminated siltstone of the Kintra Phyllite. The lamellae show grading to the north. Note also the vertical dip of the rocks. The rocks here show younging toward the north.

Plate 4. Note the shear zone at the bottom of the plate. This plate was taken from the Kintra Phyllite, south of Laggan Bay.

Plate 5. Note the dolomitic lamellae; the hammer head points in their direction. The shear zone occurs below the hammer shaft. To the top left corner, the dolomitic lamellae have been thinned; the black lime marks a zone of shear or displacement.

Plate 6. Kintra Phyllite at the Mull of Oa. The phyllite here occupies the cliffs of the Mull of Oa, just below the Monument. Note the shallow dip of S3 cleavage toward the north-west. Note the quartz veins having the same strike and dip as S3.

Fig 7

The Moal an Fhithich Quartzite stretches about three miles along the west and north-west of the Oa, and has excellent exposures in the cliffs. The rock is white and crystalline in the north, changing to flaggy in the south. The quartzite contains small pebbles of pink granite, quartzite and feldspar. Some of the quartzite includes films of green to dark slate, and on the cliffs of Alt an Duine (fig 6) (plate 1) facing the sea, the quartzite is conspicuously flaggy with layers of phyllite 1 foot thick, and pebbles of slates. Rast and Litherland (1970) described current bedding in this quartzite which indicates younging to the south-east. The writer observed graded bedding, particularly in microconglomerates (fig 6), as well as other way up structures; the latter show younging to the south-east. The quartzite has in general a steep dip to the south-east, and becomes almost vertical in the south (plate 2). In the north the quartzite in the south-west cliffs of Laggan Bay is slightly shattered; the plane of shattering near the junction with the overlying rocks does not disturb the stratigraphic succession. In the south, the quartzite becomes more flaggy and sheared, and its junction with overlying rocks is a tectonic one (for detail see chapter 5).

2. <u>Kintra Phyllite</u> (fig 7)

From field evidence the Kintra Phyllite stratigraphically overlies the Moal an Fhithich Quartzite and underlies the Kintra Limestone. This phyllite has been described as well as the rest of the Lower Dalradian by Bailey (1916), Allison (1933), as one group named the Moal of Oa Phyllite. This name has no place in this thesis, and what was called

Moal of Oa Phyllite has been broken down to several units, the stratigraphic position of which is determined from field evidence base on way up structures.

The Kintra Phyllite in the Oa outcrops in three localities (fig 7). In locality three the phyllite forms the core of the Oa Anticline, in locality two it forms the core of the Mull of Oa Anticline, and in locality one it forms part of the south-east limb of the Islay Anticline. For a detailed description of structure refer to chapter 5 .

The following four units can be identified in the Kintra Phyllite.

Top	Silver slates	d
	Laminated Phyllite	b
	Dark, gray Phyllite	b
Bottom	Transition zone	a

The Transition zone

This is seen only in locality one. The phyllite is semi pellitic with small lamina of psammite, 1 : 2 MM thick. The junction between the transition zone and the underlying Moal an Fhithich Quartzite is stratigraphic; here the phyllite and the quartzite are interbedded for about seven meters. At the top the phyllite becomes more laminated, (the lamina reaching up to 3 cm in thickness), and slightly dolomitic. The phyllite of this zone passes directly upwards into the Kintra Limestone. No graded bedding was found in it.

The dark, gray phyllite

This sub unit occupies the core of the Oa Anticline the phyllite is characterized, on its dull lineated cleavage surface, by a grey to greenish hue produced by chlorite in the rock matrix. Original bedding which is commonly seen, is exhibited well in the washed exposures of Moal Chrasdail (a mile and a half west of Lower Cragabus). Here light and dark zones of sandy limestone and green graphitic phyllite can easily be picked out (plate 3).

The typical close lamination, is metamorphic in origin and is produced by the effects of a composite cleavage. Small ellipsoidal bodies (Most probably grains) were discovered at the bottom of the light coloured bands, Ca 2 : 5 mm across.

The Laminated Phyllite

This outcrops at locality 3 flanking the limbs of the Oa Anticline, and in locality 2 occupying the Mull of Oa Anticline. The phyllite is partly composed of pale creamy-coloured, sandy to dolomitic bands, and partly of pale siltstone grading into dark mudstone; the thickness of each ~~verve~~ varies from 2 : 10 cm. Exposures are excellent on the shore of Laggan Bay 20 meters west of Kintra farm, along the cliffs west of Killeyan and on the cliffs of the Mull of Oa; the lithology in these localities charac*istically associated, with 7 : 40 cm fine grained saccaroidal quartzite and buff to creamy, weathered sandy limestone.

Along the south shore of Laggan Bay, is a well exposed stretch of the phyllite. The suggested laminates are well graded and show younging to the north and north-east. The phyllite forms large tracts of folded rocks. The junction between the phyllite and the limestone

(Kintra Limestone) at Port Alseig is tectonic, where the central Islay slide separates the two units. Besides these are small scale slides (plate 4) developed 50 meters west of Kintra Farm.

To the south-east the phyllite is folded in a major scale and appears as several distinct horizons especially well shown at the cliffs west of Lower Killeyan. The laminaes are well graded and small current bedding has been recorded at the top most part of the phyllite (fig 7a). These structures show younging to the south-east. The phyllite passes upwards into the Kintra Limestone to the south-east, a zone of about 30 meters of interbedded phyllite and flaggy limestone.

The area has been affected by large scale F_3 folds with refolded F_2 folds (plate 5). These large scale folds have considerably affected the lithology of the phyllite. In the lower limb of the fold, the rock is more flaggy and slightly higher in metamorphism than in the top limb of the fold (plate 57). This is in general well observed wherever large scale folds occur.

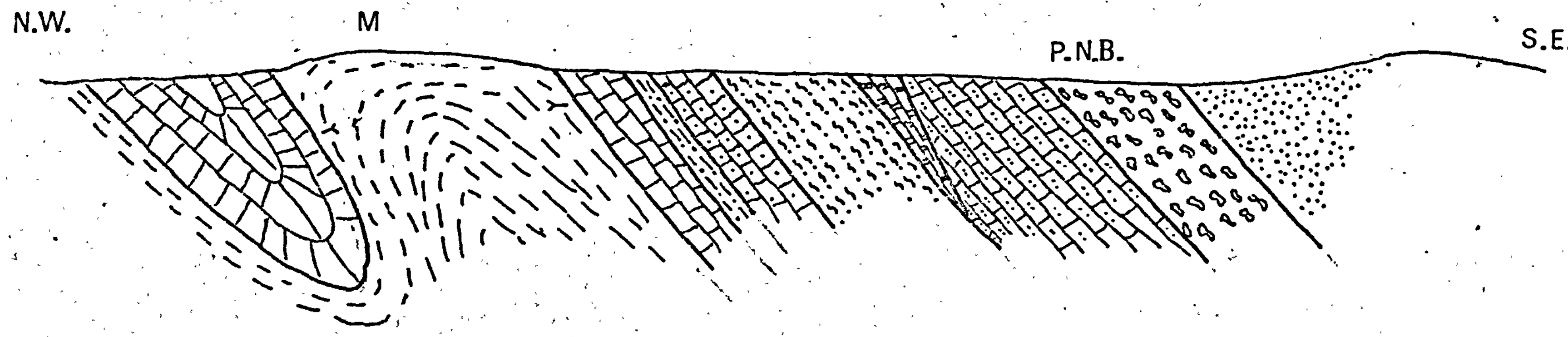
After establishing the position of the varved phyllite at the Kintra Farm and at Lower Killeyan, a similar zone was found at locality number two, the Mull of Oa. "The Mull of Oa Phyllite" was given to the rocks which occupy the central Islay by Bailey and Allison et al. The phyllite outcropping here occupies the core of a large anticline, the axis of which trends in a north east direction, passing in the vicinity of the war memorial which is the main land mark in the area.

Plate 7. Kintra limestone at the cliffs of the Mull of Oa. Here the limestone outcrops on the cliffs for about half a mile. Note the thickness of each bed.

Plate 8. Kintra limestone from the southern cliffs of the Laggan Bay.

Plate 9. Typical Cnoc Don Limestone. The Limestone is gray with light-coloured stripes. (Tiger rock).

Fig 8

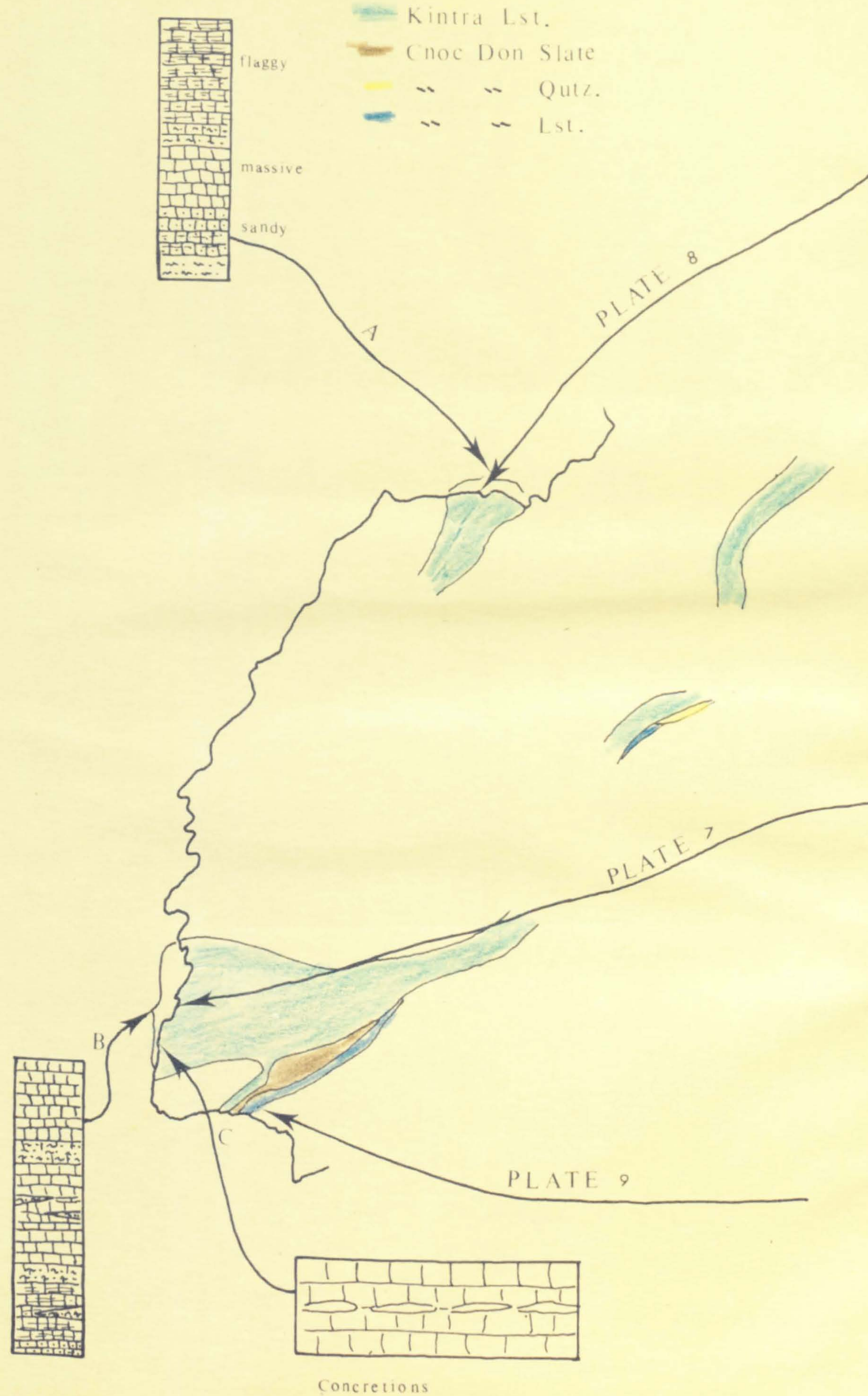


Traverse cross section from M. to P. N. B. (Oa district)

P.N.B. Port Nan Gallan Bay

M. Monument

Fig 9


Kintra Lst.
Cnoc Don Slate
〃 〃 Qutz.
〃 〃 Lst.
flaggy
massive
sandy
A
PLATE 8
PLATE 7
B
C
PLATE 9
Concretions

The phyllite is very well graded and show easily recognizable, small scale current bedding; the cleavage bedding relationship is well observed and will be discussed in chapter 5. All these structures prove that the rock outcropping 50 meters to the north-west of the Memorial younging to the north-west, whereas the varved phyllite east of the memorial younging to the south-east. On both sides of the memorial, the phyllite passes upwards into the Kintra Limestone. A traverse section from Alt na h-Uraich (140 meters north-west of the memorial) to Port nan Gallan (fig 8) shows that the phyllite is in its correct stratigraphic position.

The Silver Green Phyllite

The phyllite forms the upper most sub-unit of the Kintra Phyllite. Its name is derived from the luster of the cleavage surfaces produced by the growth of white mica. This sub unit is not well represented in the Oa. At Cnoc Ard 250 meters west of Lower Cragabus, the phyllite possesses excellent parting, and is intercalated with thin 2 : 9 mm laminae of sandy limestone; the latter are in some places gray. The phyllite exhibits impressive facies changes from phyllite to limestone.

3. Kintra Limestone (fig 9)

The Kintra Limestone is the first major calcareous horizon in the Islay succession.

In the southern cliffs of Laggan Bay, about 400 meters west of Kintra farm, a stretch of about half a mile of limestone has been discovered. The limestone in this locality was first seen and recognized by Rast (1968) (personal communication) and later by the writer in the summer of 1969. The limestone is pale, schistose, and dolomitic in its lower portion, becoming thick, dark gray and graphitic at its top. The lower 10 meters of the limestone is flaggy and schistose becoming increasingly interbedded with massive 10 : 40 cm beds of dolomitic limestone that are buff to yellowish on their weathering surface. Away from this margin, the limestone becomes dark, remaining impure and sometimes interbedded with sandy, weathered layers of black graphitic schist. Thin siliceous ribs are good bedding indicators and form a tightly folded sequence. The uppermost part of the limestone has been partly cut-out and partly transformed into graphitic flaggy layers by the Central Islay slide. An apparent stratigraphic thickness of the limestone has been established (fig 9).

The same limestone is folded on a major scale and appears in several distinct (fig 8) horizons especially well shown at the south-west cliffs of the Oa stretching for about a mile and a half from Lower Killeyan to Alt na h-Uraich (140 meters north-west of the memorial). Here the complete section of Kintra Limestone is represented from top to bottom and a stratigraphic section has been described (fig 9) (plate 7).

This limestone has been described by the Geological Survey (1907), Bailey (1916), Green (1924), Gregory (1928), Allison (1933) and generally accepted as an outlier of Triassic age. This idea has no proof and the writer has proved without doubt that this limestone belongs to the same horizon which outcrops on the south-west coast of

Laggan Bay (Kintra Limestone). The limestone in this area is part of the south eastern limb of a large scale fold which repeats the appearance of this limestone. Besides the well-observed primary structures, current and graded bedding, support this fact. Lithologically the limestone resembles the limestone in Laggan Bay and in other localities. The base of the limestone is well exposed at the cliffs west of Lower Killeyan where the contact with the underlying rock, the Kintra Phyllite, is transitional and the changes in facies is very clear. Away from the base, towards the top, the limestone is never free from dark graphitic slate which is interbedded with it, in some places the limestone is replaced by graphitic schist. At the top the limestone is dark gray, and small irregular concretation - like ellipsoids of a dolomitic nature (fig 9c) are discovered in it. The limestone has been refolded on a large scale which results in the repetition of the limestone, and explains its large apparent thickness in this locality.

The limestone in the above-described locality is regarded by the writer as belonging to the Kintra Limestone (Lower Dalradian) for the following reasons:-

1. The facies change is a transitional one
2. There is no sign of unconfirmity between the underlying Kintra Phyllite and the overlying rocks.
3. The strike of the limestone and the phyllite are almost the same.

4. The transitional passages from the Kintra Phyllite to the Limestone can easily be demonstrated in the field, and persistence of the limestone beds along their strike for long distances (15 miles) convinces me that I am dealing with a reasonably continuous sequence.
5. Furthermore, graded and current bedding has proved that the Kintra Phyllite youngs towards the limestone, and the limestone youngs to the south-east.
6. The lithological resemblance with the limestone outcropping at the south-west of Laggan Bay, with respect to the metamorphism.
7. Structurally, the limestone is a continuous south eastern limb of the Oa Anticline stretching for about 15 miles.

For the above-mentioned reasons the writer has no doubt in including this limestone with the Kintra Limestone.

At 150 meters east of the Memorial (fig 9) the limestone outcrops again in the eastern limb of the Mull of Oa Anticline. The limestone is dark gray, graphitic, with good graded bedding, which shows younging to the south-east (fig 9).

A calcite dyke cuts through the limestone and the phyllite. The contact with overlying rocks in the southern cliffs of the Mull of Oa, is transitional and the limestone passes to black graphitic slate. About 1 mile inland, this slate is non-existant and the Kintra Limestone is overlain by Baharradail Phyllite and dark greenish-blue limestone (Ballygrant Limestone). The contact here is tectonic due to the effect of the Mull of Oa Slide, which is responsible for the disappearance of part of the Lower Dalradian and thinning of the rest in the Oa; details of this is the subject dealt with in chapter 5 .

4. <u>The Cnoc Don Slate</u>

Typically the slate is black or dark gray, sometimes pyritous and graphitic, with a dull cleavage surface; bedding is occasionally seen as thin silty laminae but nowhere as well developed as in the quarry-type locality at Central Islay. Massive pods of black and yellowish - weathered limestone, are common in the slate at Central Islay and Oa. At the Oa exposures occur only east of the Memorial; at Bruthach Mor, 120 meters west of Port Nan Gallan, the slate contains graded laminae of siltstone. Nowhere else in the Oa does the slate outcrop. The junction between the slate and the overlying succession in this locality is tectonic; the Mull of Oa Slide cuts through it; developing a graphitic shear zone.

5. <u>Cnoc Don Quartzite</u> (fig 9)

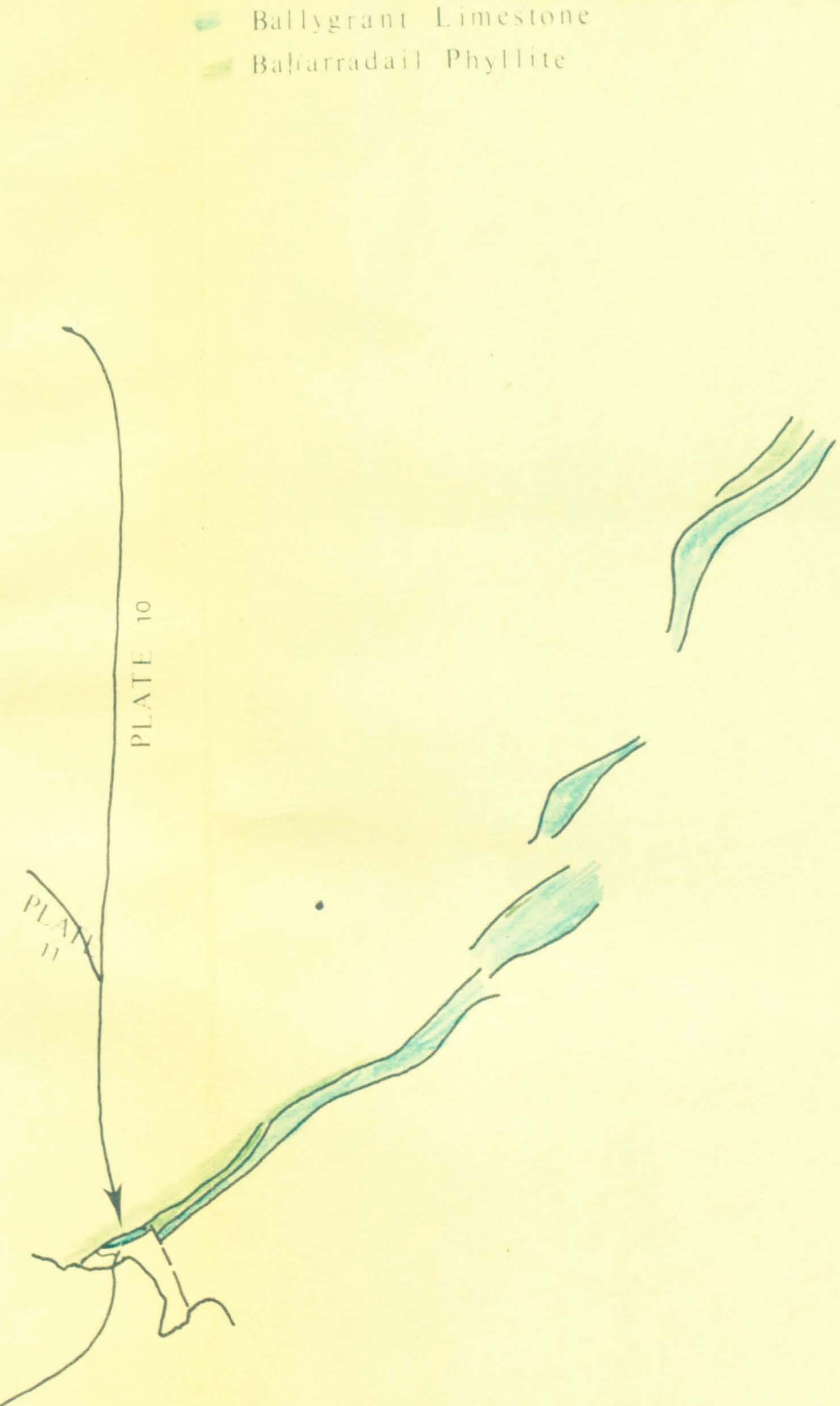
The quartzite is completely cut out in the Oa by the Mull of Oa Slide.

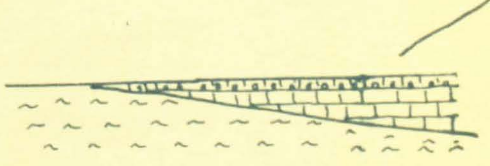
However a small outcrop of quartzite in the Oa is - regarded by the writer as belonging to the Cnoc Don Quartzite. The outcrop measures 3 meters by 15 meters and no particular way up structures have been found in it. This quartzite is white, spotted with white feldspar, and its stratigraphic position lies between two limestones:

Plate 10. Note the unconformity marked by the hammer and black line, between the blue and red dolomitic limestone (Ballygrant and Port nan Gallan Limestone respectively).

Plate 11. Graphitic conglomerate marking the zone of the unconformity, at the base of the Port nan Gallan Limestone. This zone outcrops inland south-west of Loch Kinnabus.

Fig 10


Ballygrant Limestone
Baharradail Phyllite
PLATE 10
PLATE 11



underlying (Kintra Limestone) which is flaggy and shows way up structures younging toward the quartzite, and overlying dark blue limestone (Ballygrant Limestone).

6. Cnoc Don Group (Limestone) (fig 9)

In the Oa, the Cnoc Don group are not well exposed, partly due to the effect of the Mull of Oa slide. Part of the Cnoc Don Limestone is exposed in the cliffs of Bruthoch Mor 130 meters west of Port Nan Gallan (plate 9). It is an impure limestone with numerous scales of calcite scattered in its surface, as well as some spheroidal shaped concretions, 4" in diameter. The rock is cut by a calcite dyke 7 feet thick; the dyke is pure calcite with reddish weathering surface.

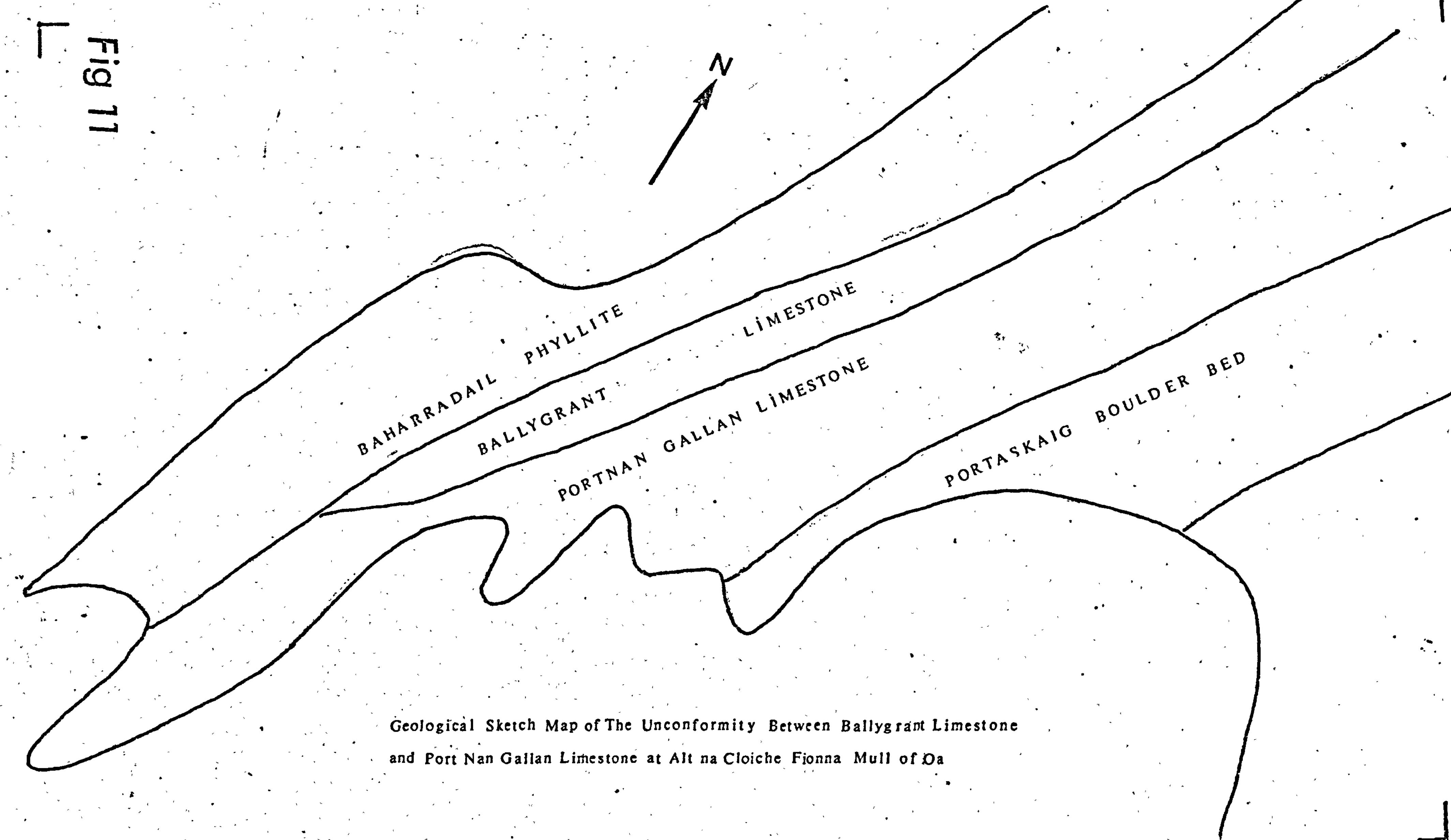
7. Baharradail Phyllite (fig 10)

This is exposed in Alt na Cloiche Fionna 100 meters to the west of Port Nan Gallan and stretches inland for about one mile. It is mainly a graphitic, muscovite-chlorite or biotite phyllite. Thin psammtic and calcareous bands 1 : 3 cm thick, occur in places. It has a typical close lamination of composite cleavage (plate 57). The phyllite in this particular area is overlain unconformably by extraneous rock which consists of boulders of limestone and phyllite in a red sandstone matrix; further away, 20 meters to the north along its strike, the phyllite passes upward conformably into the Ballygrant Limestone (fig 11).

8. The Ballygrant Limestone (fig 10)

The limestone is exposed along the south east limb of the Mull of Oa Anticline; it forms a continuous bed for more than 15 miles. It is dark blue with a reddish to slightly yellow weathering surface; veins of pure white

Fig 11



Geological Sketch Map of The Unconformity Between Ballygrant Limestone and Port Nan Gallan Limestone at Alt na Cloiche Fionna Mull of Oa calcite intensed it and are clearly seen on a fresh surface. Graded bedding in its sandy top-most bed show younging to the south-east. The limestone shows variable thickness along its strike; it has a maximum thickness of 60 meters in the Central Oa, thinning dramatically to the south-west, to disappear in the cliff of Alt na Cloiche Fionne (fig 11). Twenty meters to the north the Ballygrant Limestone is disconformable with the overlying rock, Port nan Gallan Limestone (plate 10). A graphitic conglomeritic zone of about 7" thick is well identifiable in the field (plate 11). The line of disconformity between, the Ballygrant Limestone at the bottom and the overlying Port nan Gallan Limestone is a sharp one. The Port nan Gallan Phyllite is missing. The line of disconformity is a stratigraphic one as a result of local erosion. This unconformity will be discussed in more detail in chapter 3.

9. <u>The Port nan Gallan Phyllite</u> (fig 12)

This phyllite has a distinctive position, being exposed between two characteristic limestones, the underlying Ballygrant Limestone and the overlying Port nan Gallan Limestone. The phyllite is exposed on the south-east limb of the Mull of Oa Anticline for about 20 miles. It has a variable thickness along its strike, changing in thickness from north-east to south-west. In the cliffs of Alt na Cloiche Fionne it is represented by a conglomeritic zone of 7" thick; for 2 miles inland, from Port nan Gallan to the south-east corn of Loch Kinnabus (fig 12), this conglomeritic is observed at the base of Port nan Gallan Limestone. As explained above the

Plate 12. General view of the cliff of Port nan Gallan. To the extreme right, note the Islay Quartzite; its contact with the underlying Boulder Bed is tectonic, mylonitization is shown. To the extreme left is the Port nan Gallan Limestone outcrop. Normal fault has displaced the rocks.

Plate 13. Note the circular shape of the Oolite, suggesting a low deformation. The Oolite appears only in the Port nan Gallan Limestone.

Plate 14. Cave filling in the Port nan Gallan Limestone. Note the huge boulder of limestone, quartzite and phyllite. Also note the slump of late structure due to the collapse of the limestone.

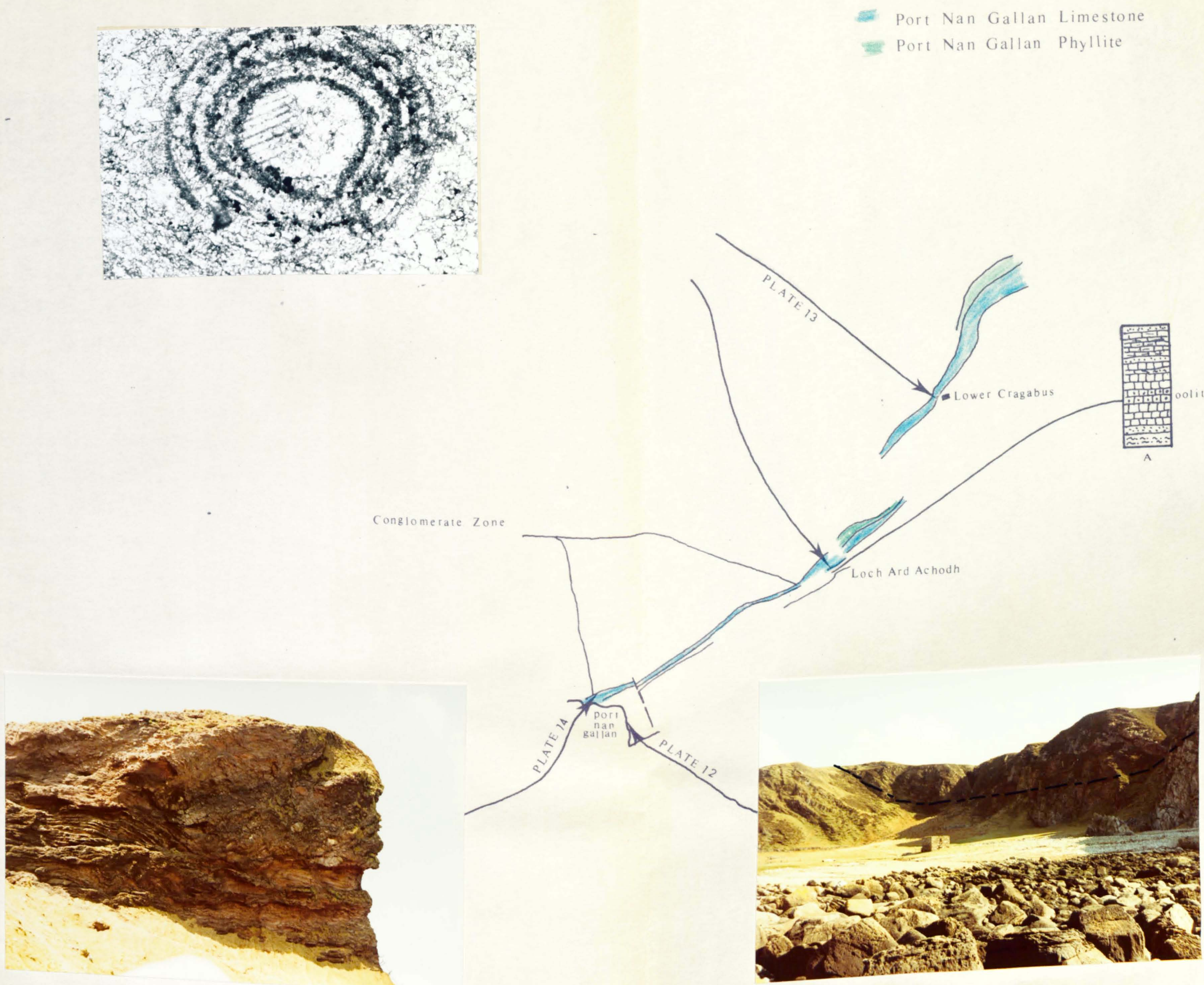

Port Nan Gallan Limestone
Port Nan Gallan Phyllite
PLATE 13
Lower Cragabus
oolitic
A
Conglomerate Zone
Loch Ard Achodh
port
nan
gallan
PLATE 14
PLATE 12

Fig 12

the conglomerate represents a period of erosion due to local uplift and following the deposition of the Port nan Gallan Phyllite.

The phyllite is black and graphitic on the cliff facing Port nan Gallan, becoming interbedded with quartzite and sandy dolomitic limestone 6" : 1' thick. It passes upwards towards Port nan Gallan Limestone (fig 11a) at the north-east of Loch Ard Achodh.

10. Port Nan Gallan Limestone (fig 12)

This limestone is the highest member of the Lower Dalradian in Islay is overlain by the Middle Dalradian group, the Boulder Bed (Hast 1963). Its thickness is variable, a stratigraphic section from Port nan Gallan has a thickness of about 60 meters (fig I). The limestone is exposed in Port nan Gallan to the west, in the cliffs facing the bay (plate 14) and inland forming good outcrops. It is an impure limestone - white, red, yellowish to dark-coloured, sandy in some localities and regularly bedded (often in beds from 20-50 mm thick). It is divided into units which are of tens of meters thick. Eighty meters to the west of Port nan Gallan, on the coast-line, the Port nan Gallan Limestone lies disconformably over the Baharradail Phyllite, and 30 meter inland it lies disconformably on the Ballygrant Limestone, with a well-observed graphitic conglomerate zone of 7" thick at its base (fig 10 & 12) (plate 11). This conglomeritic zone is also observed in the cliffs facing Port nan Gallan and 2 miles inland in the south-west corner of Loch Kinnabus. Above the conglomerate the limestone is massive becoming flaggy, to white on red dolomitic in some localities. Oolitic structures have been recorded from several localities, to the north-east of Loch Ard Achodh, and in a quarry 5 meters south-east of Lower Cragabus Farm (plate 13). The Geological Survey observed the presence of the Oolitic limestone within the (Islay Limestone Formation) at several other localities (Wilkinson et al 1907 pp 33-5). All of these localities have been visited, and without exception, all belong to the Port nan Gallan Limestone. In all localities in the Oa, the Port nan Gallan Limestone is overlain unconformably by the Portaskaig Boulder Bed.

B. - Lower Dalradian in Central Islay

The Lower Dalradian succession is well exposed in Central Islay, where the succession is complete and well established. Here the rocks occupy the cores of complete antiforms and synforms: the Islay Anticline and the Mull of Oa Anticline; and bringing the younger succession in contact with the older one, to the south-east and north-east at its closure. As will be seen later (map 1) the slide is of the same age as the folds. Although the area has more than one phase of metamorphism, it sedimentary structures are still well preserved, and the following stratigraphic succession has been identified in Central Islay.

Top	Port nan Gallan Limestone
	Port nan Gallan Phyllite
	Ballygrant Limestone
	Baharradail Phyllite

Cnoc Don Group (a) Phyllite

(b) Quartzite

(c) Limestone

Cnoc Don Quartzite

Cnoc Don Transition

Cnoc Don Slate

Kintra Limestone

Bottom Kintra Phyllite

Kintra Phyllite (fig 7)

This phyllite is not well exposed in Central Islay, except where rivers cut through the superficial deposits, exposing good cross sections. Three sub units of the Kintra Phyllite which have been described (plate 1) in the Oa localities, are recognized in Central Isaly; these sub units are:-

Top (a) Silver Slates

(b) Laminated Phyllite

Bottom (a) Dark gray phyllite

The transition zone is not represented in Central Islay.

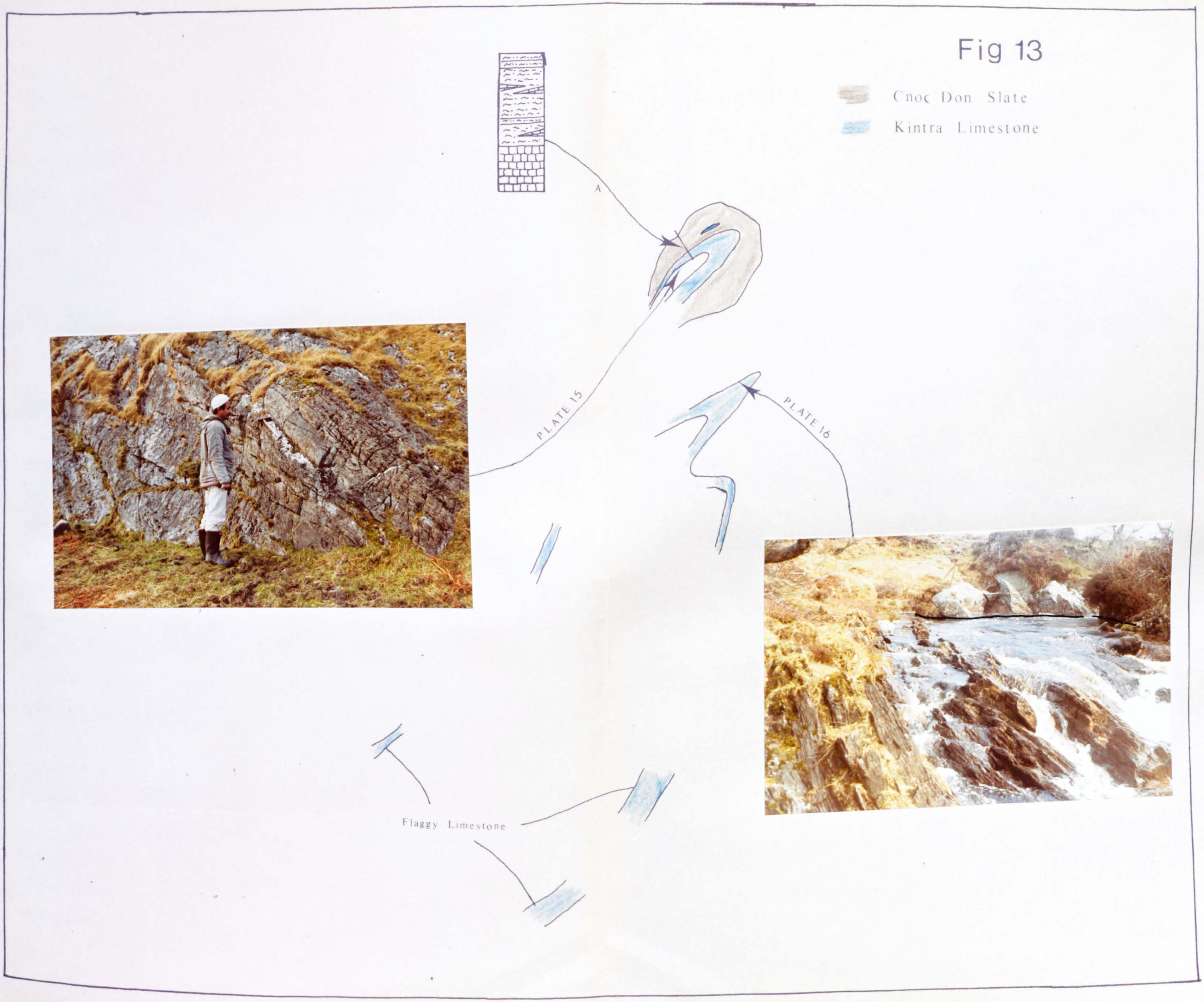
a - The Dark Gray Phyllite

The phyllite forms the core of the Mull of Oa Anticline. This phyllite is exposed in the Glen Egedale east and west of the (Port Ellen - Bridgend) rood and in the Glenegdalemor; here the phyllite is graphitic-black, with a slightly greenish colour. Close foliation which is metamorphic in origin, is produced by the effects of a composite cleavage s_1 and s_2 striking to the north-east and dipping to the south-east.

Plate 15. Kintra Limestone Central Islay. Here the limestone is gray and massive. Note the Mullion structure on the bedding plane. The hammer shaft points east to south-east, toward the plunge of the Mullion.

Plate 16. Kintra Limestone Central Islay. Here the limestone occupies the closure of the Oa Anticline. The black line marks the closure.

Fig 13



Cnoc Don Slate
Kintra Limestone
A
PLATE 15
PLATE 16
Flaggy Limestone

b - The Laminated Phyllite

This is well exposed in Torra river east side of Bowmore, Port Ellen Rood, and in Gleann nan Mallaichean; 2 miles East of Rood. The phyllite is green, chloritic with pyrite crystal on its surface. No banding is observed but still dolomitic laminae are present. In some places the phyllite lithologically resembles sub unit three (the silver slates). The close lamination observed in the underlying dark phyllite is still present, and s_1 in some places has been folded. (See map (1)).

c - The Silver Green Phyllite

This phyllite is well exposed in the Abhatri-dail half a mile south-east of Kilennan House, and Abhainn Bhogie. It forms the uppermost sub unit of the Kintra Phyllite. Its smooth cleavage surface has a greenish lustrous appearance. In the river near Abhatri-dail, the phyllite is intercalated with thick (2 : 7 cm) beds of sandy yellowish limestone, anticipating the development of the Kintra Limestone. Here the phyllite exhibits impressive facies changes from Phyllite to Limestone. At the core of the Islay Anticline the phyllite is only exposed at one locality (G.R.3859).

Kintra Limestone (fig 13)

The Kintra Limestone in Central Islay is well exposed in the core of the Islay Anticline and the core of the Oa Anticline (map 1).

The limestone in the Islay Anticline consists of a pale, schestose and sometimes dolomitic lower portion, overlain by a dark upper portion. The contact with the underlying rock is not well exposed. Grading is good in the sandy limestone and shows younging to the north-west. Rodding - a development of early boudinage structure along the bedding (plate 47) - has a trend to the south-east with a 40^{o} plunge.

The limestone in the core of the Oa Anticline, is best exposed in Kilennan river, below a waterfall. Here the limestone is coarsely laminated and has a light-coloured dolomitic, dark pelitic lithology, which gives it a striped appearance. The limestone forms the closure of the Oa Anticline (plate 16), where the limestone steeply plunges under the Cnoc Don Quartzite. S_2 cleavage is well developed throughout having a uniform trend - north-east to south-west - and dipping to the south-east.

<u>The Cnoc Don Slate</u> (fig 13).

This outcrops on the south eastern slope of Cnoc Don. The typical lithology is a black or dark gray, sometimes pyritous, graphitic slate, with a dull cleavage surface; bedding is occasionally seen as thin silty laminae. The best exposures are in the three quarries at Coill a' Ghuail. Massive pods of black and yellowish limestone are common (fig 13a). The slate passes upwards into a psammitic phyllite, 5 feet thick; the latter resembles the transition group of the Ballachulish, but is not sufficiently exposed for this resemblance to be conclusive. This transitional phyllite passes upwards into a massive quartzite Cnoc Don Quartzite.

Plate 17. Typical outcrop of the Cnoc Don Quartzite. Note the white spot (feldspar) characteristic of that rock. Also note the cross-bedding. The rock in this locality has overturned and shows younging toward the north-west.

Plate 18. Typical rock of the Cnoc Don Group. Note the interbedded Limestone and Quartzite bed in the rock. The hammer head points toward the limestone bed. Also note F1 fold marked by the 2p. coin. The yellow pen shows the development of S3 cleavage.

Plate 19. The surface of the Cnoc Don Limestone has calcite scales. This has been recognized andis shown in this plate. The match stick lies within these scales.

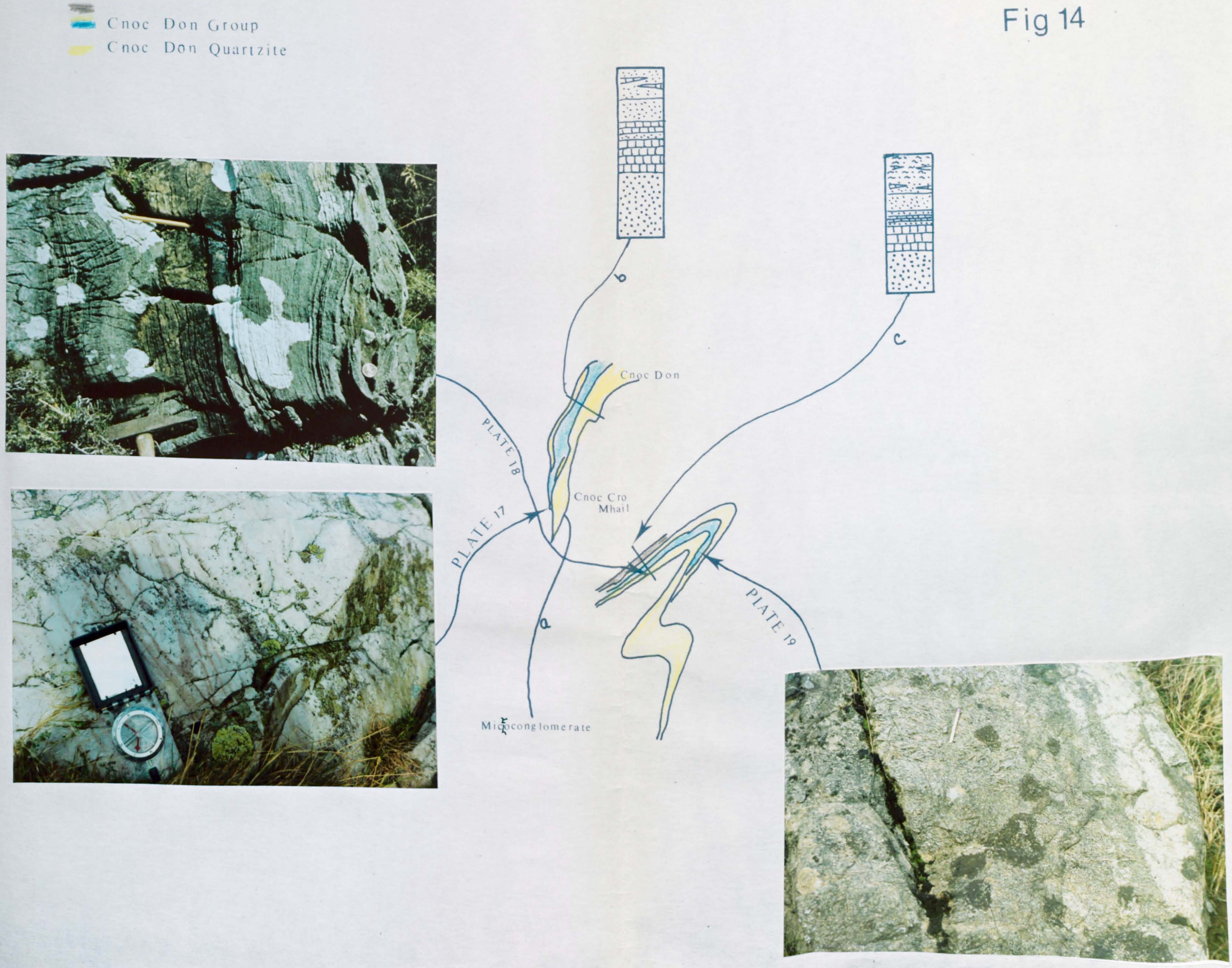

Cnoc Don Group
Cnoc Don Quartzite
b
c
Cnoc Don
PLATE 18
Cnoc Cro
Mhail
PLATE 17
a
PLATE 19
Microconglomerate

Fig 14

Ballygrant Limestone
Baharradail Phyllite

Fig 15

The Cnoc Don Quartzite (fig 14)

This unit is exposed in Cnoc Don and stretches to the south-west (Cnoc Cro a'Mhail), for about 2 miles. It is a thick quartzite to the north-east but thins slightly to the south-east at Cnoc Cro a'Mhail. This quartzite forms the inverted western limb of Islay Anticline as will be discussed later. Other exposures occur 2 miles south-east of the first locality, at Kilennan river. Here the quartzite form the limbs of the Mull of Oa Anticline; the south-east limb stretches for 3 miles to the south-west where it is thin and cut completely by the Mull of Oa Slides; the north-west limb is refolded forming the Central Islay syncline and is cut by the Central Islay slide see section 5 for detailed structures.

The quartzite is white, spotted with white feldspar crystals (plate 17) and its weathered surface being a dusty grey. The quartzite is graded with a base of microconglomeritic at the south-east slope of Cnoc Cro a' Mhail, large and small cross bedding, has been observed in the quartzite.

The Cnoc Don Quartzite West of Central Islay

Here the cross bedding is seen as thin red stripes on the steeply dipping surface fractures of the white quartzite. The best structures are seen in the Cnoc Cro a' Mhail (fig 14). The exposure of cross-bedding indicates that the beds are inverted towards the west, and that the Cnoc Don Quartzite have lies stratigraphically above the Cnoc Don Transition Phyllite and below the Cnoc Don Group (Limestone).

Grading is observed and indicates that the quartzite younging and faces towards the north-west. This indicates that this quartzite is a folded part of the main Cnoc Don Quartzite forming an anticline and separated from the south-east limb of the Islay Anticline by Central Islay Slide.

The cross-bedding and grading leave no doubt that the stratigraphic sequence in the Cnoc Don is as follows:-

interbedded { (g) phyllite
(f) quartzite
(e) limestone }

(d) quartzite

(c) some pellitic phyllite

(b) slate

(a) limestone

The Cnoc Don Quartzite South-East of Central Islay

The quartzite here forms the south-east and north-west limb of the Mull of Oa Anticline. Cross-bedding and grading indicate that the quartzite forms an anticline having the same axis and plunge as the Islay Anticline. The same stratigraphic sequence as that established above in the Cnoc Don area, occurs in this locality.

Cnoc Don Group (fig 14)

The following succession have been identified in Central Islay

Phyllite

Quartzite } interbedded
Limestone }

The lithological character of this limestone is conspicuous that it can be immediately recognized in the field. The characteristic member of the group is brown-weathering, crystalline dolomitic limestone, cream coloured or buff on fresh surface. The limestone are interbedded with a few impure quartzite bands (fig 14) (plate 18) and pass upwards into banded quartzite; with a few bands of the limestone. This agrees with the characters of the .... described by McCall (1954), Pitcher and Shackleton (1966) in Donegal. The banded quartzites are well exposed in the north-west of Cnoc Don, and on the limbs of the Mull of the Oa Anticline in the Kilennan River.

The limestone exposed in Kilennan river 60 meters to the west from a waterfall, here scales of white calcite develop on its surface (plate 19) the scale-like crystals form small isoclinal folds with random fold axes. These structures are very similar to sun-crack structures; their preservation is significant, since it suggests that casts and molds of organic remain could easily be preserved in the Islay rock of similar low metamorphic grade.

The above-described beds pass upwards into greenish semi pelitic phyllite, the latter form the highest member of the Cnoc Don Group; they are interculated with calcareous beds, up to 40 cm in thickness.

Baharradail Phyllite (fig 15)

The type locality is at Loch Baharradail where the relation of this phyllite with the overlying limestone (Ballygrant Limestone) is best seen. In Central

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Islay, the phyllite is exposed in several localities; the best are north-east of Cnoc Don where the phyllite is brought in contact with Cnoc Don Slate, Cnoc Don Quartzite and Cnoc Don group by the Central Islay Slide. Other outcrops are in the south eastern side of the Central Islay Slide, forming part of the Oa Anticline. The phyllite is mainly graphitic, muscovite - chlorite - or biotile bearing. Psammitic and calcareous bands (1 : 3 cm thick) occur in places, especially north-east of Cnoc Don. The typical close foliation previously described in the Oa, is observed and is metamorphic in origin, produced by the effect of composite cleavage (plate 57). Graded and current bedding in the psamatic lamellae in the south face of Beinn Bharrad, show younging to the north-west. The phyllite forms the north western inverted limb of Islay Anticline. It passes upward into the Ballygrant Limestone.

The Ballygrant Limestone (fig 14)

The limestone is exposed in the north-west and form the inverted limb of the Islay Anticline. The same limestone is folded on a major scale and appears in several distinct places at Kattadale Farm and beyond to the south-east, and stretching to the north-east for about 4 miles up to the quarry in Ballygrant village. The limestone is dark blue, veins of pure calcite can be observed on fresh surfaces. Graded bedding in its sandy top most bed shows a clear younging and helps in establishing the sequence. Here the limestone is thicker than of the Oa reaching 70 meters (fig 1). In the east of Cnoc na tri dail the limestone becomes a few meters thick. Tectonic thinning is common in Islay and the more incompetent pelitic and dolomitic horizons may be locally cut out. However, the possibility of original depositional thinning cannot be ignored (page 61).

Port Nan Gallan Phyllite (fig 16)

This phyllite is better exposed in Central Islay than in the Oa. It is exposed in the south-east of Central Isaly, near the source of the Kilennan river, near Allallch, west of Loch Allallaidh and near Loch Dubh, in the latter locality the phyllite is in a contact with the Islay Quartzite.

The phyllite in general is graphitic black, becoming interbedded with psammitic (sandstone and siltstone) beds upto 14 cm thick. The sandstone beds are very variable in thickness when traced laterally; they show small-scale percontemporaneous loading structures and commonly have ptygmatic and dykelets penetrating downwards from their bases (fig16a).

The phyllite everywhere underlies the Port Nan Gallan Limestone except at Abhuimn at Sithein and 100 meters south-west of Loch Allallaidh, and north of Loch Allallaidh by about 3 miles: at Abhuimn the phyllite underlies the Portaskaig Boulder Bed and north of Loch Allallaidh, it underlies the Islay Quartzite. The phyllite in these two localities is unconformable with Portaskaig Boulder Beds and Islay Quartzite; it is thrust underneath the quartzite, resulting in the disappearance of the Port nan Gallan Limestone, the Portaskaig Boulder Bed and the Dolomitic Group.

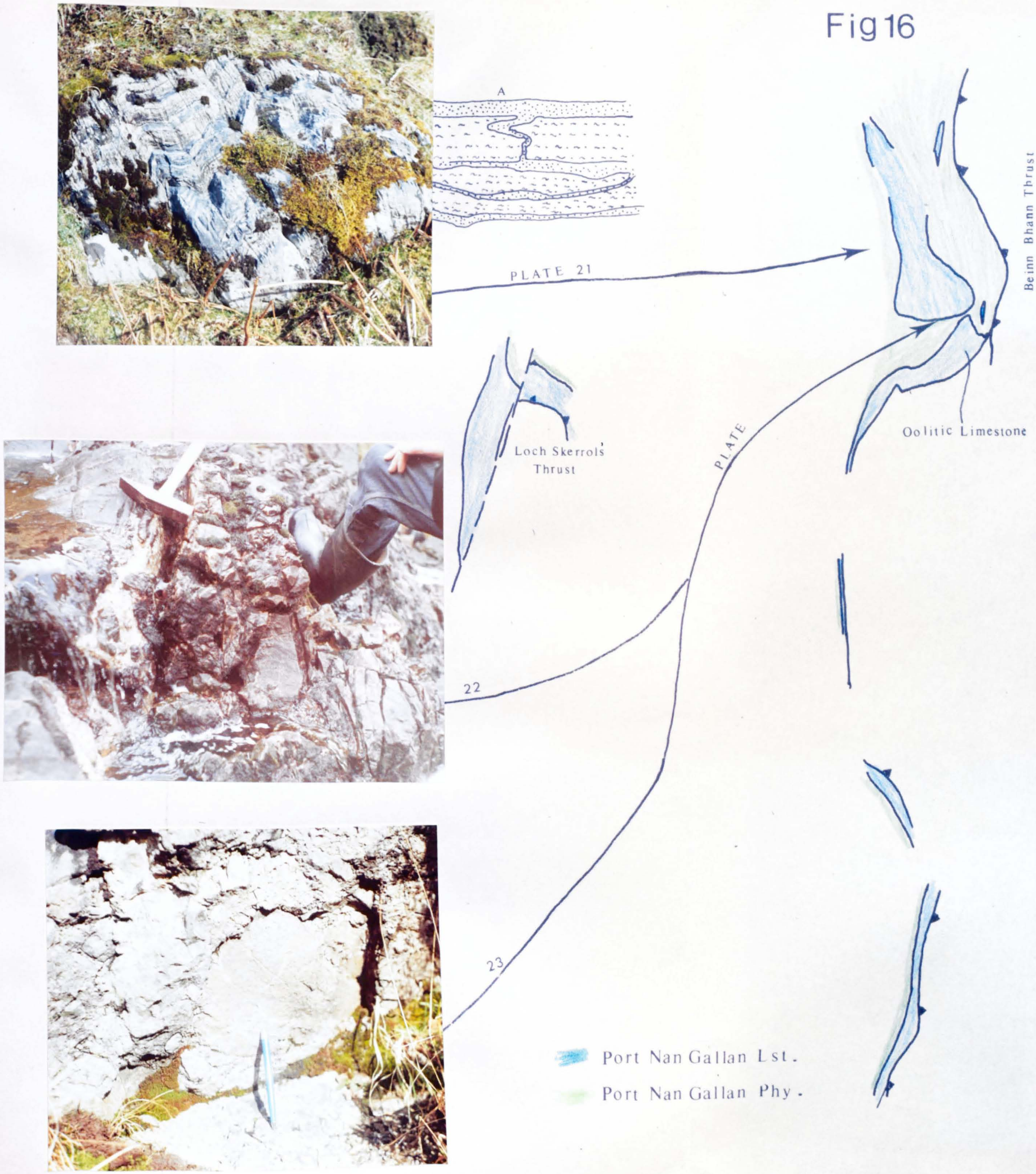
Spencer (1966) described this phyllite, east of Loch Lossit underlying unconformably the Portaskaig Boulder Bed; he regarded this phyllite as the uppermost part of Port nan Gallan Limestone (Islay 1st). The writer visited the Lossit area and from the mapping carried out in southern Islay, believes that Loch Lossit is an early F_1 fold (fig 48) refolded later by Islay and Oa Anticline F_2.

Plate 21. Typical rock of Port nan Gallan Phyllite. Note the banded psammite and siltstone in the rock. These bands have a thickness of 5 inches.

Plate 22. and 23. Note the brecciated rocks of the Port nan Gallan Limestone, marked by the hammer head and the blue pen. The breccia preserve an early cleavage (pre-faulting).

Plate 23.

Fig 16


A
PLATE 21
Beinn Bhann Thrust
Loch Skerrols Thrust
PLATE
Oolitic Limestone
22
23
Port Nan Gallan Lst.
Port Nan Gallan Phy.

The Middle Dalradian

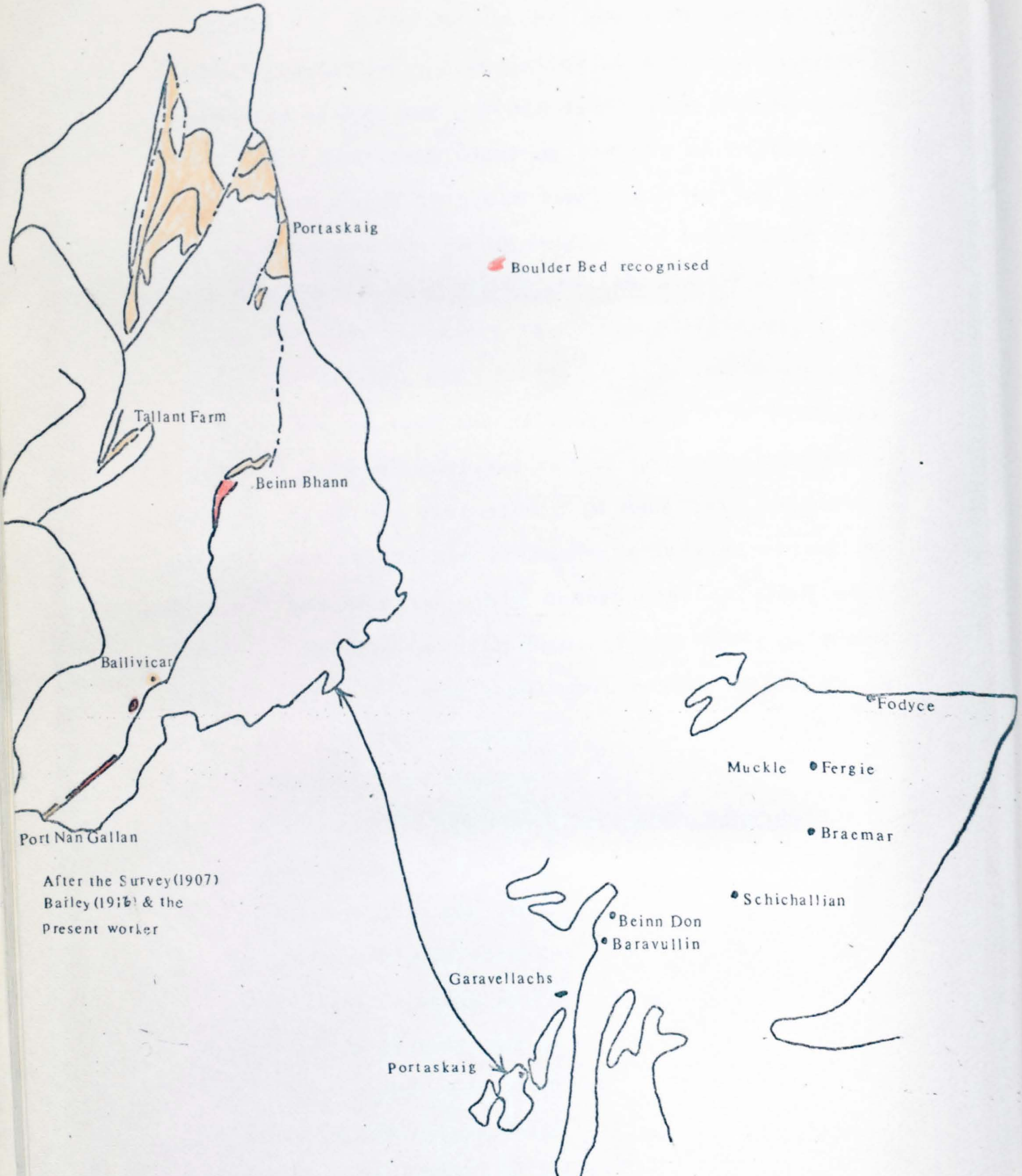
In this thesis all of those rocks above the Port nan Gallan Limestone are placed within the Middle Dalradian, which is marked by the Portaskaig Boulder Beds at its base (Rast 1963). The Middle Dalradian succession is exposed in three districts. In Central Islay, on the north-west slope of Beinn Bhann and in the north-west of Tallant Farm; in the south-east of the Oa and in Kildalton, which form the south-east limb of Islay Anticline. These rocks are referred to as Kildalton and Oa succession. The general lithology consists of Boulder Beds at the base of the Middle Dalradian, marking the unconformity with the Lower Dalradian, followed by a dolomitic and thick horizon of quartzite with a graphitic bed at its top, passing into phyllite interbedded with quartzite and limestone, becoming grity quartzite at its top most part. Ten Units can be mapped from these localities as follows:-

<u>Top</u>	Ardmore Grit
	Ardmore Conglomerate
<u>Laphroaig formation</u>	{ Kildalton Limestone
	{ Laphroaig Quartzite
	Port Ellen Group
	Scarba Conglomerate
	Jura Slate
	Islay Quartzite
	Dolomitic Group
<u>Bottom</u>	Portaskaig Boulder Bed

<u>Portaskaig Boulder Bed</u>

Because of its critical significance a detailed discussion is required.

Fig 17



Location of The Portaskaig Boulder Bed

After Spencer & Pitcher (1968) Litherland (1970)

The Portaskaig Formation in the Dalradian of Scotland and Ireland has long been known as "the Boulder Bed" because of the occurrence within it, of granite boulders of all sizes, dispersed through thick, unbedded pelitic quartzite. The Boulder Bed as a whole contains many such individual bouldery horizons separated from each other by horizon of normal bedded sediments, mostly dolomites, siltstones and quartzites.

Stratigraphical Position in the Dalradian

The Portaskaig Boulder Bed forms an excellent marker within the Islay succession of the Dalradian occurring between Port nan Gallan Limestone and the overlying Islay Quartzite, along a strike section which stretches from Perthshire in Scotland to Cannemara on the west coast of Ireland. Rast (1963 p. 125) has used the Boulder Bed to define the base of the Middle Dalradian within his stratigraphical division of the Middle Dalradian (map 1). The position of the Boulder Bed within the Islay succession is shown in (fig 17).

Previous Work

The earlier work on Islay is summarized in the Geological Survey Memoir (Wilkinson et al 1907 p. 6-8) and the subsequent work resulting from the paper by Bailey (1918) on the Islay Anticline, is summarized by Allison (1933 pp. 128-9). The survey recognized the overall Juxta position of the Port nan Gallan Limestone (Islay Limestone). The Portaskaig Boulder Bed, the Lower Fine Grained Quartzite (part of the Portaskaig Boulder Bed), and the Dolomitic Group; the way of these formations was determined by Bailey and confirmed later by Allison

In 1960 a paper by Pitcher and Shackleton discussed the succession in the Garavellach Islay in relation to the succession within the Portaskaig. Kilburn, Pitcher and Shackleton (1965 p. 388) suggested a thickness for the first time.

In 1966, Spencer (Ph.D. Thesis) gave a detailed stratigraphy of the Boulder Bed and suggested the thickness of the Portaskaig Boulder Bed in the title area. He suggested a thickness of 750 m. for the Boulder Bed in Islay (1966 p. 347), which is much thicker than the Garavallach. These thicknesses will be discussed later.

The Outcrops of the Portaskaig Boulder Bed in Southern Islay Spencer (1966) and other previous authors recognized five area, which were first recognized by the Geological Survey Map. The author's have examined the areas 3, 5 and 6 in more or less detail, and visited the outcrop area (1) with Spencer. The stratigraphic succession in (fig 17) is the result of the work from localities 3, 5 and 6 which have been examined in detail and which have provided most of the information.

<u>The Boulder Bed in Port nan Gallan</u>

The boulder bed here is fairly well exposed along the shore of the Port nan Gallan, and in the cliffs facing it (plate 12). The relation of the Boulder Bed with the underlying Port nan Gallan Limestone and the overlying Islay Quartzite is well observed and very well exposed; the Boulder Bed lying unconformably (fig 18a) over the Port nan Gallan Limestone. The following units have been established in the area, part of the exposure to the south-east is concealed by the higher water tide.

Plate 24. Boulder bed from Port nan Gallan. Note the boulders of limestone, granite and quartzite,

Plate 25. Note the small scale sandstone dyke cutting across the bedding plane, and folded. Also note the alignment of the pebbles with the S1 and S2 cleavage.

Plate 26. One outcrop of the Boulder Bed recognized in the Oa. Note the dolomite and quartzite boulder in the sandy matrix.

Plate 27. The conglomerate bed within the Portaskaig Boulder Bed is very clear, on the northern slope of Beinn Bhann.

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Fig 18

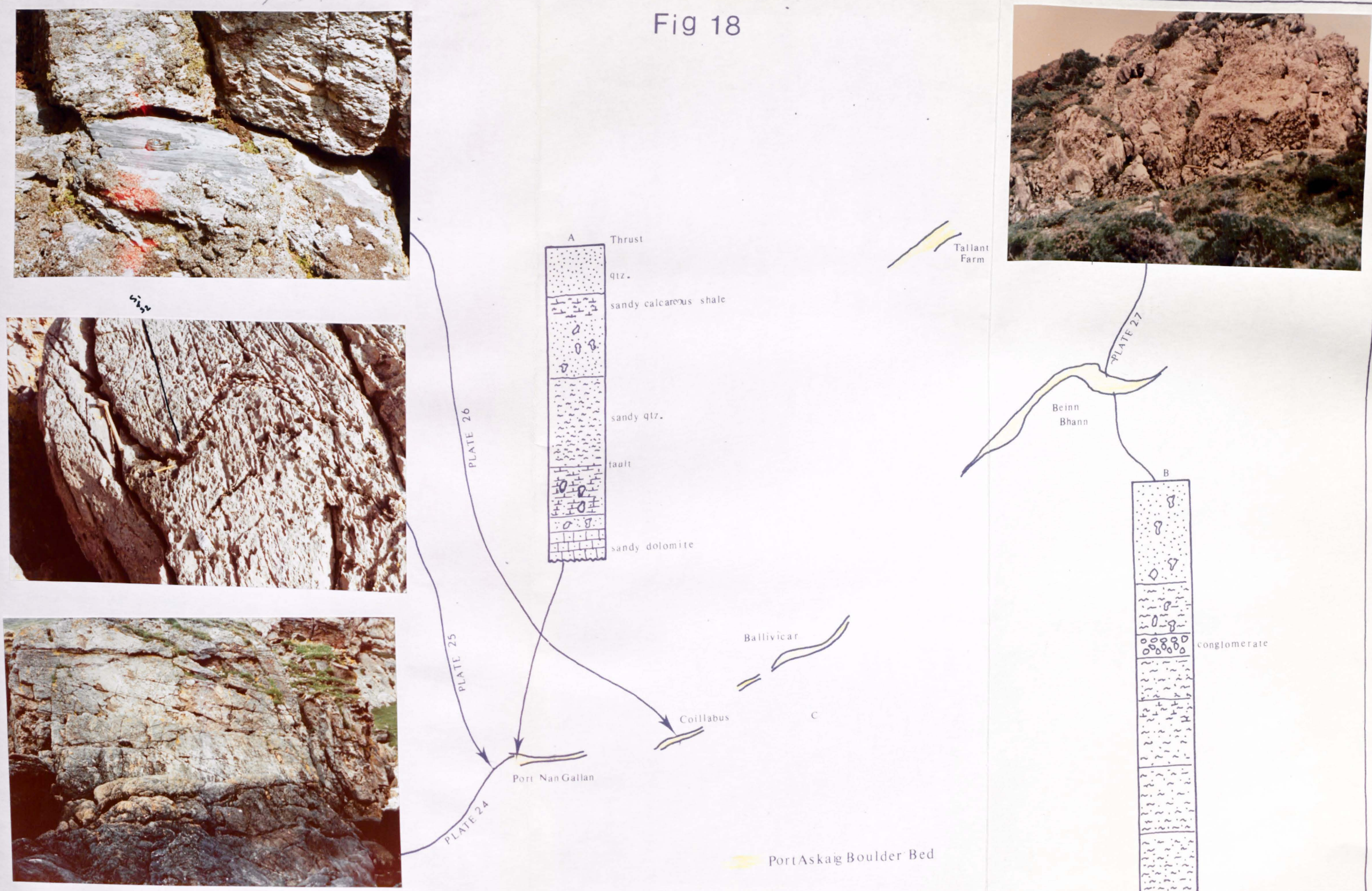


PLATE 26
PLATE 25
PLATE 24
PLATE 27
A
Thrust
qtz.
sandy calcareous shale
sandy qtz.
fault
sandy dolomite
Tallant Farm
Beinn Bhann
B
conglomerate
Ballivicar
Coillabus
C
Port Nan Gallan
Port Askaig Boulder Bed

The contact of the Boulder Bed with Port nan Gallan Limestone is very well exposed in the area to the west of Port nan Gallan. There (fig18a) the lowest Boulder bearing horizon is sandy dolomitic 1 meter in thickness and lies disconformably on the top of the Port nan Gallan Limestone. The boulders are of limestone and granite, the later forming less than 28 of the clasts and pebbles of quartzite. Overlying the basal dolomitic bed is a thin, sandy quartzite with boulders of limestone and granite. Next in order comes 4 meters of sandy calcareous shales with rusty weathering, containing slightly larger boulders (up to 1 foot long) of yellow and red dolomitic limestone, quartzite and granite. The boulders in the above-mentioned beds are elongated parallel to the bedding plane and S_1 cleavage (pl. 25), the longest pebble axes trending approximately to the north-east. Cracks have developed almost parallel to the intermediate pebble axis. Nowhere else in Southern Islay is this phenomenon observed. The calcareous beds are followed by a sand dolomitic bed 2 meters thick with pebbles of quartzite 2" in diameter and no boulders of either granite or limestone are found in it. The contact between these two dolomitic and the underlying shales is a tectonic due to a strike slip fault at their junction; the Geological Survey (1907) has also recognized the same. Following this bed is a succession (fig18a) of 4 beds: sandy shale, alternatively with thin quartzite, the thickness of this succession is 9 meters. Overlying this succession is quartzite bed 3 meters thick including boulders of granite only. The overlying two beds are of sandy calcareous shale, and sandy quartzite;

they measure 4 meters in thickness.

The top of the Boulder Beds in the Port nan Gallan is truncated obliquely by the Bheinn Bhann thrust under the Islay Quartzite. A fault running north-west south-east displaces the Boulder Bed in the north-east cliff facing the Port nan Gallan to the south-east. Most of the above beds are missing or probably burried under the recent deposits; however the boulder beds are still represented by 10 meters of a sandy calcareous bed at its bottom to sandy shale at the top; boulders of limestone are recorded in the lowest beds; no other boulders have been observed.

Several small exposures of the Portaskaig Boulder Bed outcrop at localities (2 and 4) (fig18b); scattered limestone boulders are seen at these localities, sandy shale with quartzite pebbles at the top of the beds. These exposures are sufficient to indicate that the Boulder Bed in Islay is continuous persisting for about 20 miles along the strike.

Beinn Bhann Boulder Bed

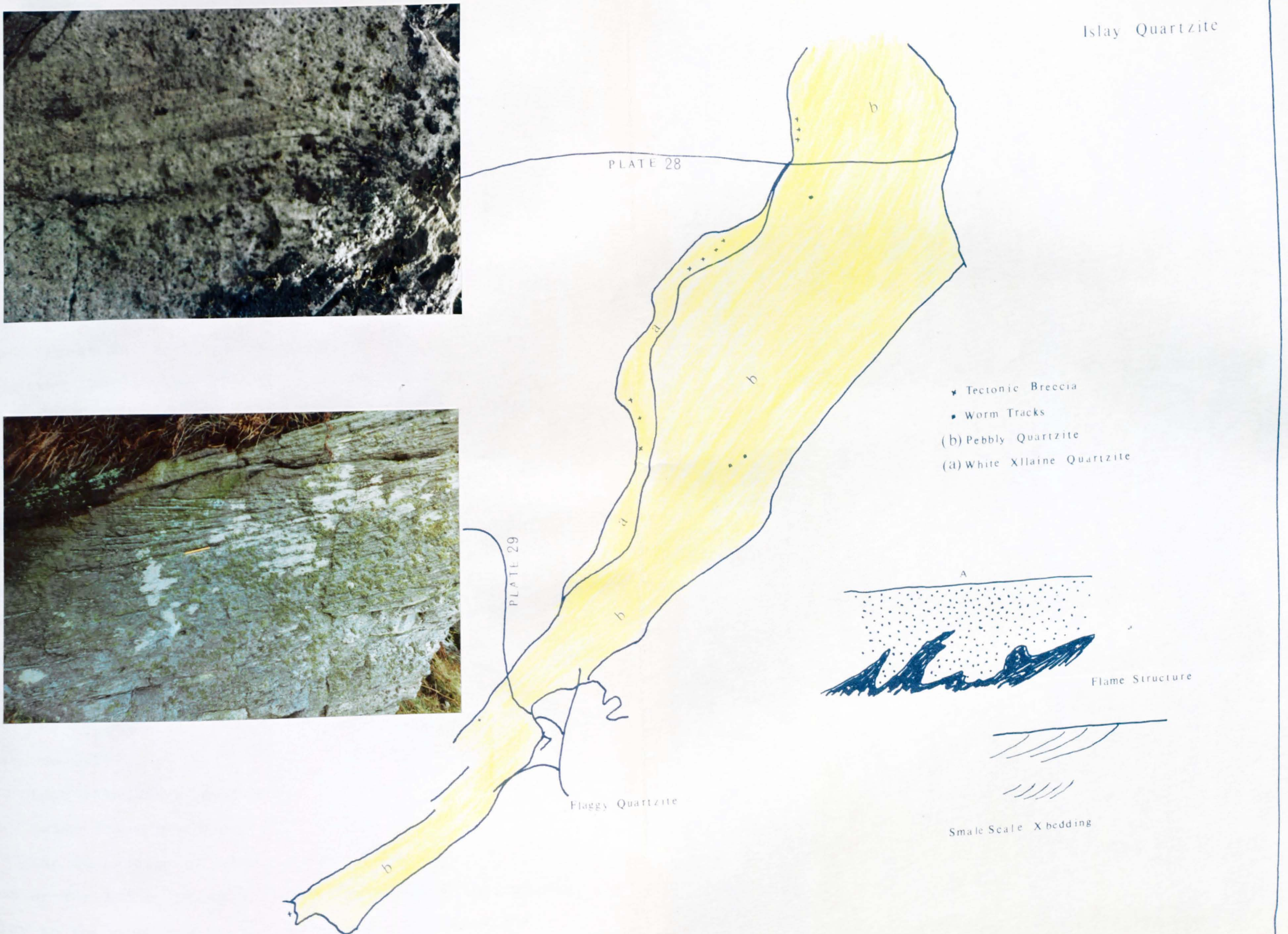
The Boulder Bed which outcrops on the north and north-west of Beinn Bhann (fig18c) (G.R.3855), stretches to the north-east and the south-west for about 3 miles.

Seven boulder beds (fig18b) interbedded with quartzite, limestone and siltstone occur at Beinn Bhann. All of the seven beds contain outside derived clasts (interbasial), the lower four have interbesial and dolomitic clasts (the interbasial (granite)) clasts having slightly higher in percentage than the dolomitic one), where as the fifth and the sixth beds contain only interbasial (granite) clasts with few scattered dolomitic ones. The topmost boulder bed in this area is quartzitic and is exposed along the north-west of Beinn Bhann. An unstratified packite conglomerate (plate 27) bed resting on the top of the first four boulder beds separates the later from the overlying two. Spencer (1966) recognized this bed as a member bed in resolving the stratigraphy and the structure of the Portaskaig Boulder Beds. He regarded the presence of such a conglomerate, as evidence of the action of extremely powerful water currents, which are most likely to occur in an interdial or fluvial environment. The conglomerate was deposited as a result of the removal of the sand and silt from the sediments by melting ice bergs, by settling through water and later transportation of the boulders by current action. This conglomerate overlies Boulder Bed No. 35 of the Upper Boulder Bed (Spencer 1966) in the Garavellach succession, and is absent from Islay succession. If this is so, then the conglomerate is a product of erosion, following a local uplift (stratigraphic break). This deduction is reasonable since there is no proof of any tectonic events at the base of the conglomerate, and secondly since bed No. 35 is absent from Islay succession. Lithologically, the conglomerate bed in the Garavellach has granite clasts only, whereas the conglomerate at Beinn Bhann and in the Portaskaig includes granite, limestone and quartzite clasts. The present writer also found phyllite clasts within the conglomerate at Beinn Bhann. The later changes in the lithology of the conglomerate can be attributed to the uplift and resulting deeper local erosion.

Plate 28 and 29

Large and small scale cross-bedding are often seen and recognized in the Islay Quartzite. Here are two plates from two localities, showing the typical cross-bedding in the quartzite; both show younging direction to the south-east.

Fig 19



Islay Quartzite
PLATE 28
PLATE 29
b
a
* Tectonic Breccia
• Worm Tracks
(b) Pebbly Quartzite
(a) White Xllaine Quartzite
A
Flame Structure
Flaggy Quartzite
Smale Scale X bedding

The Dolomitic Group

This group is exposed only on the north-west slope of Beinn Bhann. The persistant non-appearance of the dolomitic group elsewhere is due to the intervention of the Beinn Bhann thrust. Bailey (1916 p. 158) regarded its disappearance as a result of a stratigraphic thinning the (Dolomitic Group) in a southerly direction. This claim has no basis and mapping shows it that the Beinn Bhann thrust plays a big role in the thinning and disappearance of the succession in the south-east limb of the Islay Anticline. Also the thinning may be that which occurs in the limbs of similar-type folds (Class 2, Ramsay 1962); this argument is supported by the fact that the Islay and the Oa Anticlines are similar-type folds.

The Dolomitic Group is composed of a sequence of white, yellow and brown dolomitic rocks, interbedded with dolomitic, green phyllite on 1.5 mm thick, and the result is a dominently bounded lithology. This group underlies the Islay Quartzite and overlies the Portaskaig Boulder Bed.

The Islay Quartzite (fig 19)

The following succession has been determined in Southern Islay.

Loch Allallaidh Quartzite

Beinn Bhann Quartzite

The succession is well exposed along the south-east limb of the Islay Anticline stretching from the Sound of Islay to the Port nan Gallan in the Oa. It forms the thickest units in the area.

Beinn Bhann Quartzite

This unit is stratigraphically younger than the Dolomitic Group. In places it overlies the Dolomitic Group, while in others it overlies the Boulder Bed or even the Port nan Gallan Limestone; this angular unconformity is due to the Beinn Bhann thrust. The quartzite is white, vitreous and fine grains. Its best seen in Beinn Bhann and contain sedimentary channels occasional cross-bedding and a few small scale sedimentary dykes.

Loch Allallaidh Quartzite

This unit is thickest of the sequence and very well exposed in the Oa and Kildalton; extending from the Sound of Islay about 300 meters from Portaskaig to the Port nan Gallan in the Oa.

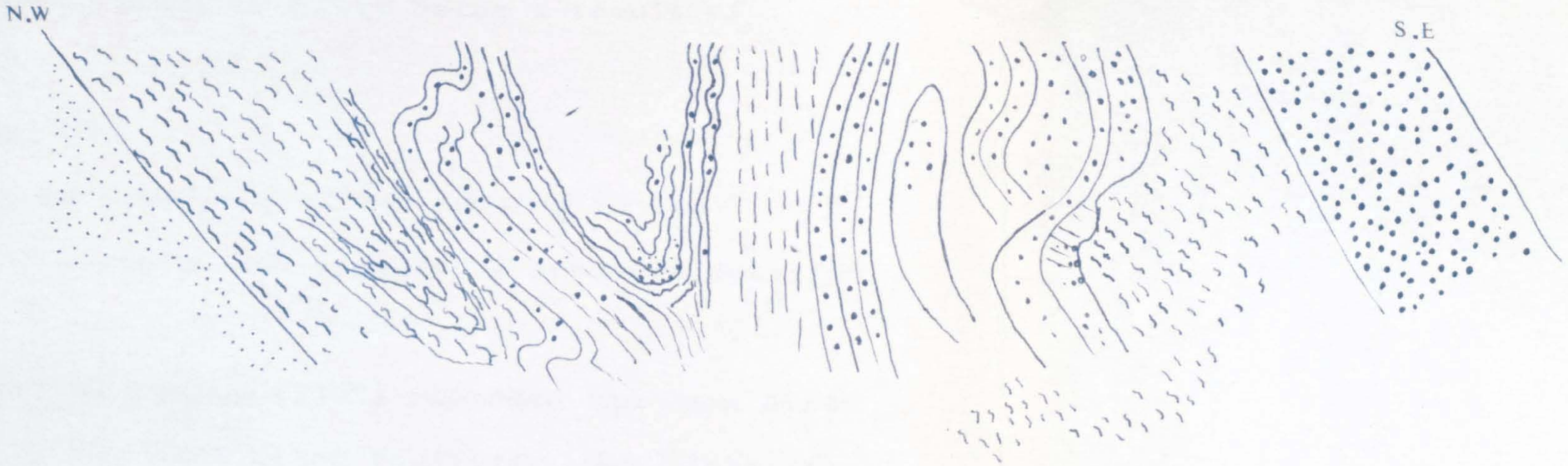
The rock is a coarse, pebbly (pebbles reach 5 mm in diameter) intercalated with thin schist at its top. At Kilnaughton Bay 1½ miles west of Port Ellen the Quartzite is flaggy and slightly schistose.

The Loch Allallaidh Quartzite becomes an outstanding lithological unit, when it is traced to the south-west slope of Beinn Bhann. Cross-bedding and grading are found almost in all the exposures of the quartzite and in particular are very good in this locality (plate 28 & 29), slump folding and large scale sedimentary dyke injections are also observed. The graded and cross-bedding and other primary structures show younging to the south-east. The rock has a constant strike to the north-east, except at Rubha Biorach (south of McArthur's Head); the strike swings to the north-south direction. This might be due to the effect of the break of Jura and Islay (Sound of

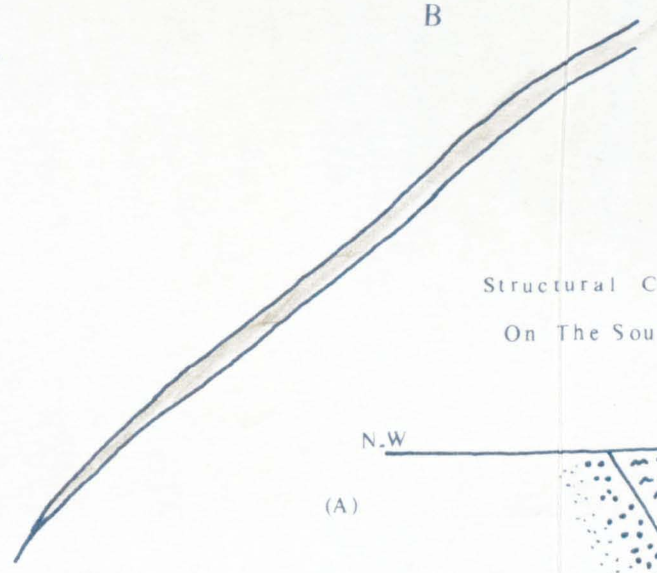
Plate 30. This plate shows the typical Jura Slate. The plate is taken from the shore near Port Ellen Lighthouse. Inland the slate is pure and has been quarried.

Fig 20

Jura Slate



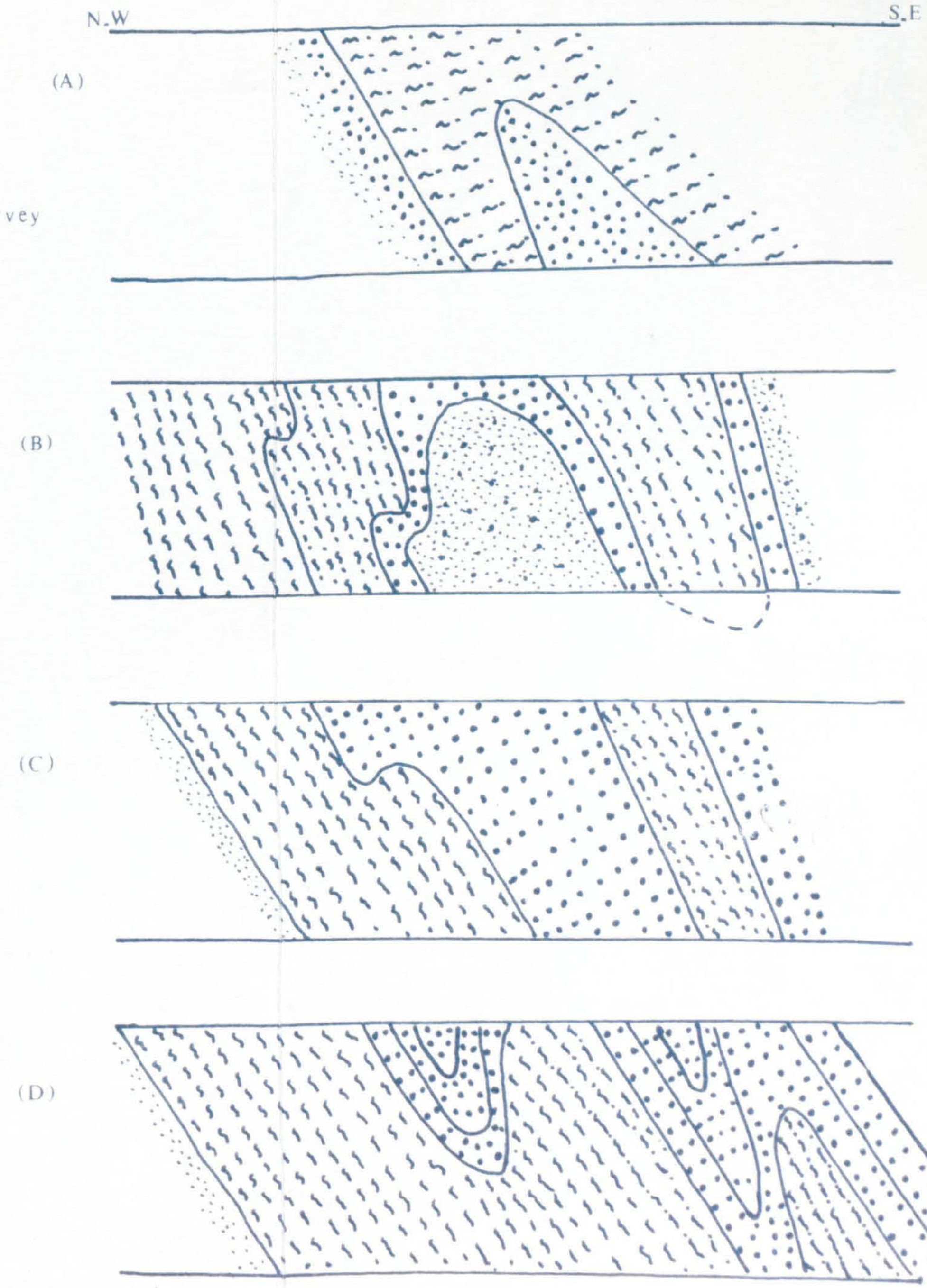
Detail Cliff Section of Alt An Daimh

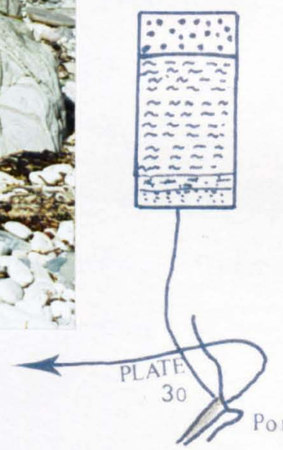


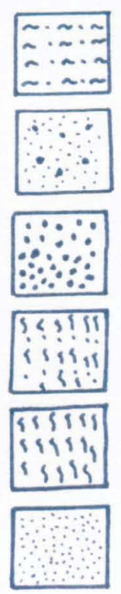
A

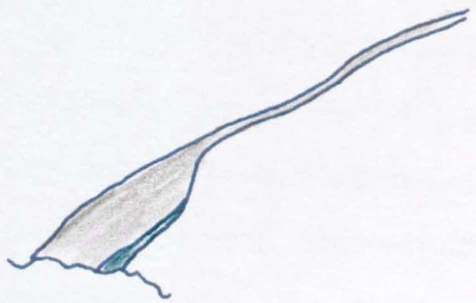
Structural Cross Section of Alt An Daimh

On The Southern Coast









Alt An Daimh

Islay); the later break probably being a result of faulting.

Jura Slate (fig 20)

This unit is a subject of controversy in its stratigraphical position and requires a somemore detailed discussion :-

The Geological Survey (1907) regarded the Jura Slate as an up-fold of the Port Ellen Phyllité. The Slate fragments have accordingly been taken as conclusive evidence that the Islay Quartzite is of later age than the Port Ellen Phyllite. Gregory (1928), Peach and Horne (1930) agreed with the Geological Survey that the Jura Slate is older than Islay Quartzite. Bailey (1916) has proved that the Jura Slate is younger than the Islay Quartzite and older than the Scarba Conglomerate (fig20b). Allison (1933) agreed with Bailey on the stratigraphic position but differed with him as to the structure (fig20c).

The Jura Slate is best exposed north Port Ellen Lighthouse and on the southern coast at (Alt an Daimh). The later is the type locality of the controversy. Other exposures occur along its strike and have the same stratigraphic position as described below.

At the Port Ellen Lighthouse, the slate is grey to black, and overlies the Loch Allallaidh Quartzite. Here the slate is not affected by any structure, and its position is clear. A 5 meter zone of quartzite muscovite-bearing and talcore in appearance is observed at its base. Overlying the slate is the Scarba Conglomerate; the junction is marked by a facies changes and slumps of slate form a part of the Conglomerate.

The present writer agrees with Bailey on the stratigraphic position of the slate as exposed at the cliff of Alt an Daimh, but differs from both Bailey and Allison on the structure (fig20d). The slate is grey impure at the bottom becoming graphitic at its top. To the west of this locality Loch Allallaidh Quartzite passes upwards towards the grey slate with a well observed transitional zone. The slate has been folded in a series of folds, and the lack of detailed mapping resulted in the previous conflicting interpretations. Graded bedding and cleave/bedding relationship (Shackleton 1957) either in the quartzite, the slate or the conglomerate, leave no doubt that the slate is older than the Scarba Conglomerate and younger than the Islay Quartzite.

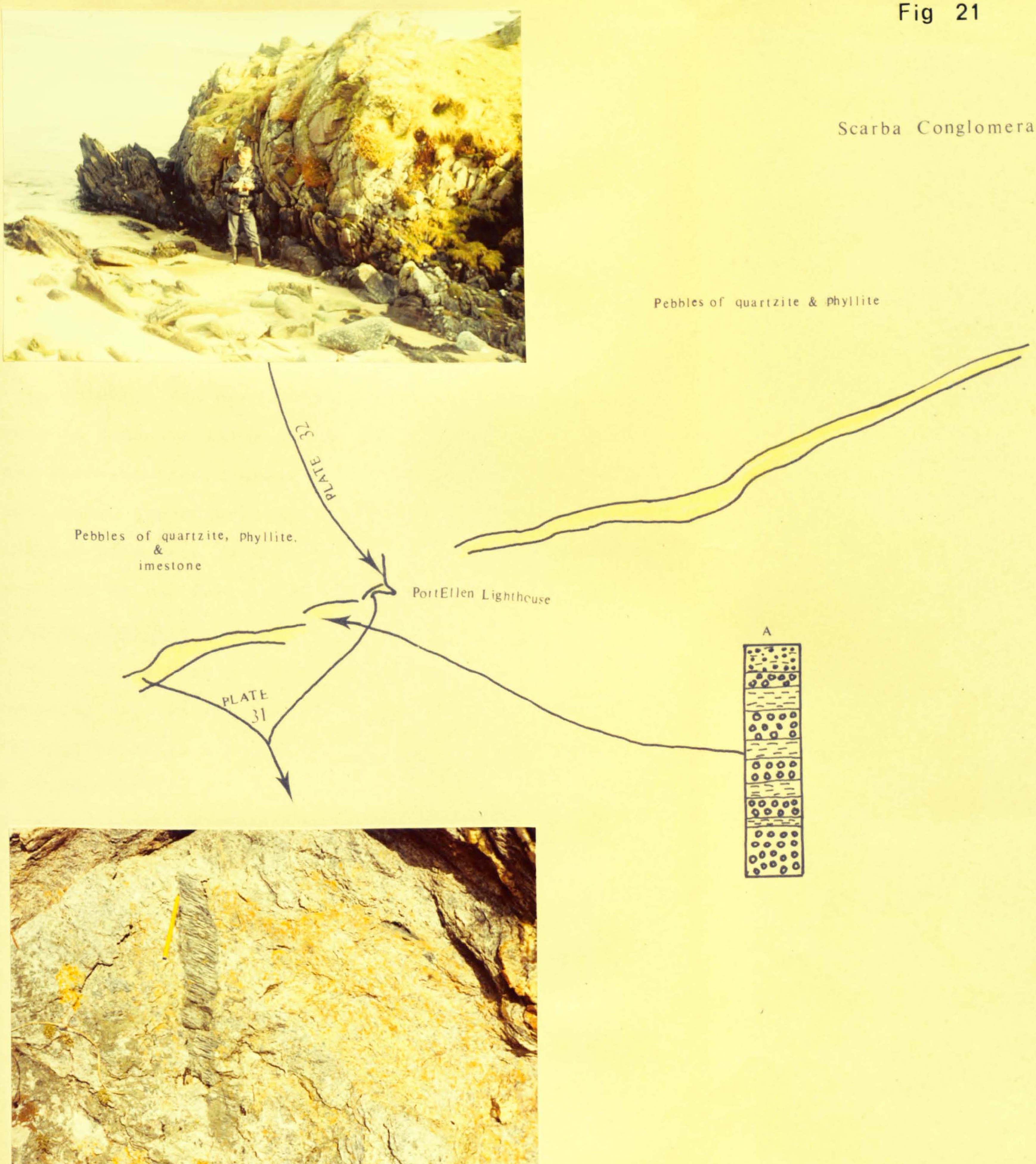
Scarba Conglomerate (fig 21)

This unit is best exposed at the Port Ellen Lighthouse, at Alt ant Sailich 300 meters south of the Lighthouse and on the east cliff of Alt an Daimh; other good exposures are at the Oa and Kildalton. The conglomerate consists of several horizons (each 50 cm thick) separated by shale beds (fig21a); the shale is greyish red, dolomitic with a reddish weathered surface. The conglomerate is composed almost entirely of rounded white and blue quartzite pebbles, enclosed in a quartzofeldspathic matrix. Pebbles and boulders of black graphitic slate (plate 31), phyllite and dolomitic limestone; the later are the least numerous. The quartzite pebbles are elongated, varying in length from 3.8 cm and gently plunge in the north easterly direction. The conglomerate shows a facies change with the underlying (Jura Slate) and overlying (Port Ellen Phyllite rocks).

Plate 31. This plate shows graphitic slumps in the Scarba Conglomerate, indicating that the Scarba Conglomerate is younger than the Jura Slate.

Plate 32. Here the junction between the Jura Slate and the Scarba Conglomerate is well shown. Note the antiform in the conglomerate and the isoclinal folds in the Jura Slate. The junction between the two are marked by a small slide. Grading in the conglomerate shows younging direction to the south-east.

Fig 21


Scarba Conglomerate
Pebbles of quartzite & phyllite
PLATE 32
Pebbles of quartzite, phyllite, & imestone
PortEllen Lighthouse
A
PLATE 31

Port Ellen Group (fig 22)

This group is exposed in Kildalton and the Oa. The following units have been recognized in the above localities.

Top Port Ellen Flagstone

Port Ellen Phyllite

Bottom Kilbride Limestone.

Kilbride Limestone

This limestone is exposed only at Kildalton (fig22b), 100 meters north of Kilbride farm, 2 miles north-east of Port Ellen village. The limestone is sandy and yellow to grey in colour. The rock overlies the Scarba Conglomerate. Nowhere in Southern Islay is the limestone exposed, except at the above-mentioned area; elsewhere it may however be covered under the superficial deposits. In the Oa and north-east Kildalton in particular the Scarba Conglomerate is overlain by the Port Ellen Phyllite.

Port Ellen Phyllite

The rock is highly deformed, compared to the rocks surrounding it. It is also the locus of a large number of epidiorite sills which have affected the rock so badly that in some places it is impossible to map. The phyllite is intensively folded particularly in Port Ellen village and in the Oa.

The prevalent rock type is a silvery-grey, sandy phyllite interbedded with quartzite and sandy calcareous beds (2.5 cm) thick. In the Oa the phyllite, at its junction with Scarba Conglomerate, is represented by a 12 meter zone of semi-pelite (plate 33).

Port Ellen Flagstone

The unit is composed of interbedded phyllite, quartzite and limestone beds, 30 cm thick. The phyllite is green and chloritic; the quartzite has a greenish dirty colour; the limestone is sandy and yellow in colour. In some places the quartzite beds show irregularities at their base (fig22a); the later show rhythmic undulations, with slightly rounded crests directed upwards. The phyllite below follows the undulations, coarse grains occupying the hollows. This indicates that the undulation formed early enough to effect the deposition. Also spheroidal shapes "probably grains" have developed at the base of some quartzite beds, developing later into concretion - like shapes (fig22e). Ripple marks large undulation of unknown origin and sedimentary dykes are also recorded (fig16a). The flagstone passes up-ward into the Laphroaig Quartzite.

Laphroaig Formation (fig22b)

This formation is exposed only in Kildalton, and consists of thick quartzite interbedded with phyllite at its top becoming calcareous at its top most part. The following units have been described.

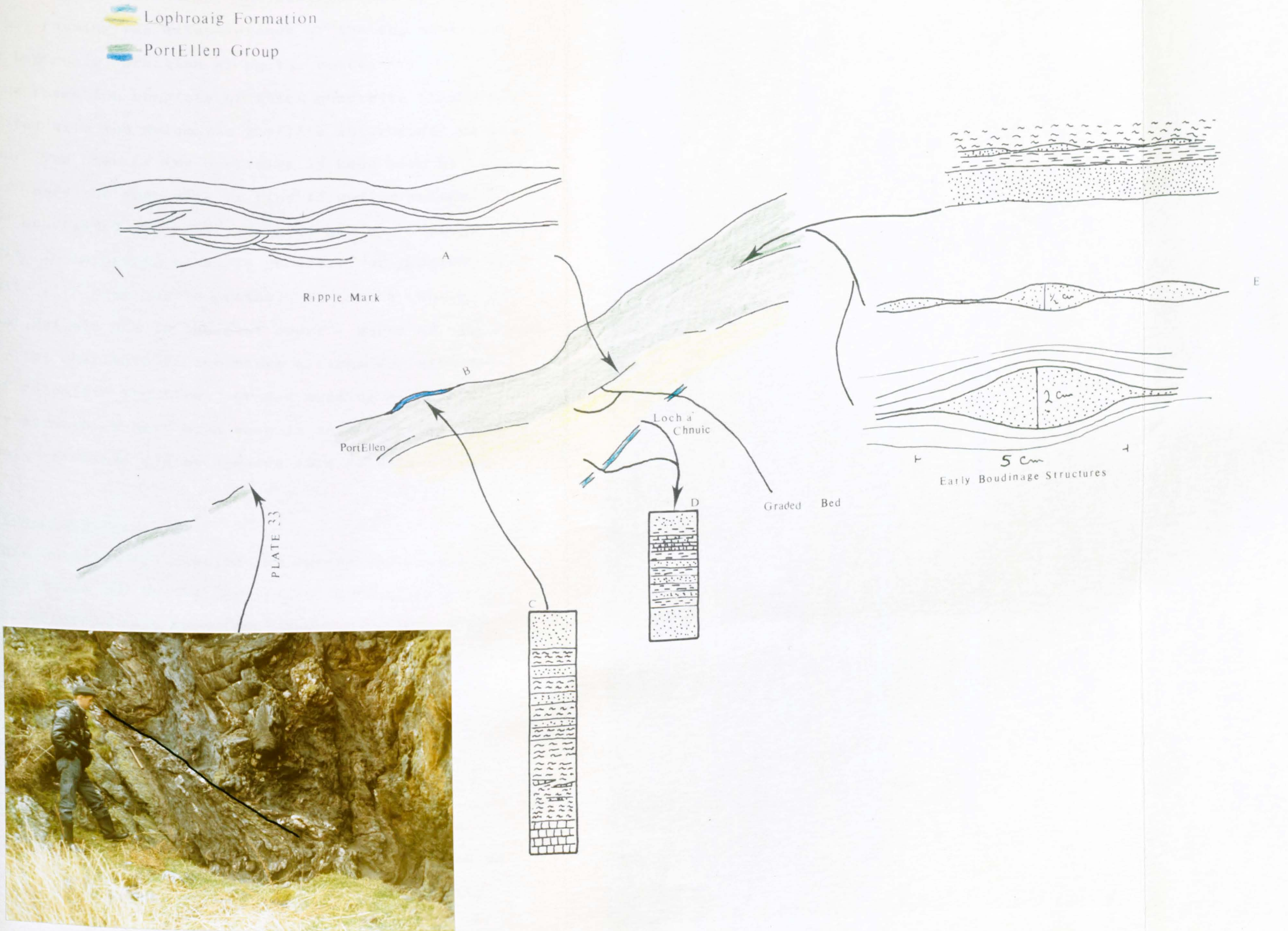
Top Kildalton Limestone

Bottom Laphroaig Formation

This formation follows directly to the south-east of Port Ellen Flagstone. It extends along the south-east coast from soth-east Laphroaig to the north Kildalton house and forms the rocks of the Isle of Texa. Epidiorite sills are

Plate 33. This plate shows the transition zone between the Scarba Conglomerate and the Port Ellen Phyllite. Note the slump structure in the phyllite.

Fig 22



Lophroaig Formation
PortEllen Group
A
Ripple Mark
B
PortEllen
Loch a' Chnuic
Graded Bed
C
D
E
½ cm
2 cm
5 cm
Early Boudinage Structures
PLATE 33

common throughout this area, and disturb many of the outcrops, causing the disappearance of the top most part of the Laphroaig Formation along the coast.

The Formation consists of thick quartzite (Laphroaig Quartzite) with red dolomitic phyllite interbedded within its top. The base of the quartzite is best seen at Loch Iarnan; here the quartzite is fine to medium grains ("poor" quartzite) and preserves good graded bedding. The quartzite in Laphroaig consists generally of reddish, gray quartzite with blue quartz grains. At Loch a Chnuic, at Loch Ant Saicein and in the east coast - north of Kildalton House - the quartzite is schistose alternating with thin beds of dolomitic phyllite. Graded bedding and other primary structures have been seen in some outcrops. The Laphroaig Formation passes upwards into Kildalton Limestone.

Kildalton Limestone

This unit is best exposed 100 meters south-west of Kildalton House and in the east coast of Ardilistry Bay. No other outcrops have been found due to the nature of the terrain which is either badly affected by the epidiorite sills, or entirely covered by peat. The limestone is sandy, brown to buff in colour and has a thickness of 8 meters; its top is not seen.

Ardmore Conglomerate (fig 23)

The Conglomerate is exposed in the south-east of Kildalton and stretches for about 2½ miles from Rudha na Muirlain (300 meters from Ardilistry Bay) to the east coast.

Its phenoclasts are quartzite pebbles, phyllite and reddish dolomitic limestone boulders up to 25 cm long (plate 34 and 35). The conglomerate shows very good graded beds and facies upwards (pebbles size decreasing to 3.5 mm in diameter). The pebbles are elipsoidal to rounded and tend to be elongated in the north-east direction. The phyllite pebbles are green and may be of igneous origin. Towards to top of the beds, only quartzite pebbles are recorded. The Conglomerate passes upwards gradually into the Ardmore Grits. The junction of the conglomerate with the underlying rock (the Laphroaig Formation) is not clean, since it is obscured by continuous epidiorite sills.

Ardmore Grits (fig 23)

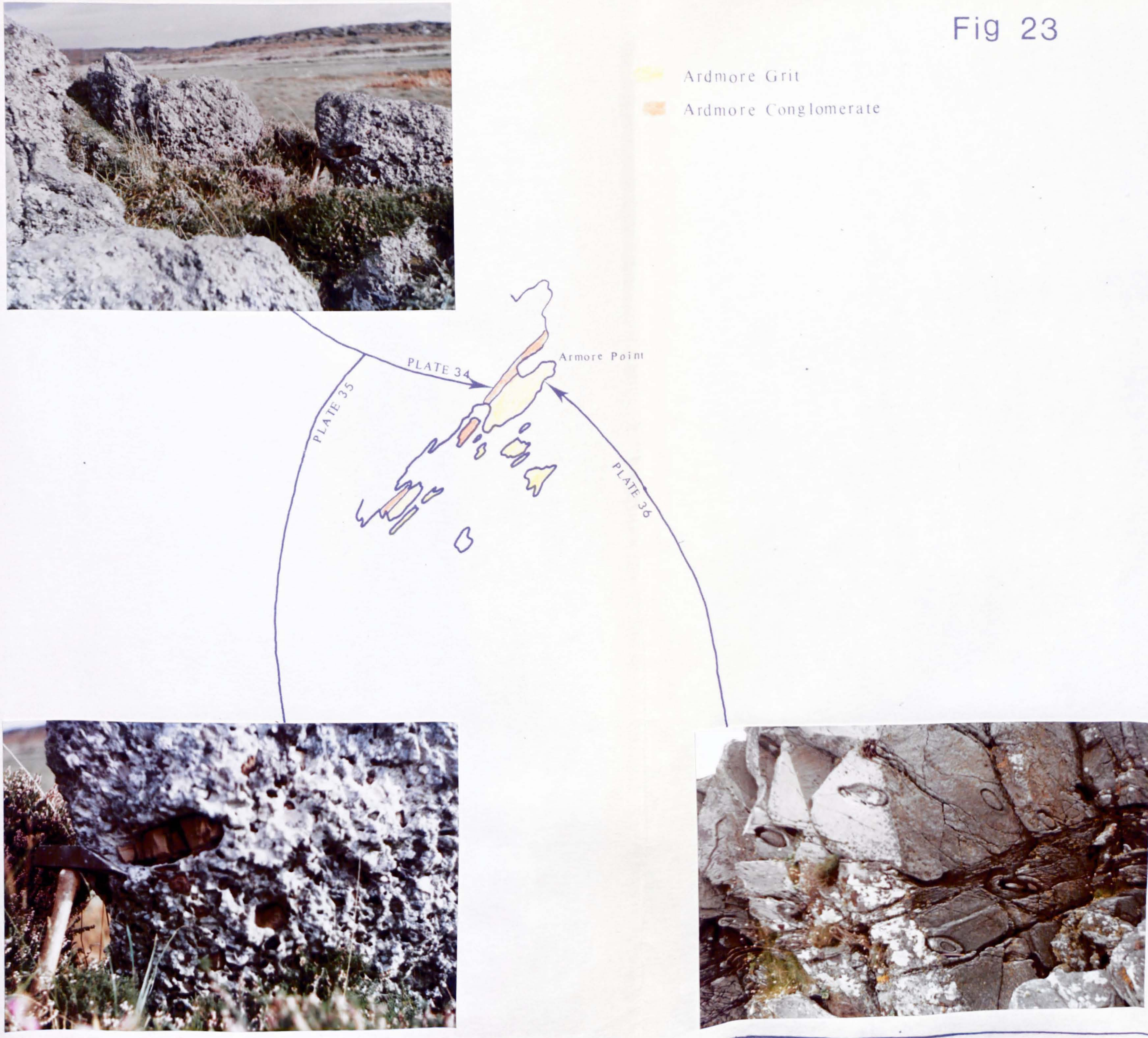
The grits are exposed in the south-east of Kildalton, and overlie the Ardmore Conglomerate. The grits are generally course to medium grained and have a high feld-spathic quartzite, with angular to sub-rounded grains. The quartzite is often thickly bedded (60 cm), it is whole thickness is not accurate since its top is not seen. The quartzite are generally pure; black slate and green phyllite are rarely present. Spherical shapes have been recognized (plate 36), having a constant direction and plunge to the north-east. These spherical shapes are regarded as products of differential in the grits lithology.

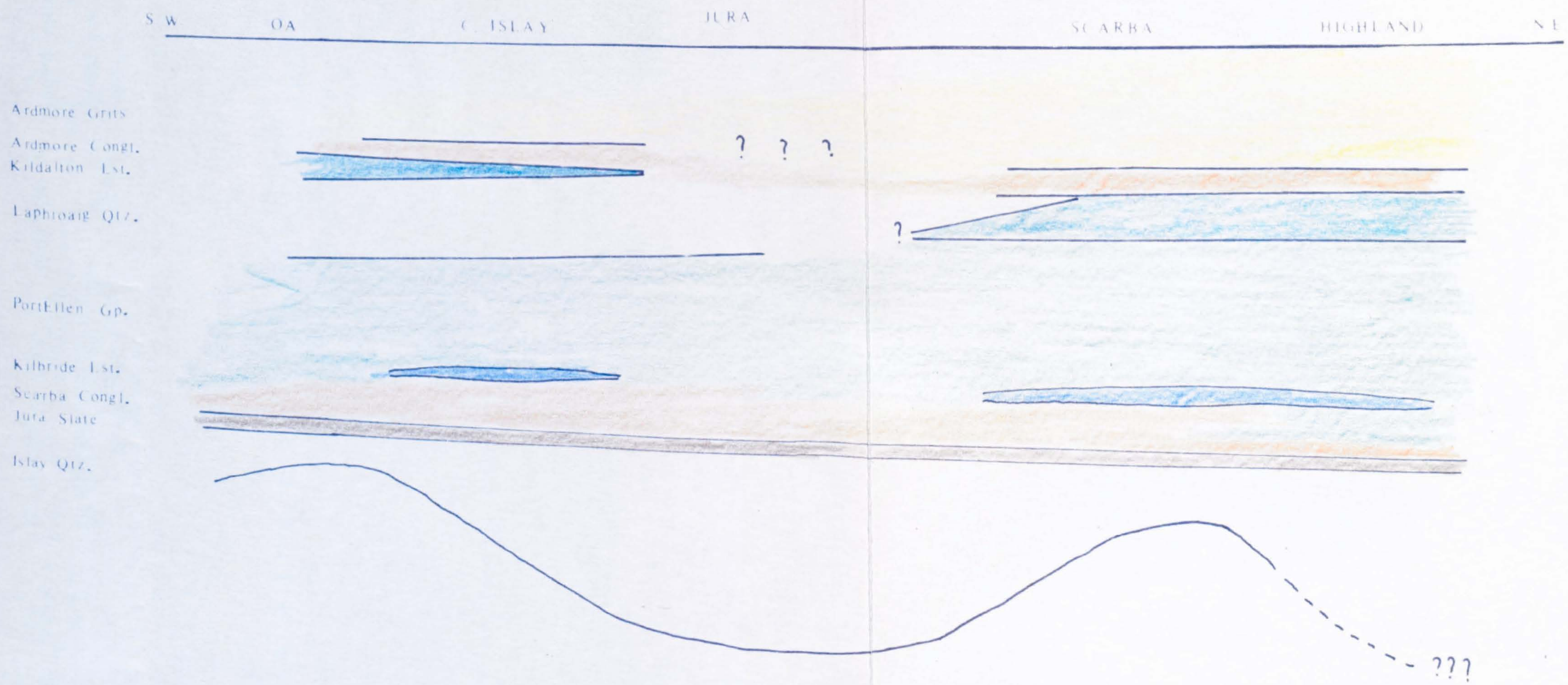
Plate 34. This plate shows the Ardmore Conglomerate, of Middle Dalradian age. Note the dolomitic fragments in the bed.

Plate 35. Close-up photograph of plate 34, showing typical dolomitic boulders and pebbles in the conglomerate.

Plate 36. Typical rock of Ardmore grits. Note the ellipsoidal shape in the grits, as a result of differences in lithology. The ellipsoidal shapes have a plunge coinciding with F2 folds in the area.

Fig 23


Ardmore Grit
Ardmore Conglomerate
Armore Point
PLATE 34
PLATE 35
PLATE 36



Diagrammatic Section For The Middle Dalradian Basin

SECTION 3

SEDIMENTATION

SEDIMENTATION

1. Introduction

The Dalradian stratigraphy and sedimentation have been subjected to vigorous sedimentological interpretation; Bailey 1930, Sutton and Watson 1955, Smith and Rast 1958, Knill (1959, 1963), Shackleton 1961, Watson 1963, Kilburn et al 1965, Roberts 1966, Spencer 1966, Kennedy 1969 and Litherland 1970. The previous workers adopted different techniques: some making use of current bedding and other primary structures to determine the direction of current flow, others making use of sedimentary affiliations for regional correlation. All, however, were faced with several problems e.g. the lack of information due to the absence of detailed mapping; the sedimentary structures are always deformed, resulting in false information, unless unfolded (Ramsay 1961). Even so, there is still a big probability of false information, if the area have been affected by more deformations, or if there is a discontinuity of a unit across the strike.

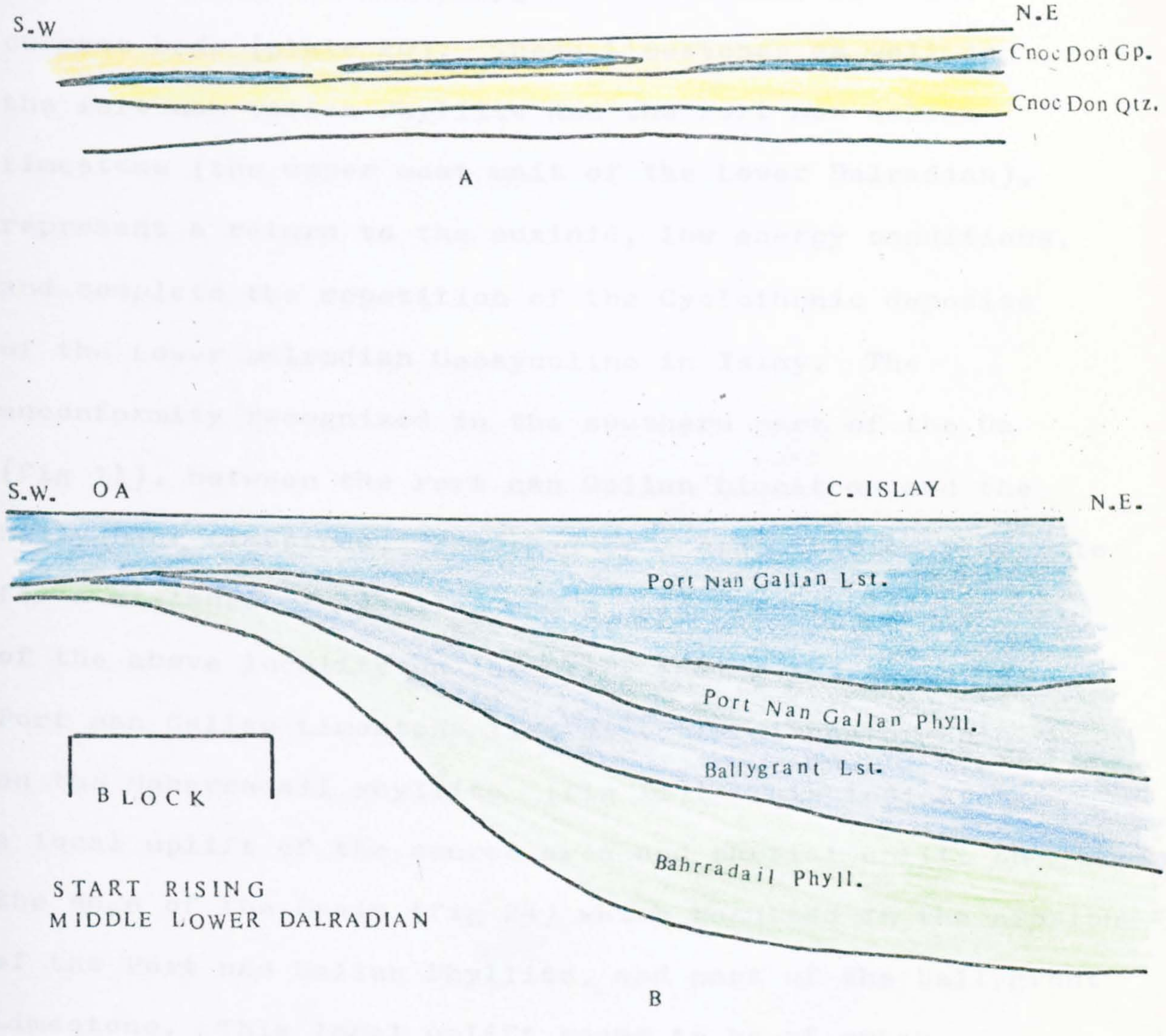
The rocks of southern Islay are well exposed across the strike and form shelf deposit sediments. They also form part of the Lower Dalradian, and the whole of the Middle Dalradian. The metamorphism in Islay is low grade. Thus in this section the present writing has a unique opportunity, in the light of this new information, to interpret the sedimentary history of Islay and if possible to apply to the Iltay and the Ballachulish successions in the mainland of Scotland. Two attempts have been made in resolving the direction of the current flow. First using current bedding (fig 19) in the Lower and Middle Dalradian, and secondly, the elongation of the pebbles in the Scarba Conglomerate. In both attempts allowance has been made for error in readings, and the effect of the strain specially for the pebbles, and correction for both plunge and dip in the palacocurrent measurements has been made. However there are only two major deformations in Islay, these are associated with F_2 folds and F_3 folds. Islay has escaped the first phase of metamorphism associated with F_1 folding the major deformation in the main land of Scotland. Also F_3 folding in Islay is slightly weak, so the correction in the rotation of the palacocurrent, and the pebbles is very small.

2. The Lower Dalradian

The Lower Dalradian Section (2) begins with Moal an Fhithich Quartzite. This quartzite is current bedded, it is pebbly at its base, and interbedded with slates; marked a shallow water deposit of a slightly rough or turbulent nature. The phyllites groups, represent a change in the environment of deposition to a much quieter environments; this can be demonstrated by the first two units of the Kintra Phyllites group section (2). The upper-most unit (the lamenated beds of clay and siltstone) show current bedding in the siltstone; this is an indication of period of some turbulence. These deposits are gradually superceded by sandy dolomitic limestone, and dark graphitic limestone (Kintra Limestone). These are shallow water deposits, representing gradual change from aerated to euxinic conditions. The Kintra Slate which follows the Kintra Limestone has pyrite crystals commonly associated with euxinic conditions. The Cnoc Don Transition, and the Cnoc Don Quartzite represent a change to high energy conditions, probably due to the uplift of the source area, which has been recognized in Islay (Section 2 p. 30); as a result of this uplift rythmic influxes of coarse sand (feldspathic), becoming massive pebbly quartzite beds with large scale current bedding, which show flow from the north-west and the west (fig 14) but do not necessarily indicate the source-direction (Potter and Pettijohn 1963). The Cnoc Don Quartzite represents a shallow water, high current intertidal domain (shelf marine). Litherland (1970) regarded the current bedding in the equivalent rock of the Ballachulish succession to be due to the constant sorting of a braded grains resulting from succession increments of fine material, and denied any action of high currents. His assumption might be valid in the Loch Crenan, but in Islay, the current bedding up to 10 feet long, cannot have been produced except by high current action Bailey (1930).

The Cnoc Don Limestone is a layered sequence of dolomite limestone, quartzite interbedded with limestone and quartzite interbedded with dolomitic phyllite. The group represents a period of instability in the sedimentary basin, during which uplift and emergence of land, (the source area) resulted in the alternate deposition and change in lithology. The limestone is dolomitic becoming impure, with scales of calcite (plate 19), which are

Fig 24



Lower Dalradian trough in Islay

regarded as sun-cracks and indication of shallow water deposition. This suggests that the dolomitic is of evaporite and not metasomatic origin.

The Baharradail phyllite, is current bedded in its psammite lamellae the Ballygrant Limestone, also has current beds (plate 20). These Limestones as well as the Port nan Gallan Phyllite and the Port nan Gallan Limestone (the upper most unit of the Lower Dalradian), represent a return to the euxinic, low energy conditions, and complete the repetition of the Cyclothenic deposits of the Lower Dalradian Geosyncline in Islay. The unconformity recognized in the southern part of the Oa (fig 11), between the Port nan Gallan Limestone and the Ballygrant Limestone, is marked by a graphitic conglomerate for a distance of 1½ miles and a half. To the south-west of the above locality on the cliff facing the sea, the Port nan Gallan Limestone lies directly disconformable on the Baharradail Phyllite (fig 11). This indicates a local uplift of the source area and partial uplift on the edge of the Basin (fig 24) which resulted in the erosion of the Port nan Gallan Phyllite, and part of the Ballygrant Limestone. This local uplift seems to be of great importance in the shape of the geosynclinal basin for the Lower Dalradian and the Middle Dalradian. The thinning of the sequence to the south-west, (see paragraph 3.1 in this section and fig 24b) is attributed to this uplift.

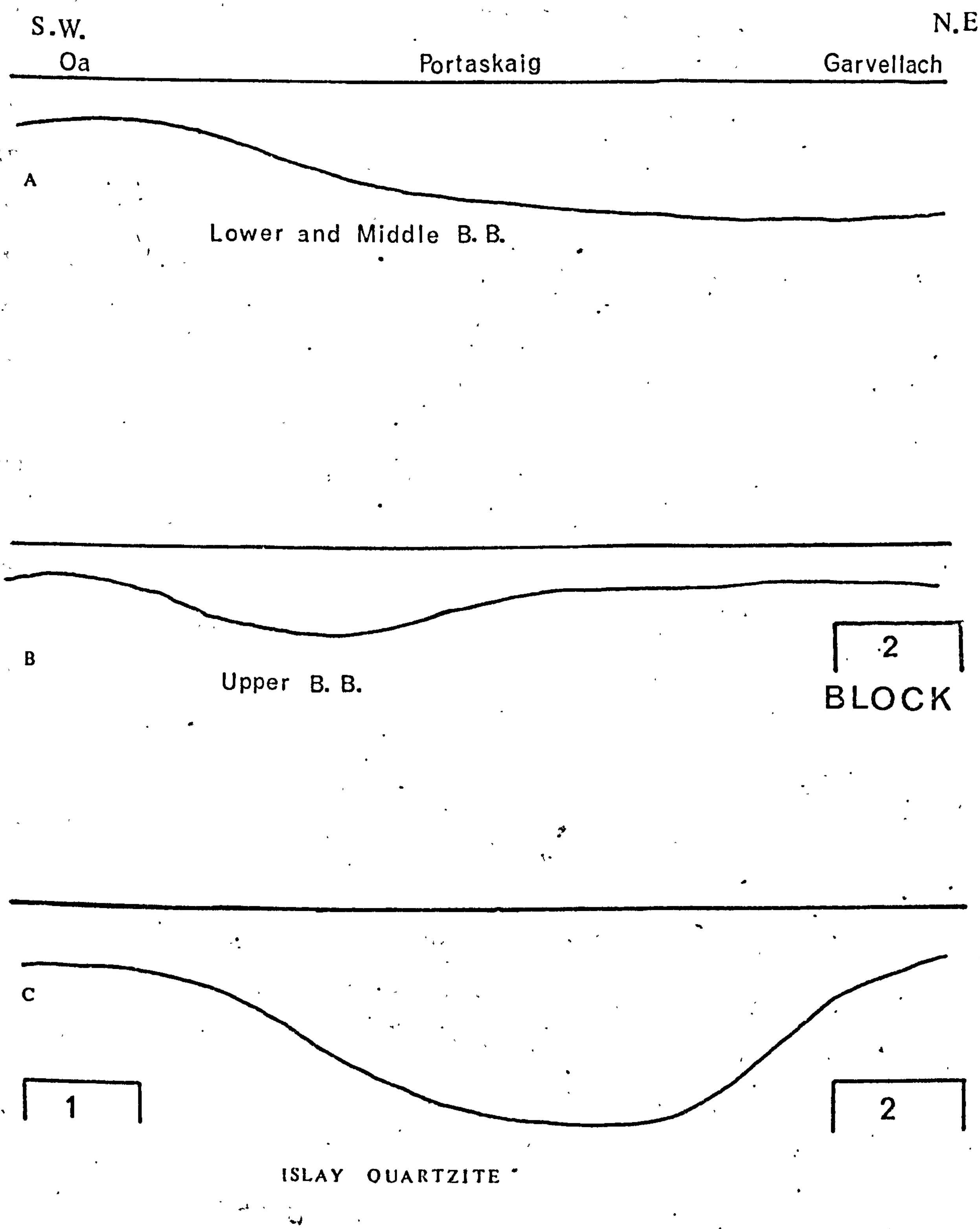
The Lower Dalradian in Islay as a whole is of the orthoquartzite carbonate suite (Pettijohn 1957) which is formed of quartzite, shales, limestone of euxinic facies, and pyrite-bearing sedimentary beds. From the point and the discussion forward in this section the writer concludes that the sediments of the Lower Dalradian in Islay belong to the shelf marine to epicontinetal domins.

3. The Middle Dalradian

The Portaskaig Boulder Beds form the base of the Middle Dalradian. The depositinal environments have been discussed by the following authors:- Shackleton 1961, Knill 1963, Watson 1963, Kilburn et al 1965, Robert 1966 and later in more detail by Spencer in 1966. The writer agrees with Spencer in attributing the origin of Portaskaig Boulder Bed to a ground ice sheet. Dr. D. Klein (1970) tried to explain the deposition and the origin of the Middle Dalradian, by describing, the Lower Fine-Grained Quartzite and applied his result and interpretation to the main quartzite (Islay, Jura Quartzite), assumed that the Fine Grained Quartzite is part of Islay quartzite. The present author has found that the Fine-Grained Quartzite (Geological Survey 1907 and Bailey 1916) is the upper most unit of the Portaskaig Boulder Beds, and has scattered Boulders of granite measuring up to 40 cm in diameter. Regarded to its stratigraphic the Fine-Grained Quartzite lies directly underneath the Dolomitic Group which is younger than the Islay Quartzite (Section 2 p. 37). Therefore, Klein's proposal for the origin of the Precambrian Quartzite of Islay is rejected since there is no resemblence between the Fine-Grained Quartzite of the upper Boulder Bed and the Islay Quartzite, the main quartzite of the Middle Dalradian.

Fig 25

Lower Middle Dalradian Trough Portaskaig B.B.



3.1 The Portaskaig Boulder Bed lies unconformably on the Lower Dalradian. The Boulder Bed includes clasts from the Lower Dalradian which indicates uplift and erosion of the latter at the time of deposition of the boulder bed. The lower Boulder Bed was deposited without any noticeable break. A conglomerate bed has been recognized by Spencer in the Garvavellach, the Portaskaig area, and by the writer on the northern slope of Beinn Bhann (Section 2 p. 41). The clasts are purely granite in Garavellach, of granite, limestone and quartzite in the Portaskaig area, and of granite, limestone, quartzite and green phyllite in the slope of Beinn Bhann. The conglomerate overlies the Boulder Bed No. 35 of (Spencer 1966), and the upper Boulder Beds in the Garavellach succession is absent from the Islay succession. The change in clasts along the strike, the absence of Boulder Bed No. 35 from the Islay succession and the thinning of Boulder Bed No. 34 (which might be absent to the south-west of Beinn Bhann), all indicate that there is a break in the deposition of the Portaskaig Boulder Beds, due to the local uplift (fig 25) of the land. This break may be viewed as a large break in the deposition of the all Boulder Bed in the Dalradian (fig 17). Spencer's assumption (1966) (Section 2 p. 41) does not explain the change of the lithology from north-east to the south-west along its strike, the absence of boulder bed No. 35 and the thinning of boulder bed No. 34.

3.2 The Lower Fine-Grained Quartzite, uppermost group of the boulder bed (Kilburn, Pitcher and Shackleton 1965 p. 348) contains boulders of granite measuring up to 40 cm in diameter. This quartzite has been recently described by G. Klein (1970) in an attempt to resolve the deposition of Precambrian Quartzite (Islay, Jura Quartzite); Klein ignores the presence of the granite boulders in the Fine-Grained Quartzite, and condradicts Knill's deltaic environment for the Islay-Jura Quartzite. Further he regards a southern shore line for the lower Fine Grained quartzite (Upper Boulder Bed). The present writer is at variance with Klein's conclusion for the following reasons:-

1. The Fine-Grained Quartzite is part of the Boulder bed succession, and not a separate unit.
2. The Islay Quartzite (main Middle Dalradian Quartzite) is separated in Islay by the Dolomitic Group, which is younger than the Islay Quartzite and older than the Fine-Grained quartzite (Section 2). Therefore we cannot correlate the two units.
3. As far as the source of the Fine-Grained Quartzite is concerned there is no doubt that it is to the north or north-west. The southern source suggested by Klein is based on his observation in the north-west limb of the Islay Anticline, that the fining-upward sequences are confined to the southern outcrops (fig 26) of the Fine-

Grained Quartzite, where as the northern outcrop consists of interbedded sandstone. There graded sequences and the sandstones represent his intervals A and B respectively (fig 26). Unfortunately he does not take into account that he is dealing with an overturned limb, so his results are contradictory.

4. As to the environment of deposition, the writer disagrees with both Spencer and Klein, where the fine-Grained Quartzite (uppermost boulder bed unit) is concerned. Klein's description of the Fine-Grained Quartzite is accepted here and a new interpretation for its environment of deposition is put forward. Two facies were recognized by (Klein 1970) in the fine-grained quartzite:-

(i) Facies 1 consist of massive, bedded, cross-stratified and rippled orthoquartzite (fig26b).

(ii) Facies 2 consist of siltstone and mud crack, isolated flat and thick lenticular bedding, tidal bedding and burrowing structures (fig26c).

These kind of facies cannot have been deposited from either floating or ground ice, as suggested by Spencer (1966). There is no doubt that the environment of deposition is shallow water belonging to tidal to sub-tidal domains.

It is accepted here that the Fine-Grained Quartzite represents a stage of deposition after the melting ice, in a new, much warmer environment. The change in the direction of the cross-bedding is an evidence of the instability of the water surface at the time of the deposition of the Fine-Grained Quartzite. The boulders of the granite in the quartzite are an evidence of still bigger rivers or a further glacier to the north still capable of supplying the Upper Portaskaig Boulder Bed with these boulders; the locality of the land to the north of Islay which supplied these granitic boulders is debatable. Another evidence to the shallow water or epicontintal deposition of the Fine-Grained Quartzite are the mud cracks, which also indicate a change from cold climate to a warmer one. This evidence is present in the Dolomitic Group: the presence of mud cracks and abundant algal stromatolites are evidence of shallow water or even an intertidal environment, with much warmer climate favourable to the algal stromatolites. The Dolomitic Group is remarkably of large thickness, and the above-suggested conditions of a climate changing from glacial to marine (warm climate), are favourable to the deposition of the dolomitic Group.

3.3 The Islay Quartzite (main quartzite) of the Middle Dalradian, has a maximum thickness of 3 km, it is a pebbly orthoquartzite, well sorted, cross bedded, becoming coarse and flaggy at its top to the south-west. The quartzite thickens at the centre and thins towards the north-east and to the south-west. This thinning is stratigraphic as well as tectonic and reveals the shape (fig25c) of the Middle Dalradian Trough. Knill 1963 has attributed the thinning of the quartzite to the north-east, to the swing in the strike; Litherland (1970) confirmed this. The following features of the Islay Quartzite are illustrated and recognized in (fig 27).

The sediments of the Islay Quartzite are an indicator of a shallow water environment (Bailey 1930) (Pettijohn 1957). The source of the Middle Dalradian has been regarded here as to have been derived from the west and north-west (fig 27) directions as proposed by Sutton and Watson (1955) Watson (1963), Knill (1963) and Spencer (1966).

A deltaic environment was proposed by Knill (1963) (fig 27). This delta is fan shaped; the coarse material was brought down to its front by the current of the main rivers, feeding the Dalradian Trough in the form of turbidity flow.

3.4 The Jura Slate, may represent a deeper water, a eustatic rise in the sea level, or a general decrease in the upper group of the Middle Dalradian.

3.5 The Scarba Conglomerate, represents conditions of high relief and consequent rapid erosion. The sediments are a conglomerate interbedded with gray calcareous phyllites. This raises a new argument concerning the environment, of deposition of the conglomerate, namely whether the conglomerate is deposited by subaqueous turbidity flows and slides, along the edges of the trough.

3.6 The Port Ellen Group. This group follows the Scarba Conglomerate; it consists of limestone at the base followed by phyllite, becoming interbedded

Fig 26

Facies sequence in the Fine grained Quartzite

after Klein 1970

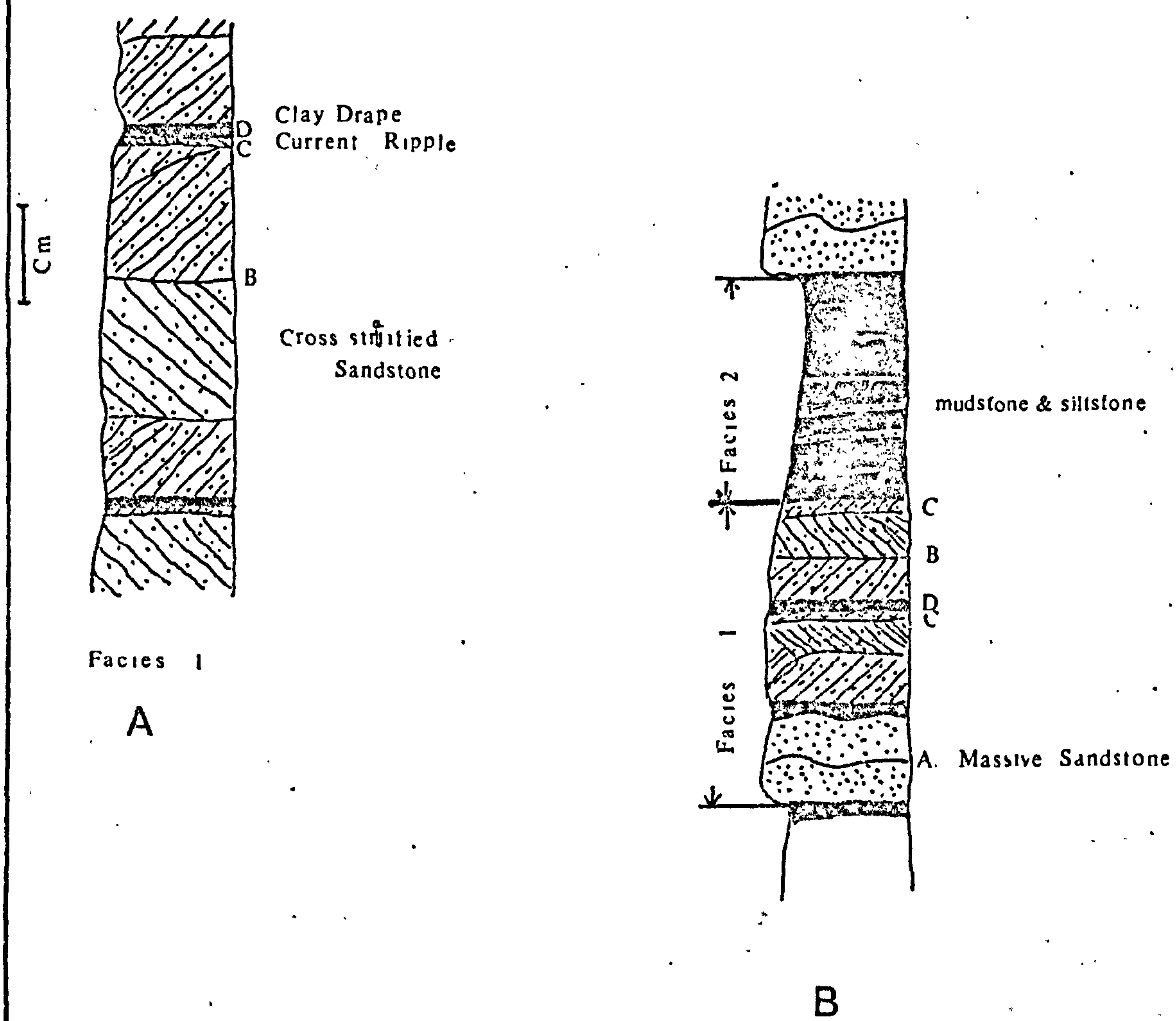


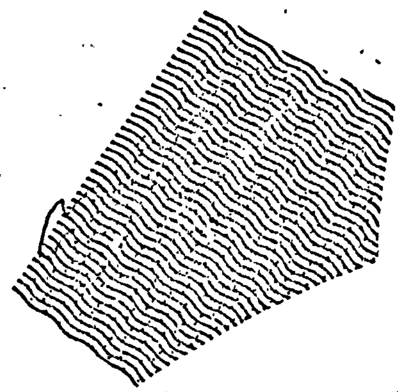
Fig 27

Palaegeograhical maps of Islay & the Southwest Mainland of Scotland

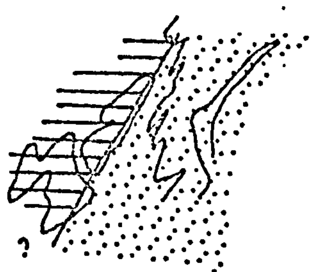
Portaskaig Boulder Bed & the Finegrained Qtz.

Islay Quartzite

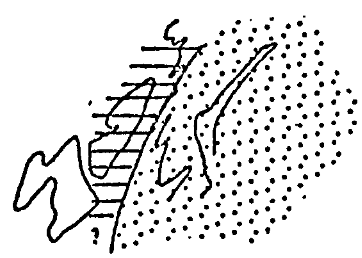
Jura Slate & Scarba Conglomerate



PortEllen Phyl. & Laphroaig Qtz.



Ardmore Grits



Tayvalich Lst.

with quartzite (flagstone). The base of this group (limestone) is correlated with Degnish Limestone (Section 4 of this thesis). The presence of limestone and black phyllite is suggestive of quiet, restricted conditions with little current flow introducing coarse detritus into the sedimentary basin. A period of more turbulent conditions followed with extensive penecontemporaneous erosion resulting in the deposition of the Laphroaig Group. This coarse facies could be the result of a period of rapid erosion; the limestone top of this group would represent deposition in quiet water again. The Laphroaig Formation and the top part of Port Ellen Phyllite are correlated with Ardishag-Craignish Phyllite (Section 4). In Islay the Laphroaig Group is represented by a thick quartzite interbedded with phyllite, and sandy limestone at its top, while in Knopdale and Loch Fyne the same group change to dark phyllite and dark limestone at their top. This change in facies along the strike of the trough is well recognized and noticeable in the Middle Dalradian sediments and is mostly attributed to the shape of the Middle Dalradian Trough (fig 28).

3.7 The Ardmore Conglomerate is largely made up of locally derived blocks of limestone, dolomite, quartzite and phyllite (plate 35) embedded in a gritty matrix. The conglomerate is polymictic, and is a product of erosion. The limestone clasts are the result of local erosion and deposition not far from the source area. The conglomerate becomes pure quartzite at the top and passes upwards into the Ardmore Grits. The latter are dominately turbidites, forming coarse-grained, graded beds. A fine-grained facies of dark siltstone is developed at the top of some of the grits. The sediments indicate a quiet water environment of deposition (Bailey 1930) with little turbidity. No palaecurrent data are obtained from these grits. Knill in Kilmartin (1963 fig 27) suggested southern-flowing current; this is still not certain since the fine-grained rock beds have variable current direction.

4. The Thinning of Sediments

As seen from the description of sediments in Section 2 and the conditions of deposition discussed above, it is clear that there is a dramatic thinning of the sediments of the Lower Dalradian as well as the Middle Dalradian to the south-west, and an absence of certain units (fig 24 and plate 11). This has been attributed to stratigraphic conditions and later important tectonic effect (see Section 5 for more detail). The stratigraphic thinning is demonstrated and proved by the disconformity in the Lower Dalradian between the Baharradail Phyllite, Ballygrant Limestone and Port nan Gallan Limestone. The disconformity is a result of local uplift in the south-west as a result of a rising block (fig24b). The local break in the Lower Dalradian and the break in the Boulder Beds (between its Middle and Upper Boulder Bed) of the Middle Dalradian, has been attributed to rising blocks (fig25b) to the south-west and north-east respectively. The sediments of the Lower Dalradian in the north-east are not seen beyond Islay, due to the steep plunge of the Islay Anticline. The thickness of the sediments in crest of the fold is very big due to the fold structure; for this reason the writer find that Spencer's (1966) estimate of the thickness of the Portaskaig Boulder Bed occupying partly of crest the Islay Anticline is exaggerated thickness, while the proposed thickness by Pitcher, Kilburn and Shackleton (1965) is more reasonable.

The Middle Dalradian in Islay and Jura represented by the Islay-Jura Quartzite, and the Boulder Bed, thin towards the north-east and the south-west. The quartzite forms a lenticular shape (its strike swinging) to the north-east where the quartzite thins out in the Ballachulish completely. The swings in the strike is due to the emergence of a new block to the north-east, which contributed to the uplift of the Boulder Bed, followed by erosion as described (Section 2, p. 41). This uplift resulted in facies changes towards the south-west and north-east. In general all the Middle Dalradian facies change along the strike of the trough from south-west to the north-east.

Tectonic thinning in the Middle Dalradian is also of great importance. Two major thrusts, the Loch Skerrol's and Beinn Bhann Thrust, played a big role in this (map 1). Both thrusts are correllated to the Fort William Slide and the Balltay Slide respectively (fig 49) (for details see Section 5). Stratigraphic columns have been constructed from the type localities in the Lower and the Middle Dalradian, to show the stratigraphic thinning and also sliding out along the south-west, north east direction.

5. Unconformities

Local unconformities have been recorded and described from both the Lower and Middle Dalradian. The only break in the Lower Dalradian is represented in the south-west by a disconformity, sedimentary slumps (fig 1land plate 11) and a zone of conglomerate. Four major breaks are recorded in the Middle Dalradian. The boundary between the Lower and Middle Dalradian is a major disconformity (Rast 1963). The second disconformity in the Middle Dalradian a break in the deposition of the Boulder Beds, between their middle and upper groups represented by a zone of conglomerate. This disconformity is the result of a block starting to rise to the north-east and controlling the shape of the Middle Dalradian Trough. The third and fourth breaks are represented by the Scarba Conglomerate and Ardmore Conglomerate respectively.

Models of a Dalradian trough have been attempted by many workers in order to solve its problems by working in higher members of the Dalradian succession. For example Knill (1959-1963) has cited evidence for a shelf margin near the Bender-Loch - Islay line in the Ardraishaig Phyllites and the Tayvallich Limestone. On the other hand Roberts (1966) suggested the axis of the Upper Dalradian trough lay to the south-east of the present Loch Awe syncline. Both authors find evidence of axial and lateral support. Sufficient to add that the present position of Islay itself represent the shelf, since evidence has been put forward for shallow water, tidal to sub-tidal and epecontinental deposition. The trough gradually expanded from its early stages, into a major trough of the Upper Dalradian.

SECTION 4

CORRELATION

The Correlation of the Islay Succession with the Highlands (Ballachulish, Iltay) and the Ireland Dalradian Successions

Introduction

For a long time the Islay succession has been included under the South-west highlands succession, that is Islay, Perthshire and Iltay (Bailey 1922, 1934), Rast (1963), Kennedy (1969) and Rast and Litherland (1970). In this thesis, the Islay succession will be dealt with alone, and will be correlated, with the Ballachulish, the Perthshire of the Highland (Mainland of Scotland) and Ireland.

The junction between the Dalradian Rocks and Torredanian (Moinin) in Islay is tectonic represented by the Loch Skerrol's thrust (fig 1), as is the junction in Ballachulish, and in Perthshire, where Bailey (1922) inserted the Iltay Boundar Slide. This slide separates the Perthshire and Ballachulish Dalradian in the western highlands; for this reason it is impossible to trace a stratigraphic junction between these two successions Bailey (1924).

Attempts have been made to correlate the Islay Loch Awe succession as one group, with Ireland on one hand, and the Central Highlands and Ballachulish Dalradian successions on the other hand. For example Anderson (1948, 1953, 1964), Rast (1958, 1963), Knill (1963), Kilburn, Pitcher and Shackleton (1965), Roberts (1966), Kennedy (1969) and Rast and Litherland (1970). In this section the correlation is explained further from the stratigraphy discussed in (Section 2) and the stratigraphic map (plate 1), it is proved that part of the Lower and all the Middle Dalradian succession are represented in Islay

Table 2

Correlation of Islay Loch Awe Succession and Ballachulish Central Highland

Bailey 1922	Anderson 1948, 1953 Ballachulish	Knill 1963
Tayvallich Limestone		Loch Avish Grits
Crinan Grits		Tayvallich Lavas
Shira Limestone		Tayvallich Limestone
Erins Quartzite	Cuil Bay Slates	Crinan Grits
Ardrishaig Phyllite	Appin Phyllite	Ardrishaig-Craignish Phyllite
Easdale Slates	Appin Limestone	(Shuna Limestone)
Islay Quartzite	Appin Quartzite	Easdale Slates
Portaskaig Boulder Bed	Ballachulish Slate	Scarba Transition Group
Islay Limestone	Ballachulish Limestone	Scarba Conglomerate Group
Mull of Oa Phyllite	Transition Quartzite & Schist	Jura Slates
Moal an Fhithich Quartzite		Islay Quartzite
		Portaskaig Boulder Bed
		Islay Limestone
		Mull of Oa Phyllite
		Moal an Fhithich Quartzite

Stratigraphic Correlation of the Islay
Succession with the Ballachulish Succession

Rast and Litherland (1970) suggested that the Ballachulish succession is represented in Islay. The determination of the extension of the Lismore Limestone into Loch Linnhe region, Litherland, Rast and Litherland (1970), indicated that Ballachulish rocks will be found in Islay.

The first stratigraphic succession in Islay was established by Bailey (1916) (table 1) and later confirmed by Allison (1933). However the stratigraphic units below the Portaskaig Boulder Bed were not clearly differentiated and grouped as follows:-

3. Islay Limestone

2. Mull of Oa Phyllites

1. Moal an Fhithich Quartzites

There it is proposed to break down of groups 2 and 3 into stratigraphic units, as described in Section 2, was established by Bailey (1916) (table . 1) and later confirmed by Allison (1933). However the stratigraphic units below the Portaskaig Boulder Beds were not clearly differentiated and were grouped as follows :-

3. Islay Limestone

2. Mull of Oa Phyllites

1. Moal an Fhithich Quartzites

The unit Mull of Oa Phyllite covers an area of 20 x 6 miles occupying the core of the Islay Anticline Bailey (1916). The new mapping techniques used in this thesis demands the necessary break down of the Mull of Oa Phyllites into smaller units and consequently a repetition of the succession by a large scale F_2 fold, named by the writer the Oa Anticline and having the same plunge as the Islay Anticline is demonstrated. In (sheet 19) there are considerable exposures of quartzite mapped in Central Islay. These were not mentioned in the Geological Survey Memoir (Wilkinson, 1907). Bailey (1916) referred to these exposures as fine-grained quartzite interbedded with the Mull of Oa Phyllites. This quartzite was recognized and proved to belong to Cnoc Don Quartzite (fig14 section 2) sequence.

The Portaskaig Boulder Bed is a marker unit within the Dalradian succession, separating the Lower and Middle Dalradian. The Boulder Bed is stratigraphically underlain by the Islay Limestone and overlain by a thick formation of Dolomitic Beds followed by a much thicker unit of quartzite, which correlates with the Central Highland and Ireland successions. The Moal an Fhithich Quartzite is correlated with the Glencoe Quartzite of Ballachulish. The rest of the Lower Dalradian of Islay can be easily correlated unit by unit with the Ballachulish succession on one hand (Rast and Litherland 1970) and with the Ireland succession (Pitcher and Shackleton 1966) on the other (table 3).

Four sub-units recognized in the Kintra Phyllite are the same as in the Ballachulish succession (Litherland 1970). A traverse from the contact of the Moal an Fhithich Quartzite to Kintra farm (fig 7) shows the following rock sequence :-

e - Dark, gray phyllite
d - laminated phyllite, striped pyllite with calcareous bands

} over turned

Table 3

Correlation of Islay Lower Dalradian with Ballachulish & Ireland Succession

	Basahel & Rast 1971 Islay Succession	Litherland 1970, Rast & Litherland 1970, Ballachulish Succession	W.S. Pitcher & R.M. Shackleton North West Donegal 1966
White pale yellowish Limestone	Port nan Gallan Limestone		
Banded Phyllite	Port nan Gallan Phyllite		Locghros Group
Blue Limestone	Ballygrant Limestone	Lismore Limestone	Falcarragh Limestone
Dark Graphitic Schist	Baharradail Phyllite	Cuil Bay Slates	L. Falcarragh Pelites
Pale Phyllite	Cnoc Don Phyllite	Appin Phyllite	
Quartzite	Cnoc Don Qtz. } Cnoc Don Group	Appin Limestone inter bedded with Qtz.	
Pale, striped Limestone	Cnoc Don Lst.		} Sessiagh Clon Mass Group
Spotted Quartzite	Cnoc Don Quartzite	Appin Quartzite	Ards Quartzite
Banded Phyllite	Cnoc Don Transition		Ards Transition Group
Dark Slate	Cnoc Don Slate	Ballachulish Slates	Ards Black Schists
Yellow flaggy and Dark Limestone	Kintra Limestone	Ballachulish Limestone	
Dark Gray Phyllite	d.		
Laminated Phyllite	c.		
Gray, black Phyllite	b. } Kintra Phyllite	Leven Schist	} Grees Lough Group
Banded Transition Phyllite	a.		
Quartzite	Moal an Fhithich Quartzite	Glencoe Quartzite	

c - Pale, yellow, sandy Dolomitic Limestone	Right way up
b - Transition zone, banded phyllite	
a - Moal an Fhithich Quartzite	

The Central Islay and in particular the Cnoc Don area (fig 14), represent a complete section of the Lower Dalradian. The Cnoc Don area forms the north-western limb of the Islay Anticline, separated from the Oa Anticline by the Central Islay Slide (C.I.S.). A traverse cross section from the south-east to north-west shows the following units:-

Bluish Limestone	Ballygrant Limestone
Dark Striped Phyllite	Baharradail Phyllite
Pale Limestone, impure with Quartzite and phyllite interbedded	Cnoc Don Group
Felspathtic Quartzite	Cnoc Don Quartzite
Thin zone of banded phyllite	Cnoc Don Transition Zone
Slate	Cnoc Don Slate
Pale yellow, dark limestone	Kintra Limestone

The same result was achieved from traverses across the north-western limb and eastern limb of the Oa Anticline from the Kleinnan River (fig 14).

Thus it is clear that Islay is a good area to establish the Dalradian succession, and in particular the Lower and the Middle Divisions of it are well represented. The Lower Dalradian succession shows an uninterrupted sequence from the Ballachulish to the Perthshire succession, and that makes Islay a unique location for the typical Lower and Middle Dalradian.

The writer suggest the following unit by unit correlation of the Lower Dalradian of Islay

Table 4

The Correlation of the Middle Dalradian Succession in Islay

Islay	Central Highland Bailey 1948 Sturt 1961	Ireland (Kimacrcnan) Pulvertaft 1961
Scarba Conglomerate	Carn Mairg Quartzite	
Islay Slates	Killiecrankie Schist	
Islay Quartzite	Schichallion Quartzite	Knokateen Quartzite
Dolomitic Group	Schichallion Boulder Bed	Knokateen Boulder Bed
Portaskaig Boulder Bed		

with the Ballachulish and Ireland (N.W. Donegal (table 3).

<u>The Correlation of the Middle Dalradian succession in Islay</u>

The whole of the Middle Dalradian succession is described from Islay in (Section 2), where the detailed stratigraphy is discussed for each unit. The rock shows good outcrops with a virtually continuous exposure along the strike. The Portaskaig Boulder Bed is taken here as a marker unit for the base of the Middle Dalradian. The Lower fine grained quartzite was included within the Portaskaig Boulder Bed forming its highest member (Section 2 p. 41). The following correlation (table 4) has been recommended to the units of Portaskaig Boulder Bed upto the Scarba Conglomerate.

The Scarba Conglomerate is overlain by the Port Ellen group and the Laphroaig Formation.

<u>The Port Ellen Group</u>

c. Port Ellen Flagstone

b. Port Ellen Phyllite

a. Kilbride Limestone

The Kilbride Limestone is sandy, yellow to gray. The Port Ellen Phyllite is green, graphitic, thin psamtic and calcareous beds 2 to 5 cm thick at its top. The Port Ellen Flagstone is green chloritic interbedded with quartzite beds up to 2 feet thick; the quartzite has a greenish dirty colour, with graded bedding in some places.

<u>The Laphroaig Formation</u>

b. Kildalton Limestone

a. Laphroaig Formation

The Laphroaig Formation is a continuation of the Port

Table 5

Islay	Loch Awe Succession	Ireland
Kildalton Limestone	Shira Limestone	
Laphroaig Formation		
Port Ellen Flagstone } Port Ellen Phyllite }	Ardrishaig-Craignish Phyllite }	(Termon Schist)
Kilbride Limestone	Degnish Limestone	The Gartan Bridge Dalradian

Ellen Flagstone but is discussed independently due to its great thickness and different lithology and environment of deposition. It consist of a thick quartzite with red dolomitic phyllite interbedded within its top. The quartzite is fine to medium grained and preserve good graded bedding. The Kildalton Limestone is sandy, yellow to gray in colour, its top is not seen due to the massive epedionite sills.

The following correlation (table 5) is proposed for the above-mentioned two groups.

Ardmore Conglomerate

This conglomerate is 10 meters thick and consists of boulders of limestone, phyllite and quartzite (plate 35); in a sandy matrix. To the writer's knowledge, this conglomerate has no equivalent, in the Middle Dalradian of Scotland and Ireland. The conglomerate passes upwards into turbidite quartzite and grits (the Ardmore Quartzite). This quartzite, the top of which is not seen, has an estimated thickness of about 100 meters. The Ardmore Conglomerate and quartzite are correlated with the Crinan Grits.

Conclusion

It is clear from the foregoing description (Section 2) and (Section 4) that Islay represents a continuous deposition of the Lower and Middle Dalradian without a major break in the deposition. It has a unique position within the Dalradian, as far as its correlation is concerned. A unit by unit correlation in Islay with the mainland of Scotland and Ireland is demonstrated. The writer suggests the Islay succession as a type stratigraphic succession for the Lower and Middle Dalradian for the following reasons.

1. The Lower Dalradian and Middle Dalradian (Rast 1963) in Islay, that is from the Ballachulish into the Perthsire succession, are continuous sequences; nowhere else do we find this continuity to the top of the Middle Dalradian.

2. Sedimentary features are represented, almost throughout the whole.

3. Transitional zones from one unit to the other are easily identified in the field.

4. Most of the units can be followed continuously along the strike. The exceptions are some units in the Lower Dalradian, that are interrupted by tectonic slides.

5. Two major episodes of deformation are associated with the Dalradian rocks of Islay F_2 and F_3 fold; Islay has escaped the major deformation (F_1 fold) of the mainland of Scotland.

All the above points support the unique stratigraphy of Islay, and a new correlation has been introduced with Islay, as the type locality for part of the Lower and the whole Middle Dalradian, with relation to the Ballachulish, Central Highland, Ireland and Achil Island successions - (Table 6.).

Table 6

GENERAL DALRADIAN CORRELATION

Islay Succession Rast and Basahel	Central Highlands Bailey & McCallien 1937)	Loch Awe Succession Bailey & Knill 1963	West Achill Succession M.J. Kennedy 1969	Ireland Succession McCallion 1935, Pitcher and Shackleton 1966
Ardmore Grits	Ben Lui Schist (Farragon Beds)			Cranna Quartzite (Kilmacrenn Grits)
Ardmore Conglomerate		Crinan Grits		
Kildalton Limestone		Shira Limestone		
Laphroaig Formation				
Port Ellen Flagstone	Ben Lawers Schist	Ardishaig-Craignish Phyllites	Achill Head Grits & Phyllite	Termon Formation (Cranford Limestone)
Port Ellen Phyllite				
Kilbride Limestone		Degnish Limestone	Keem Limestone	
Scarba Conglomerate			Keem Conglomerate	
Jura Slates	Ben Eagach Schists	Easdale Slates	Dooagh Schist	Slieve League Formation
Islay, Jura Quartzite	Perthshire Quartzite		Croaghun Quartzite	Slieve Tooey Quartzite
Dolomitic Group			Slievemore Dolomitic	
Portaskaig Boulder Bed	Schichallion Boulder Bed		Doogort Boulder Bed	Boulder Bed
Port nan Gallan Limestone	White Limestone		Doogort Limestone	Dolomite of Fanda
Port nan Gallan Phyllites	Banded Group		Doogort Schist	Loughros Group
Ballygrant Limestone	Dark Limestone		Doogort Quartzite	Falcarrngh Limestone
Baharradail Phyllite	Dark Schist			Falcarrngh Pelites
Cnoc Don Limestone Group				Sessiagh-Clonmass Group
Cnoc Don Quartzite				Ards Quartzite
Cnoc Don Transition Zone				Ard Transition Group
Cnoc Don Slates				Ards Black Schist
Kintra Limestone				Altan Limestone
Kintra Phyllites				Creeslough Group
Moal an Fhithich Quartzite				

SECTION 5

STRUCTURAL INTERPRETATION

Introduction

A - Structural Work in Islay

The first real structural work to emerge was the of Bailey (1916) in which he interpretated the rocks in terms of the "Islay Anticline." The Anticline pitches north-east ward, with a core of Moal an Fhithich Quartzite and (Mull of Oa Phyllite), flanked by successively higher members of the sequence, upto the main Quartzite (Islay Quartzite) to the north-west and up to still higher Ardmore and Laphroaig Quartzite to the south. Green (1924), however, suggested a synclinal structure complicated by isclinal folding. He inverted Bailey's sequence and introduced a large unconformity below the Portaskaig Boulder Bed. Gregory (1928) accepted most of Bailey's interpretation of the structure and sequence of that part of Islay which lies between the Loch Skerrol's thrust and the (Beinn Bhann fault). He rejected the Moal an Fhithich Quartzite as an independent formation, but regarded it as a downfaulted outlier of the lower Quartzite, and in this followed (Wilkinson 1907). He refers to the succession east of the (Beinn Bhann Fault) as the Marine Quartzite (Islay Quartzite). This is distinct from the main quartzite of north Islay, in that it is older than the Mull of Oa Phyllite of Wilkinson (1907) and it is followed eastward by an inverted outcrop of still older formation, Jura Slate, Port Ellen Phyllite. Elles and Tilley (1930) accepted the succession of Bailey and agreed with him that the structure of Islay is an Anticline. They, however, separated the Moal an Fhithich Quartzite from the Mull of Oa Phyllite (Kintra Phyllite of this thesis) by the continuation of the Loch Skerrol's Thrust. Peach and Horn (1930) also accepted the greater part of Bailey's ideas on the structure of the Island. Peach still holds, however, that the Jura Slates are an upfold of the Port Ellen Phyllite, and that the Scarba Conglomerate is a downfold of the Laphroaig Quartzite. The Moal an Fhithich Quartzite he considers as a downfaulted portion of the Main Quartzite (Islay Quartzite). Allison 1933 used the way up criteria and demonstrated to Green and Gregory that Islay Quartzite is younger than the Portaskaig Boulder Bed, and Islay Quartzite youngs up into the Jura Slate and Scarba Conglomerate.

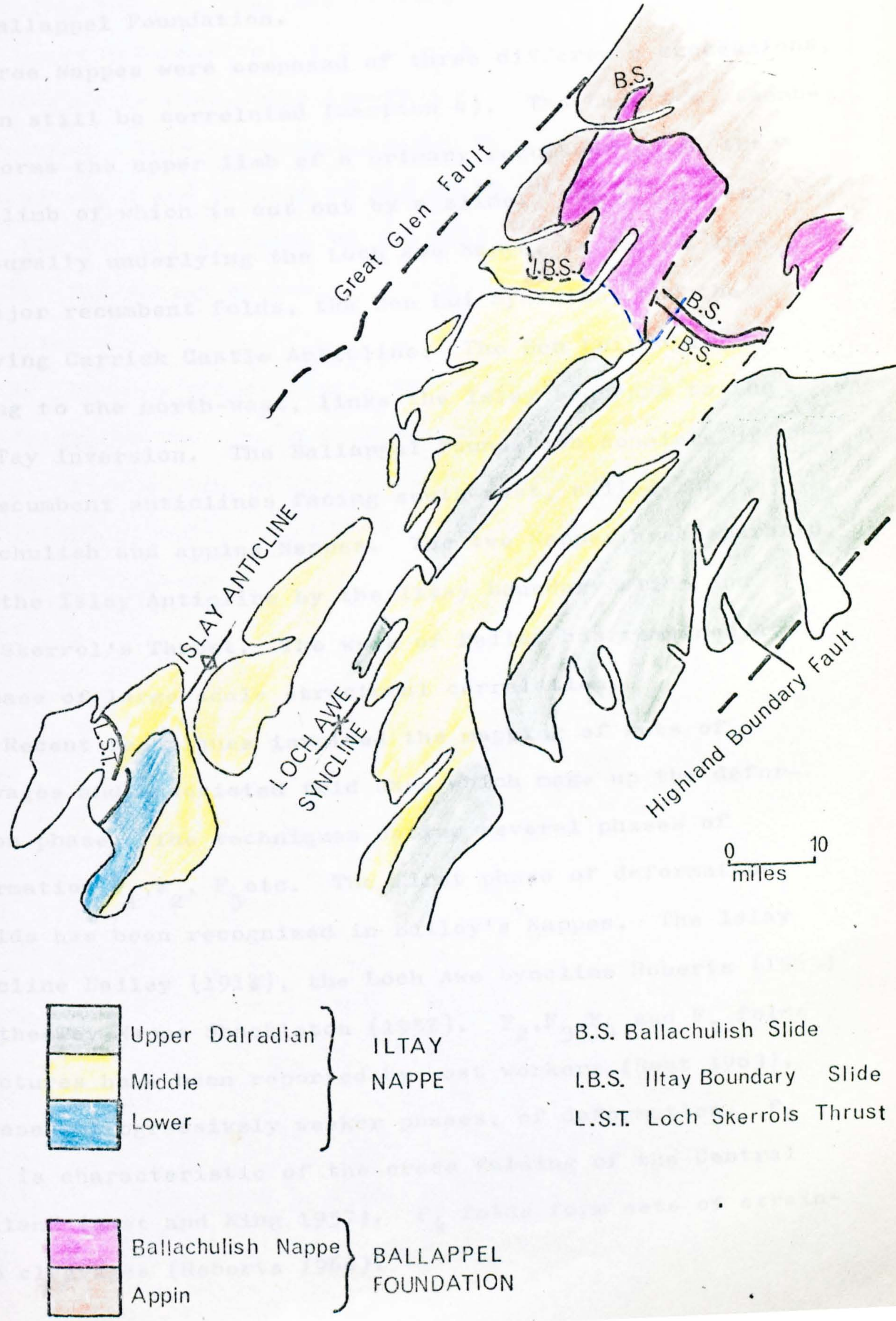
B - Dalradian Structure

The modern investigation and analytical approach to the structural problems of the Dalradian originated from the establishment of criteria by Clough (1897) for determining the structural history of deformed rocks by using small scale structures, and the claim that such structures to a certain extent reflect the form of the major structures. Vogt (1930) introduced the use of sedimentary structures such as graded bedding and current-bedding to determine stratigraphic order. Shackleton (1958) introduced more sophisticated techniques (facing of structures) by studying relations of sedimentary structures to the small-scale tectonic structures. These approaches have recently been used to distinguish various phases of deformation (e.g. Rast 1958, Sturt 1961), Johnson 1962), Roberts 1963, Treagus 1964 and Litherland 1971).

In 1922 Bailey proposed a structural synthesis covering Islay, Loch Awe and the Ballachulish. In it he interpretated the structure in terms of three primary recumbent folds.

Fig 29

The Southwest Highlands



Dalradian of these areas into three nappes as follows (fig 29):

Loch Awe Nappe;

IItay Nappe;

Ballappel Foundation.

The three Nappes were composed of three difference successions, but can still be correlated (Section 4). The Loch Awe assemblage forms the upper limb of a primary recumbent fold, the lower limb of which is cut out by a slide. The Iltay Nappe, structurally underlying the Loch Awe Nappe, is folded into two major recumbent folds, the Ben Lui Syncline, and the overlying Carrick Castle Anticline. The Ben Lui Fold, closing to the north-west, links the Islay sequence to the Loch Tay Inversion. The Ballappel Founlation consists of two recumbent anticlines facing south-east, called the Ballachulish and Appins Nappes. The two Nappes are separated from the Islay Anticline by the Iltay Boundary slide and Loch Skerrol's Thrust. The work of Bailey has remained at the base of large scale structural correlation.

Recent techniques involved the mapping of sets of cleavages and associated fold axes which make up the deformation phase. The techniques define several phases of deformation F_1, F_2, F_3 etc. The first phase of deformation F_1 folds has been recognized in Bailey's Nappes. The Islay Anticline Bailey (1916), the Loch Awe Syncline Roberts (1963) and the Tay Nappe Shackleton (1957). F_2, F_3, F_4 and F_5 folds structures have been reported by most workers (Rast 1963), represent progressively weaker phases, of deformation. F_2 fold is characteristic of the cross folding of the Central Highland (Rast and King 1957). F_4 folds form sets of strain-slip cleavages (Roberts 1966).

The work of Bailey (1916) and the work of Roberts (1963) related to Islay structures are discussed later as the author rejects the proposal put forward by Bailey and accepted by others, that the structures in Islay are the first phase deformation. The conclusion reached in the present work is that Islay represents a second F_2 phase of deformation. This conclusion, drawn entirely from the detailed study and mapping of the southern part of Islay sheet (19 and 20) is based on the following evidence:-

1. The second cleavage is main cleavage in Islay.
2. In many places the first cleavage has been folded by the second deformation.
3. At the core of the Islay Anticline down-facing structure show F_1 fold having been folded by F_2 structures.

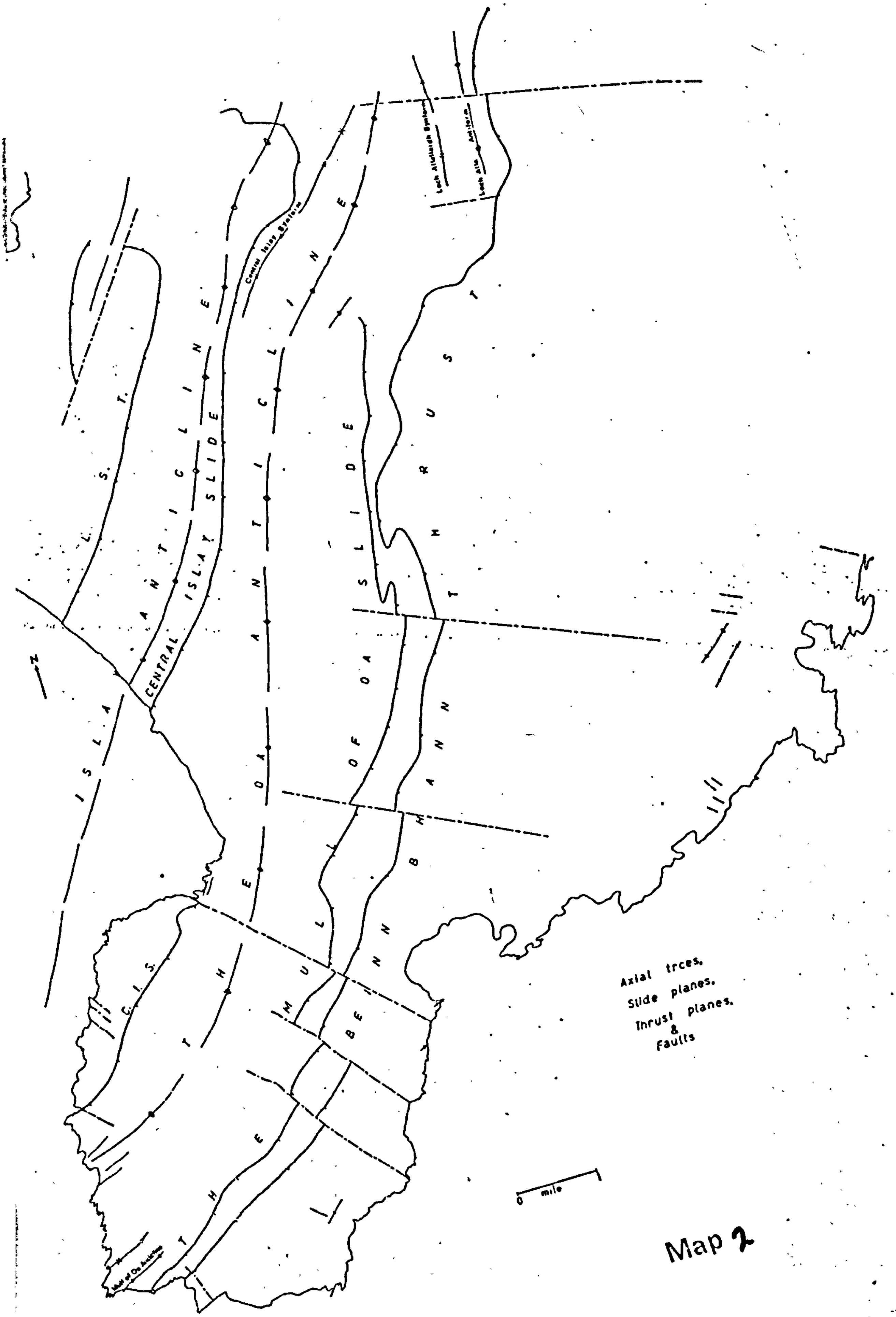
A – The Large Scale Structures

The Dalradian structural history of the area involved four major phases of folding of which only the F_2 are the larger folds with wavelength greater than a mile and longitude of more than 25 miles. The major folds of Islay have a south-west north-east trend which is direction of Islay Anticline, and which was established by Bailey (1916) in his Islay Anticline. No F_1 large scale folds have been reported in the area mapped, but further to the north-east and in particular near Loch Lossit and on Kiells Moor (C.R. 4489), F_1 folding is recognized from downward facing structures established in the current bedding, the later is inverted and cut by steeper S_2 cleavage. F_3 and F_4 are relatively weak phases in Islay Dalradian Rocks.

General discussion of the large scale structure will be put forward in order to obtain a structural synthesis for Islay in particular and the south-west Dalradian structures in general. This will be followed by a detailed discussion of each individual structure.

The Islay Anticline (Antiform) (fig30a)

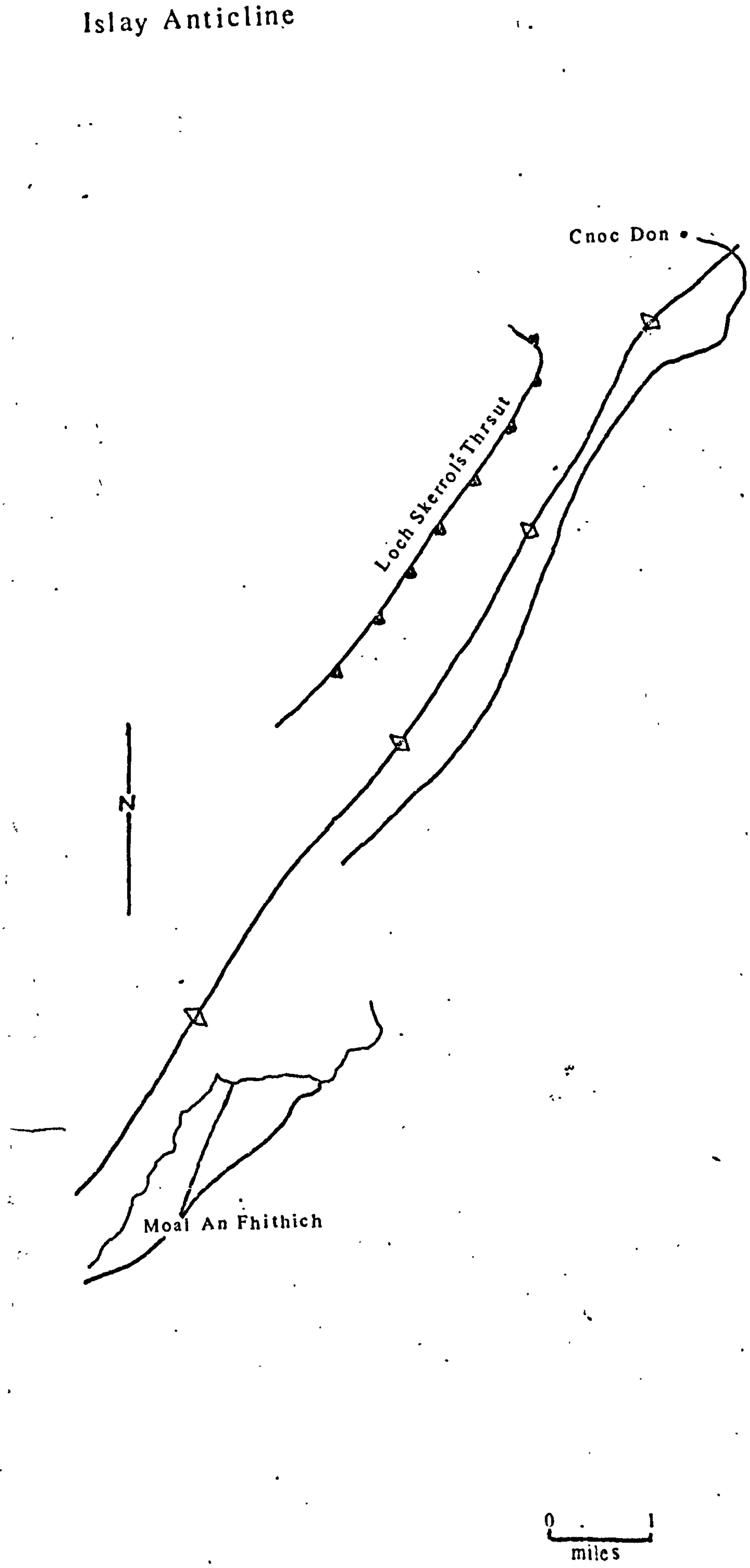
The Islay Anticline is the largest structure in Islay Bailey (1917). It is marked by the repetition of the successions of the lower and part of the middle Dalradian Rocks, across its axial trace. The most marked horizons are the Islay Quartzite, the Portaskaig Boulder Bed, the Port nan Gallan Limestone and the Ballygrant Limestone. The present mapping reveals the fold as plunging steeply 40 : 50 north-east wards. The whole Lower Dalradian disappears as well as part of the Middle Dalradian Rocks (Portaskaig Boulder Beds and the Dolomitic Group beneath



L. S. T.
ANTICLINE
CENTRAL ISLAY SLIDE
THE OA ANTICLINE
SLIDE OF OA
MULL OF OA
BENN BHANN THRUST
THE
C. I. S.
Axial trces,
Slide planes,
Inrust planes,
&
Faults
0 mile

Map 2

Fig 30a


Islay Anticline
Cnoc Don
Loch Skerrol's Thrsut
N
Moal An Fhithich
0
1
miles

the Islay Quartzite in the Sound of Islay. The closure of the Islay Anticline is well seen in the Cnoc Don, marked by the closure of the Cnoc Don Quartzite, Cnoc Don Slate and Kintra Limestone, where the trend of its axis is established and well defined. At Cnoc Don the closure of the Islay Anticline is partly removed by a slide (Central Islay Slide), which brings the younger rocks of Baharradial Phyllite in contact with the Cnoc Don Slate, Cnoc Don Quartzite and Cnoc Don Calcareous Group.

The following features demonstrate the Islay Anticline:

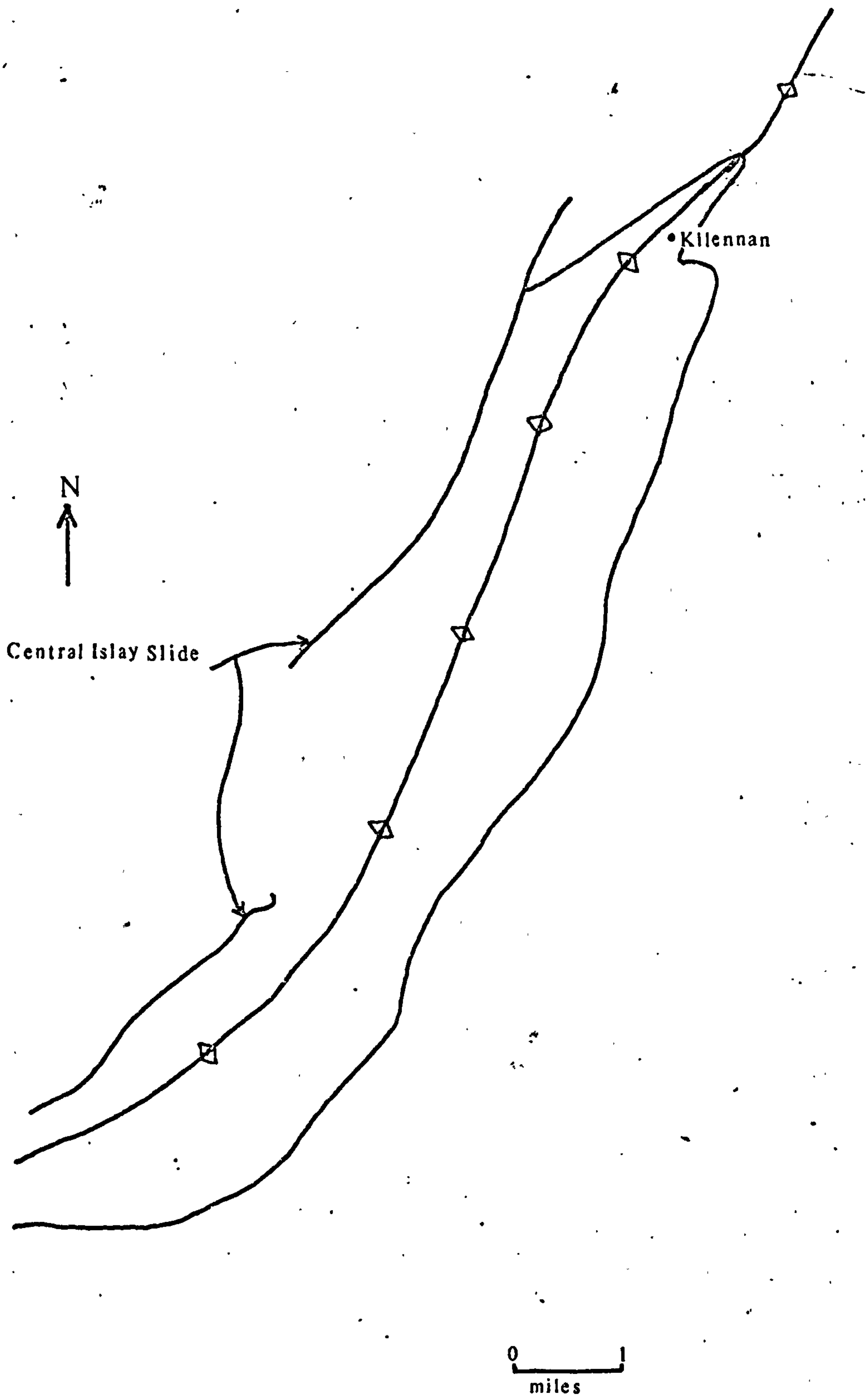
i The stratigraphic succession youngs away from the core of the Kintra Limestone in the Cnoc Don area. This is seen from graded and current bedding in the Cnoc Don Quartzite. The rocks young to the north-west in the overturned limb.

ii South-east of Beinn Bhann the Islay Quartzite youngs to the south-east, forming an upward facing sequence.

iii The repetition of the stratigraphic succession of the Lower and Middle Dalradian to the south-east and north-west. The most important horizons involved are Islay Quartzite, and the Portaskaig Boulder Beds. The Dolomitic Group and the whole of the Lower Dalradian (Section 2). The repetition of the Islay Quartzite and the Portaskaig Boulder Bed have been established by Bailey (1916) and Allison (1933).

Fig 30b

The Oa Anticline



The Oa Anticline (fig 30b)

The Oa Anticline is the second largest structure in the area, and stretches for about twenty miles. The Anticline can be proved in the two districts the Central Islay and the Oa. In the first district, and in particular in a water fall of Kilennan River (G.R. 3858) a closure of this fold is well seen (plate 16). The Oa Anticline is marked by the repetition of the Kintra Limestone, Cnoc Don Quartzite and Cnoc Don Group. In the Oa district, the Anticline is marked by the repetition of the Kintra Phyllite and the Kintra Limestone. This can be seen in two localities: at the Kintra Farm the phyllite shows younging to the north- and overturning, in the Lower Killeyan Farm (G.R. 2747) the laminated phyllite youngs to the south-east with a transitional zone younging towards the Kintra Limestone (south-east).

The present mapping reveals that like the Islay Anticline, the Oa Anticline plunges 50-60^0 to the north-east. The trend of the plunge was best obtained from the closure of the anticline in the Kilennan River. To the south-west in the Oa district the Oa Anticline plunges gently to the north-east by 20-30^0. This suggests the disappearance of the successions to the north-east.

The Central Islay Slide (Map 1 & 2)

The symmetrical repetition across the axial traces of the Oa Anticline and the Islay Anticline ceases in the north-west limb of the first (G.R. 3759) and in the eastern limb of the second. Instead of the Cnoc Don Quartzite and Cnoc Don Limestone Group on the eastern limb of the later, flaggy limestone belonging to the Ballygrant sequence are in contact with Cnoc Don Slate (map 1). This asymmetry marks the Central Islay Slide. The north-east of the Islay Anticline closure, the Cnoc Don Quartzite and Cnoc Don Limestone are in contact with the Baharradail Phyllite. A zone of shear marks the line of the slide in this area. The slide passes down to the south-west separating the Islay Anticline from the Oa Anticline. The exposure in Central Islay is poor when the slide passes, covered by superficial deposits; the slide appears at Knockangle Point (G.R. 3151) only to disappear in the sea of Laggan Bay; it reappears again in Port Alsag (G.R. 3148) and continues up to Dian Mor Ghil (G.R. 2845). The slide was established from the detailed mapping and a study made along the line of the slide. The following observations were made:

i In Central Islay the discontinuity of the stratigraphic succession on the north eastern limb of the Oa Anticline and the discontinuity of the stratigraphic in the south-eastern limb of the Islay Anticline marks the slide.

ii In the Oa district, the discontinuity is between the Kintra Phyllite and the Kintra Limestone (map 1); further to the south-west the top unit of the Kintra Phyllite is in contact with the Moal an Fhithich Quartzite. The discontinuity can be traced from the Cnoc Don in Central Islay to the Din Mor Ghil in the south-west.

iii The slide cuts through the F_2 folds. This can be seen from the relation of the small scale folds to the cleavage.

iv Shear zone foliation is seen in and when the outcrops are good (plate 37) these foliation and S_2 cleavage are parallel.

The slide is curved around the core of the Islay Anticline in the Cnoc Don area. The curvature is of a later deformation, but is still associated with F_2 deformation. As a result of this curving the Baharradail Phyllite is thrust over the Cnoc Don Quartzite, Cnoc Don Limestone Group and Cnoc Don Slate, with south-eastern movement along this plane (map 1). The Central Islay slides runs parrallel to the Islay Anticline axial plane. This suggests firstly that the movement started pre F_2 i.e. a movement which occurred prior to the second phase of deformation. Secondly, that the movement continued during the second phase of deformation. Both hypotheses are arrived at from the field evidence, summarized in the following points:

i. In many localities, however, the S_2 cleavage, the shear zone (foliation) in the slide and the small scale slides in the Kintra Phyllite are parallel (fig 31and plate 39 & 40).

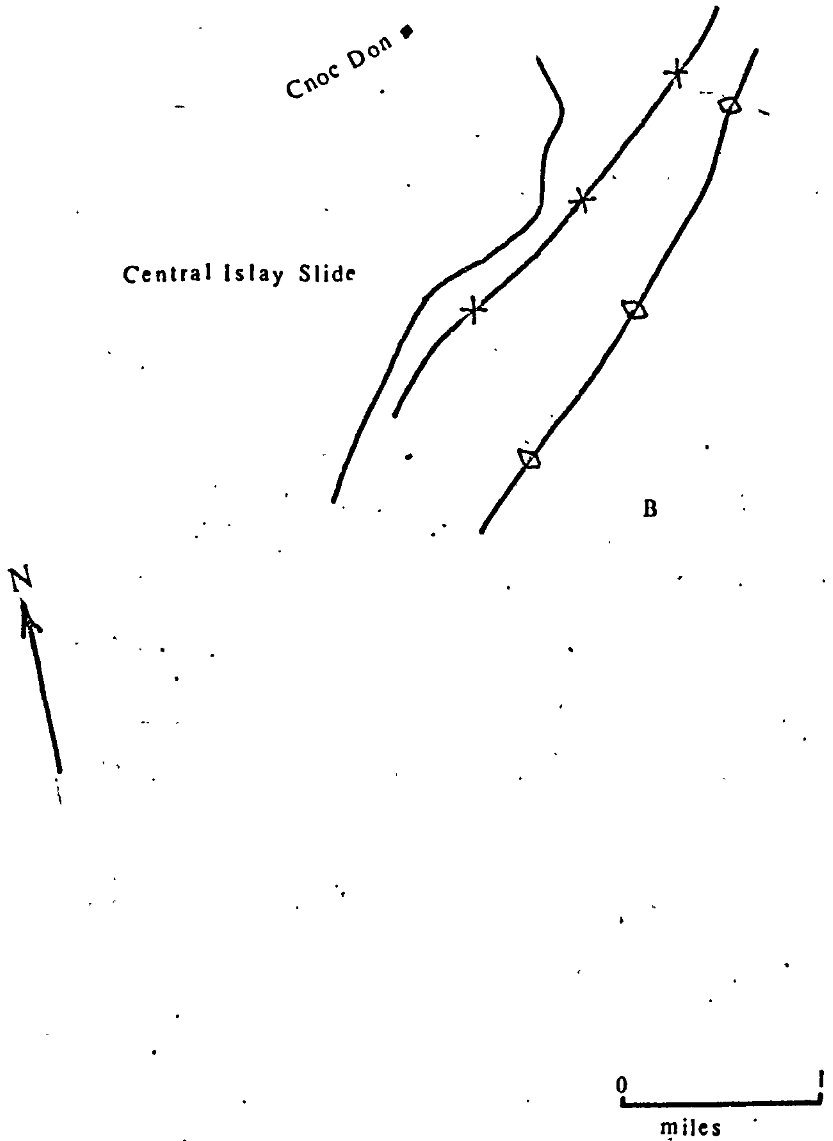
ii The slide has been folded in some places in the same style as F_2 folding.

The recognition of the Central Islay Slide is of great importance in establishing the stratigraphy and defining the general structure in Islay, where it separates two large scale Antliclines, the Islay and the Oa Anticlines.

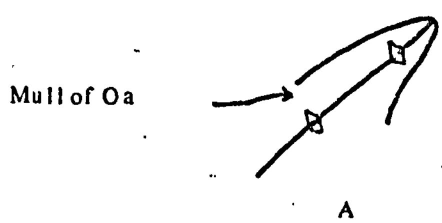
Elles and Telley (1930) extend the Loch Skerrol's Thrust to the Oa, where it passes separating the Moal and Fhithich Quartzite from the Kintra Phyllite (Mull of Oa Phyllite of Wilkinson 1907). The present worker has proved in section two that the junction between the above two units is of a stratigraphic, and for that reason the extension of Loch Skerrols Thrust to separate between the Moal an Fhithich Quartzite and the Kintra Phyllite is rejected.

Fig 30c

The Central Islay Synform



The Mull of Oa Antiform



Instead it is proposed that the Central Islay Slide is occupying the plane between these two units as what shown in (map 1). The Loch Skerrols Thrust passes to the north-west of the Moal an Fhithich Quartzite.

The Mull of Oa Slide (Map 1 and 2)

The Mull of Oa Slide is responsible for the removal of part of eastern limb of the Oa Anticline, and the thinning of the remaining successions. The Mull of Oa Slide passes from the 300 meters south of Kilennan Farm (G.R. 3857) to the Mull of Oa (map 2). It has been folded in the same style as F_2 folds. This suggests the same movement as in the Central Islay Slide, as well as its age. Along the eastern limb of the Oa Anticline, the Cnoc Don Quartzite has been completly cut out, except for one small out crop (G.R. 3245) where we can see the continuation of the Cnoc Don Quartzite retained. Along the Slide plane the Kintra Limestone are in contact either with the Baharradail Phyllite or the Ballygrant Limestone. The Cnoc Don Slate and Cnoc Don Limestone Group are completely cut from the Central Islay along the Slide plane and in the Oa their outcrops retained in two localities, in Mull of Oa 400 meters to the south-east (G.R. 2841) and in (G.R. 3245).

The Central Islay Synform (fig 30c)

The Central Islay Synform, as its name implies, occurs in Central Islay, separating the Islay and the Oa Anticline. The synform allows to elucidate the stratigraphy as well as the structure of the Dalradians in Central Islay. Its north-west limb is cut out by the Central Islay Slide; the south eastern limb, however, is retained. The structure of the Synform is distorted by the fold of the Central Islay Slide;

in the vicinity of the closure of the Islay Anticline, the oldest rocks appear to occupy the core of the syncline.

<u>The Mull of Oa Antiform</u> (fig30c)

The Lower Dalradian in the Mull of Oa (Kintra Phyllite and Kintra Limestone) has been interpreted in this thesis as an antiform marked by the repetition of the Kintra Phyllite and the Kintra Limestone (map 1). The interpretation is based on the detailed study of a particular area, and is vital to the interpretation of the stratigraphy of Islay Dalradian successions.

The following observations were made:

i 200m to the west of the Monument on the Mull of Oa the limestone and the phyllite adjacent to it are both younging to the west, while the succession as a whole in the Lower Killeyan (G.R. 2743) youngs to the south-east.

ii The succession east of the Monument youngs to the south-east. This conclusion was deduced from the cleavage relationship as well as the grading.

iii A cross section (fig 8) shows that the succession is in its correct stratigraphic order.

<u>The Allallaidh Synform</u> (Map 2)

The Allallaidh Synform has a south westerly plunging closure, which can be picked out in the outcrop of Port nan Gallan Limestone in the Allallaidh (G.R. 4158) and in the stream adjacent to it. The structure is complicated due to later deformation (F_3 ,F_4 etc.) and latter by recent faulting. The following points confirm the existance of the synform:

i The core of the fold is occupied by the Port nan Gallan Limestone, and flanked by the Port nan Gallan Phyllite.

ii The Port nan Gallan Phyllite in the Allallaidh (G.R. 4158) stream strikes towards the Port nan Gallan Limestone. This is the consequence of later faulting and deformation such as F_3 and F_4 etc. In the above area the Limestone has been brecciated (plate 22) and shows early cleavage (foliation). This early cleavage is an indication of an early deformation prior to faulting. The latter is the latest deformation in the southern Islay, and has the same trend as the normal faults of the area.

iii To the east of Allallaidh a north-easterly plunging antiform is inferred; this is the Loch Allallaidh Antiform. A small outcrop of the Port nan Gallan Limestone, and Portaskaig Boulder Bed appear on the eastern limb of the structure, confirming the proposed antiform (map 1 and 2).

iv To the north of the Loch Allallaidh the Portaskaig Boulder Bed and the Port nan Gallan Limestone thin-out and disappear completely; instead the Port nan Gallan Phyllite is in contact with Islay Quartzite as far as Sound of Islay. All this is attributed to the intervention of the Beinn Bhann Thrust.

Loch Skerrol's Thrust

The Loch Skerrol's Thrust was first recognized by the Geological Survey Wilkinson (1907), and later confirmed by Bailey (1916). The thrust follows a sinuous south-westerly course (fig 1) from Ban-an Uillt on the east shore of Loch

Gruinart to the south-west of Laggan Bay. In the area mapped in this thesis (sheet 19)(of the Geological Survey), the thrust is concealed mostly under the superficial deposits, and there is no actual contact between the Bowmore Sandstone and the Dalradian rocks, except on the locality of the Tallent Farm (G.R. 3358) where the Skerrol's Thrust has been faulted by a normal fault. Here the Dalradian Portaskaig Boulder Bed and the Port nan Gallan Limestone, have been sheared, a quartzite belonging to the Portaskaig Boulder Bed has also been cleaved and slightly sheared, together with the schist of that unit. The Port nan Gallan Limestone shows isoclinal folds which are associated with the F_2 deformation. The rocks at the Tallent Farm are folded into Tallent Synform, which is later cut by a normal fault situated along its axial plane. The Loch Skerrol's Thrust curves around the synform in the same style as the Central Islay Slide does around the Islay Anticline, which is of the same age and same style of deformation. The the south-west at Laggan Bay, the Bowmore Sandstone outcrops; there is no evidence to support the existence of the Loch Skerrol's Thrust in that area, and in the same time we cannot eliminate its persistence to the shore of the Laggan Bay. The Loch Skerrol's Thrust plane dips to the east south east beneath the Islay Quartzite; this is well seen in the north, and in the Tallent Farm. The plane is marked by a sheer zone and well observed north of Loch Skerrol's; it continues up to the north at Ban-an Uillt. The overturned folds with north-west ward direction above the thrust plane suggests the thrust plane as well as its movements to the south-east.

The Beinn Bhann Thrust (maps 1& 2)

The Beinn Bhann Thrust is important in the interpretation of the Dlaradian structure and the stratigraphy of Southern Islay. It extends inland in a southerly direction from a point on the Shore of the Sound of Islay (G.R 4366) a little south of An Meall to the Oa "Port nan Gallan Bay." The Geological Survey (Wilkinson 1907) recognized the Beinn Bhann Fault from the Sound of Islay to Beinn Bhann. This has been confirmed later by Bailey (1916). The detailed mapping carried out by the present worker proves that this is another thrust, the same as the Loch Skerrol's Thrust and originated during F_2 deformation.

The following points suggest this :-

1. To the east of Loch Allalladh, the quartzite has been shattered and shows a sheared quartzite and breccia zone. The shattering and tectonic brecciation are followed as far south as to the Port nan Gallan Bay in the Oa. The quartzite in the latter locality has been mylonitized, and the mylonitisation extends to the east for about 200 meters.

2. Partof the Lower and Middle Dalradian have been thrust beneath the Islay Quartzite; this has been recognized in the following localities:

i in the Loch Allalladh the Islay Quartzite is in contact with the Port nan Gallan Limestone, which is represented by a limestone of few meters in thickness. Further north, up to the Sound of Islay, the Islay Quartzite is in contact with the Port nan Gallan Phyllite. Here three thick units are missing, the Port nan Gallan Limestone, the Portaskaig Boulder Bed, and the Dolomitic Group. The non-existence of these thick units from the eastern side of the Islay Anticline can only be explained by a fault thrust, since there is no evidence of any other alternative.

ii South of Loch Allalladh, the missing units, the Port nan Gallan Limestone, and the Portaskaig Boulder Bed, and at G.R. 4157 the Dolomitic Group, appear again. The latter unit does not extend beyond the above locality further than about 200 meters. The Portaskaig Boulder Bed and the top most units of the Lower Dalradian, the Port nan Gallan Phyllite and Limestone thin to the south. The thinning of these units, have been explained in Section 3 as being partly sedimentary and partly tectonic thinning.

3 In the locality between Moal nan Caorach (G.R. 3855) and Moal Mheadhoin (G.R. 3852), the contact between the Islay Quartzite and the (Mull of Oa Phyllites) of the Geological Survey in sheet 19 is of a tectonic contact (thrust) and not stratigraphic.

4 The fold styles in Islay Quartzite are mainly tight recumbent F_2 folds. The thrust line has been folded with F_2 deformation; which suggests the same age as the slides in the area.

The views of the present worker expressed in Section (5 A and B) on the interpretation to be assigned to the Islay Anticline differ from those of Bailey (1916). Bailey proved that Islay is an anticline on stratigraphic grounds. Bailey did not go into the detail of the structure of the area concerned, and included the Islay structure within the major F_1 structure deformation in the south-western Dalradian Caledonian Belt. This view has been accepted by several writers for example Roberts (1963) and Litherland (1971). The present interpretation (Section 5B) proposes that the second deformation is the main one with S_2 axial plane cleavage to the Islay Anticline and the Oa Anticline; S_1 cleavage where it is seen in the core of either of these two anticlines has been folded. The term composite has been assigned to the cleavage where only S_1 and S_2 are seen parallel to each other.

Fig 32a

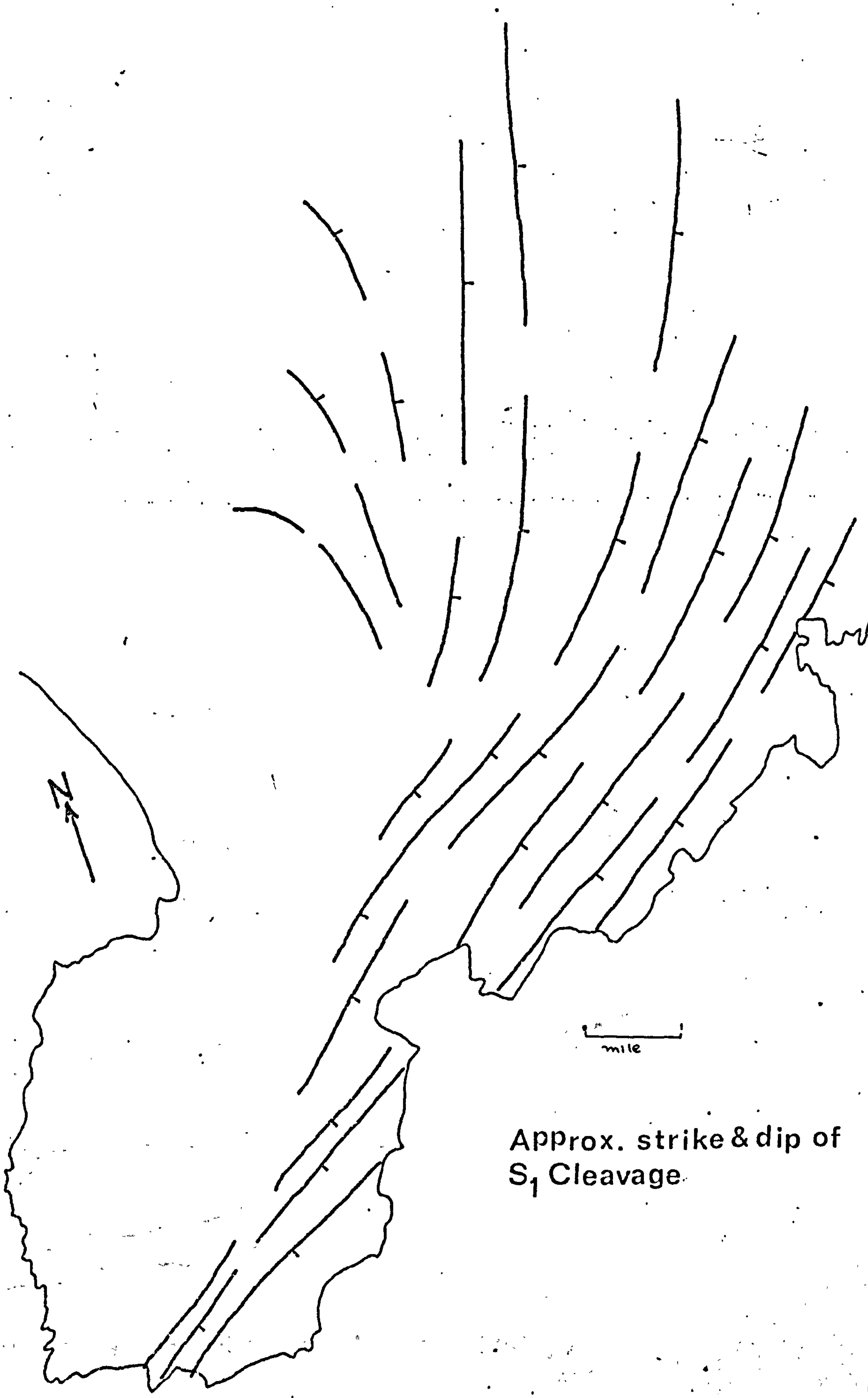
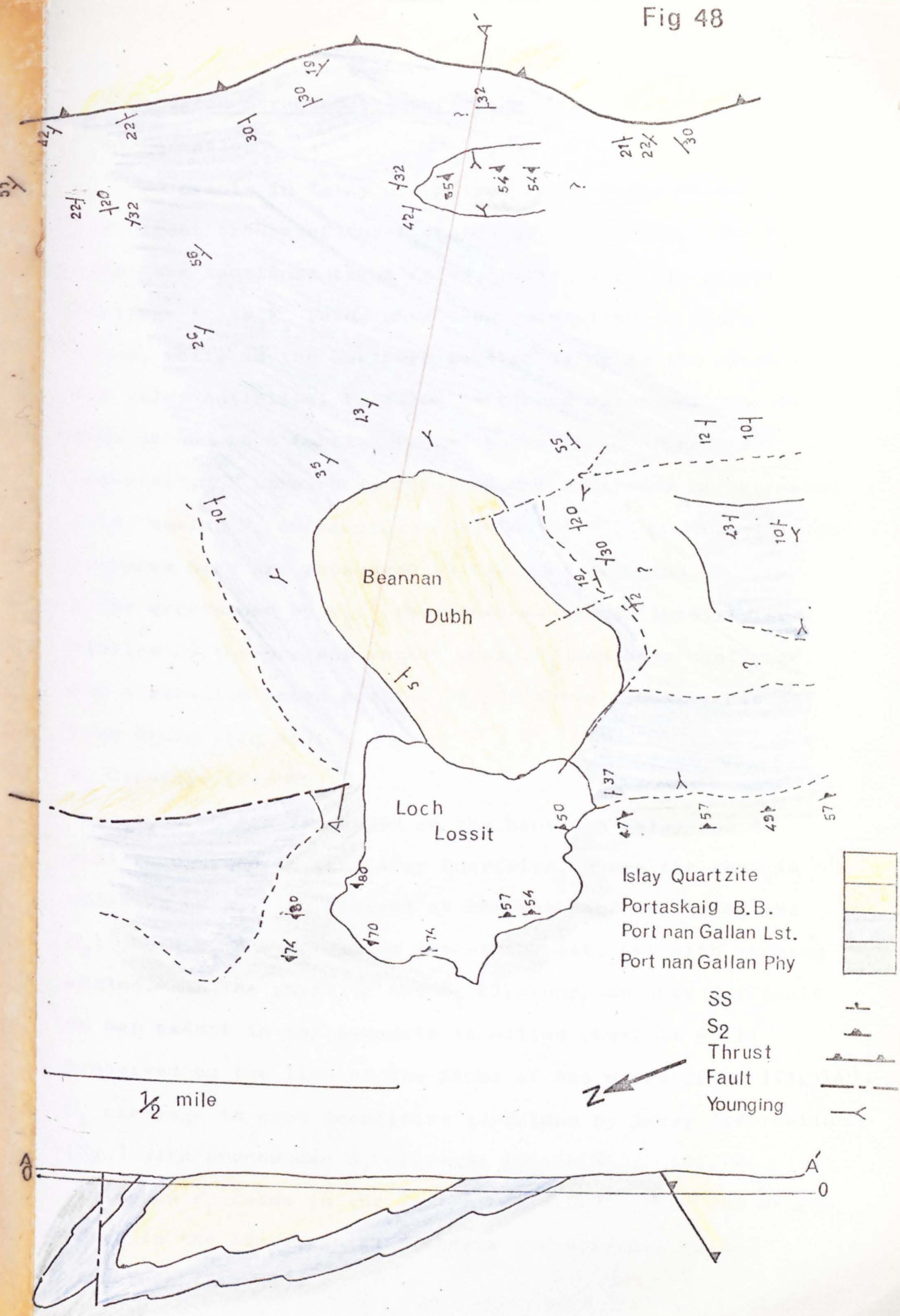


Fig 48



Geological map of the Loch Lossit (Islay)

After Spencer (1966), Wadsworth (1969) & the writer

B - Detailed Structural Description

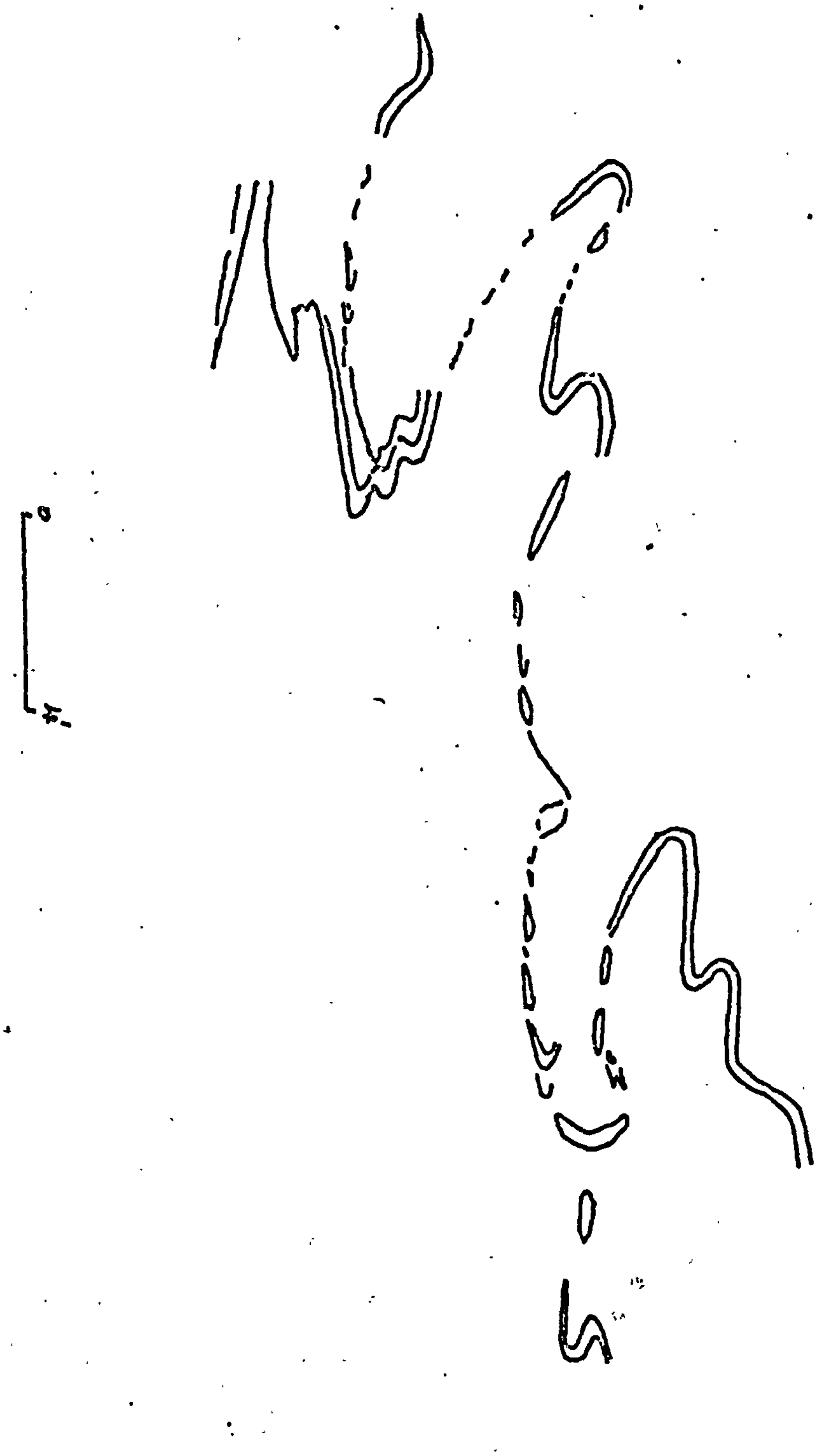
F_1 Deformation

F_1 events in Islay are not of great deformation, and few direct traces of the F_1 folds are preserved. The F_1 folds are isoclinal tight folds, having variable plunge. No large scale F_1 folds have been recognized in Southern Islay, while in the Northern part of Islay on the closure of the Islay Anticline, F_1 folds have been detected. In the area around Loch Lossit, P. Wadsworth (B.Sc. Thesis the University of Liverpool) reported the existence of recumbent folds having F_1 deformation (Section 5 P.79). The minor-folds features here are preserved in tight F_1 synclinal later overturned by F_2. The above-mentioned locality was visited by the present worker where F_1 has been confirmed, and a detailed cross section to the above locality has been drawn (fig 48).

S_1 Cleavage (fig 32)

S_1 Cleavage is mapped in the Southern Islay and is well recognized in the Islay Quartzite, where the rock is upfacing on S_1. In general it has the same strike as the S_2; both S_1 and S_2 dip to the south-east, but with varying angles. In the phyllite the S_1 cleavage was very difficult to map except in the psammite lammellae where it still preserved on the limb of the limbs of the minor folds (fig34a). S_1 cleavage in most localities is folded by later deformation (F_2) with pronounced S_2 cleavage (plate 56). Relict siliceous F_1 folds in the Kintra Limestone, which are attenuated in the limbs, still preserve the original (real) F_1 structure (fig 33).

Fig 33



Relict siliceous F_1 folds in the Kintra Limestone

Fig 32b

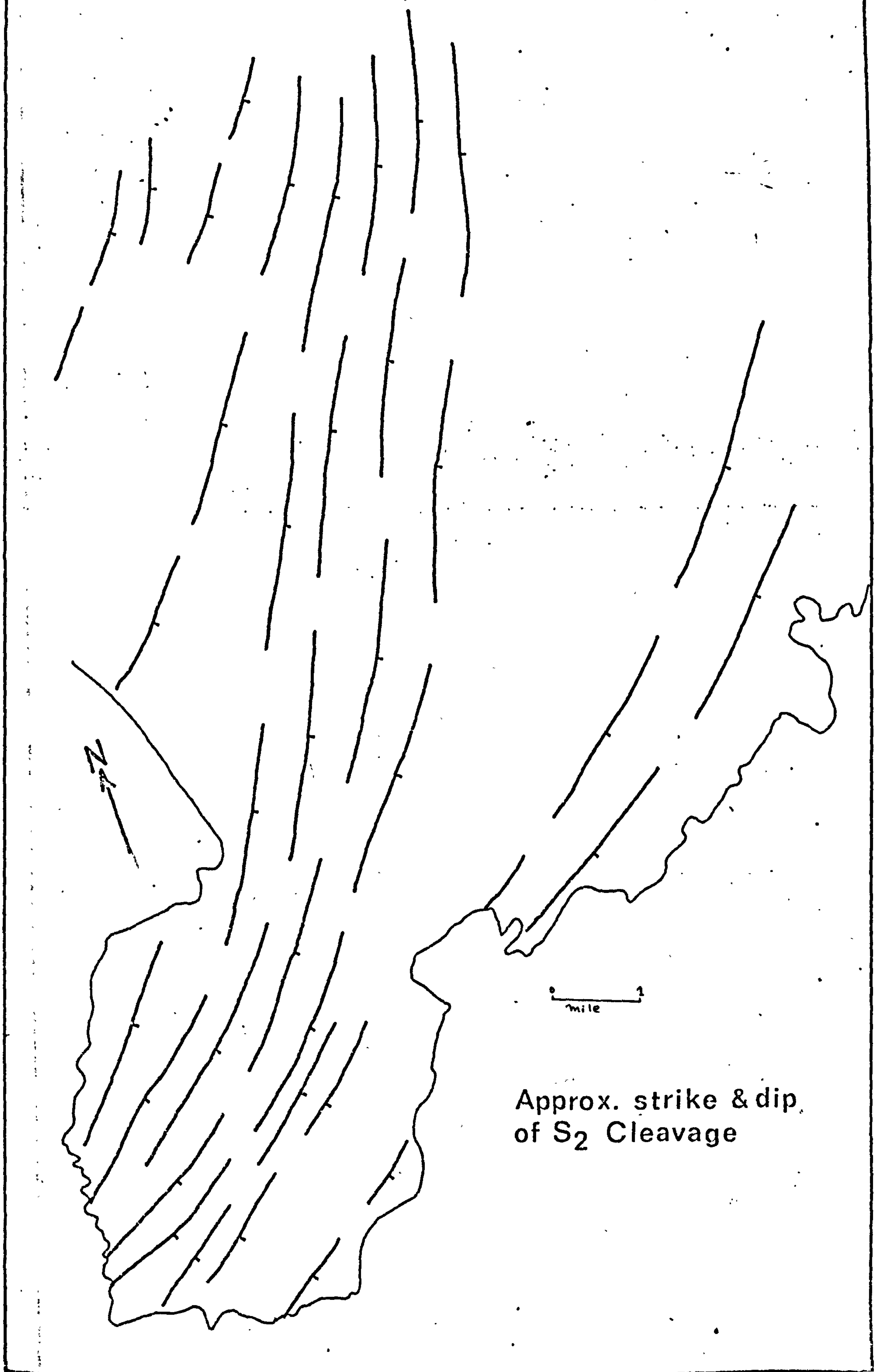
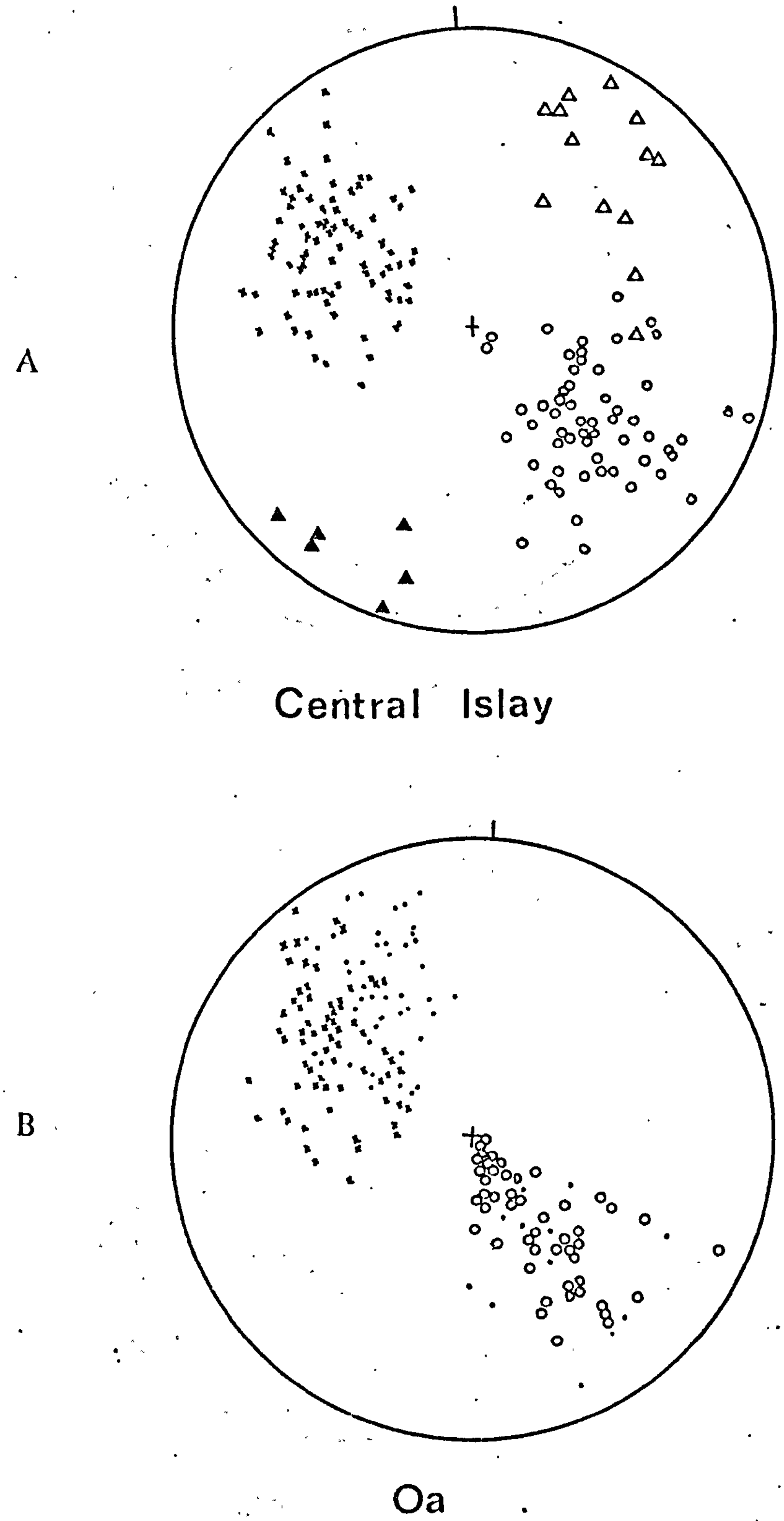
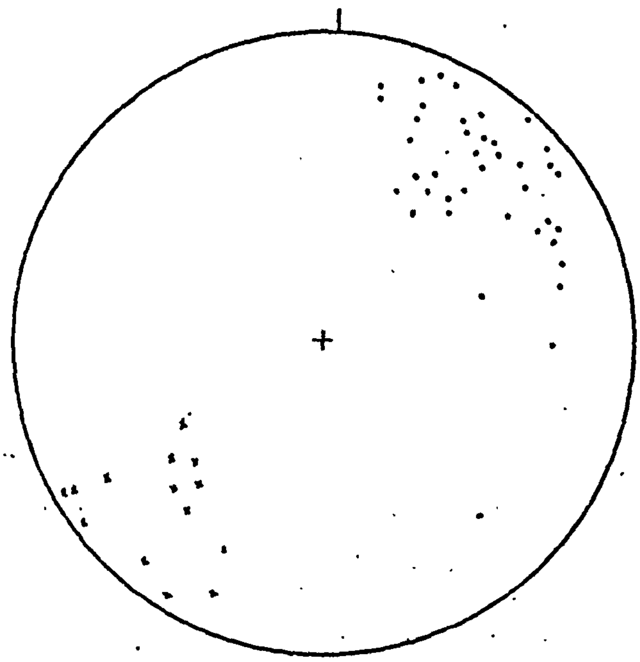


Fig 45

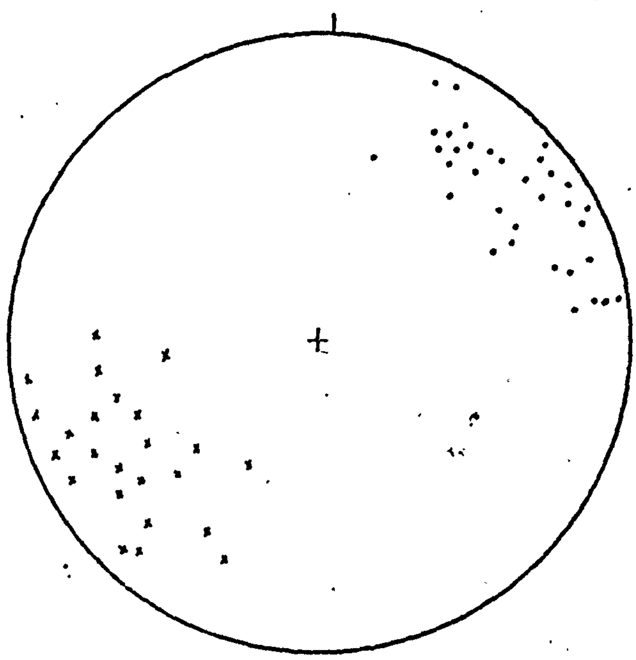


• S_1 Poles
× S_2 Poles
o S_3 Poles
△ F_2 Minor folds
▲ F_3 Minor folds

Fig 46



Central Islay



Oa

• L_2

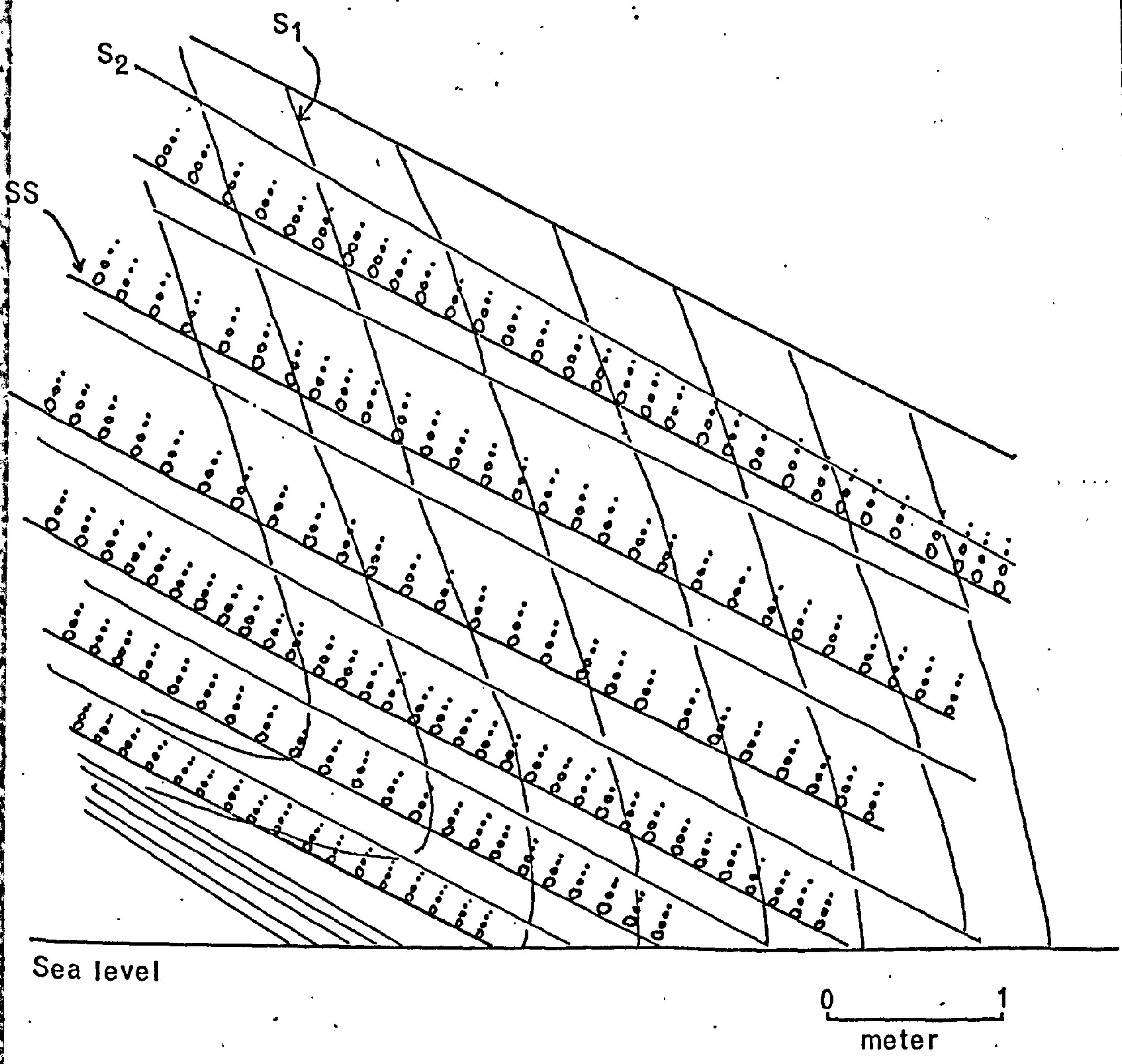
× L_3

F_2 Deformation

The F_2 phase established the fold pattern of the Islay Rocks on a large scale, forming a series of structures of about 6 km in wavelength and over 40 km in amplitude. All the folds are upward facing on S_2 and are generally over-folded to the north-west. They present large scale buckling of sedimentary layers. During this buckling, the layers were subjected to internal strain which, resulted in the formation of S_2, the main cleavage which is axial planar to the buckles. This flattering, however, is not the last stage of the F_2 phase for the following points:-

1. S_2 phases are often seen re-crystallized and with quartz orientated and elongated in the same direction as the axial plane (plate 66) e.g. in the south-west north-east direction.
2. The Central Islay Slide and the Mull of Oa Slide are buckled as F_2 folds, suggesting a post S_2 sliding.
3. In the locality of Kintra Farm, the Central Islay Slide cuts across the F_2 folds on a lesser scale. In the above-mentioned locality, illustrations show, how F_2 buckling continues after the formation of S_2 cleavage, and how this later buckling can result in major sliding.
4. The Loch Skerrol's Thrust and the Beinn Bhann thrust are associated with F_2 deformation. The Loch Skerrol's Thrust in the north-east of the Tallent Farm has been curved around F_2 fold in the same manner as the Central Islay Slide around the closure of Islay Anticline.

Fig 35



Field sketch of the relation between SS, S_1 & S_2 (G.R. 3444), (sea plate 56). Note that S_1 have been folded.

F_2 folds on a minor scale exhibit a wide variety of styles, which have a direct relationship to the tectonic environment. These minor folds will be discussed accordingly:-

(a) Minor F_2 Folds in the Oa

In the first zone, at the eastern limb of the Islay Anticline, the first (S_1) foliation dips more steeply than the S_2. The F_2 styles in this locality are different from the folds in the phyllite and those in the quartzite (more competent rocks). In the phyllite slightly tighter, isoclinal similar folds with detached limbs and thickened cores indicated the style of the large scale folds, where as in the quartzite, the style is of similar but slightly more open folds (plate 41).

This relation between the two styles is well illustrated at the Port Ellen Lighthouse, between the Jura Slate and the Scarba Conglomerate (plate 41). The junction between the above two units is a minor slide (plate 42). The Scarba Conglomerate forms an antiform, plunging toward the north-east, like the Islay Anticline. S_2 cleavage forms an axial planar foliation to the above-mentioned fold, while the S_1 has been folded. The isoclinal F_2 folds in the Jura Slate are very clear in (plate 41), and have S_2 axial planes. The slide in the above locality cuts through F_2 and is parallel with S_2 axial plane foliation. To the south-east (.G.R. 3444) is another example of the isoclinal F_2 folds in the Islay Quartzite (plate 56). Here the relation between S_S, S_1 and S_2 is of great importance: it is demonstrated that S_S and S_1 have been folded into isoclinal similar F_2 fold styles with relation to S_S, S_1 and S_2 are drawn in (fig 35).

Fig 34

F_2 Fold Styles in zone 2 of the Oa district

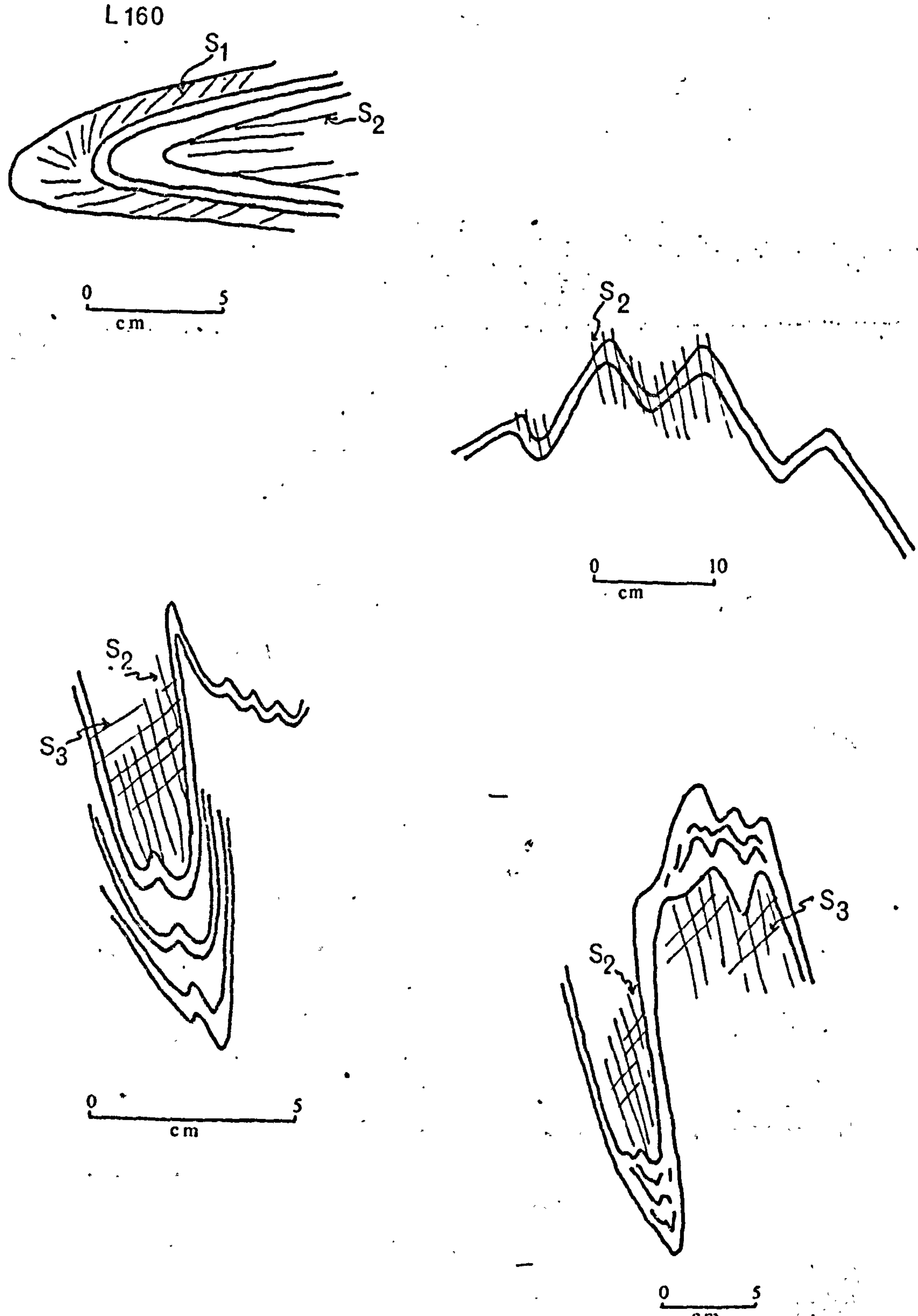
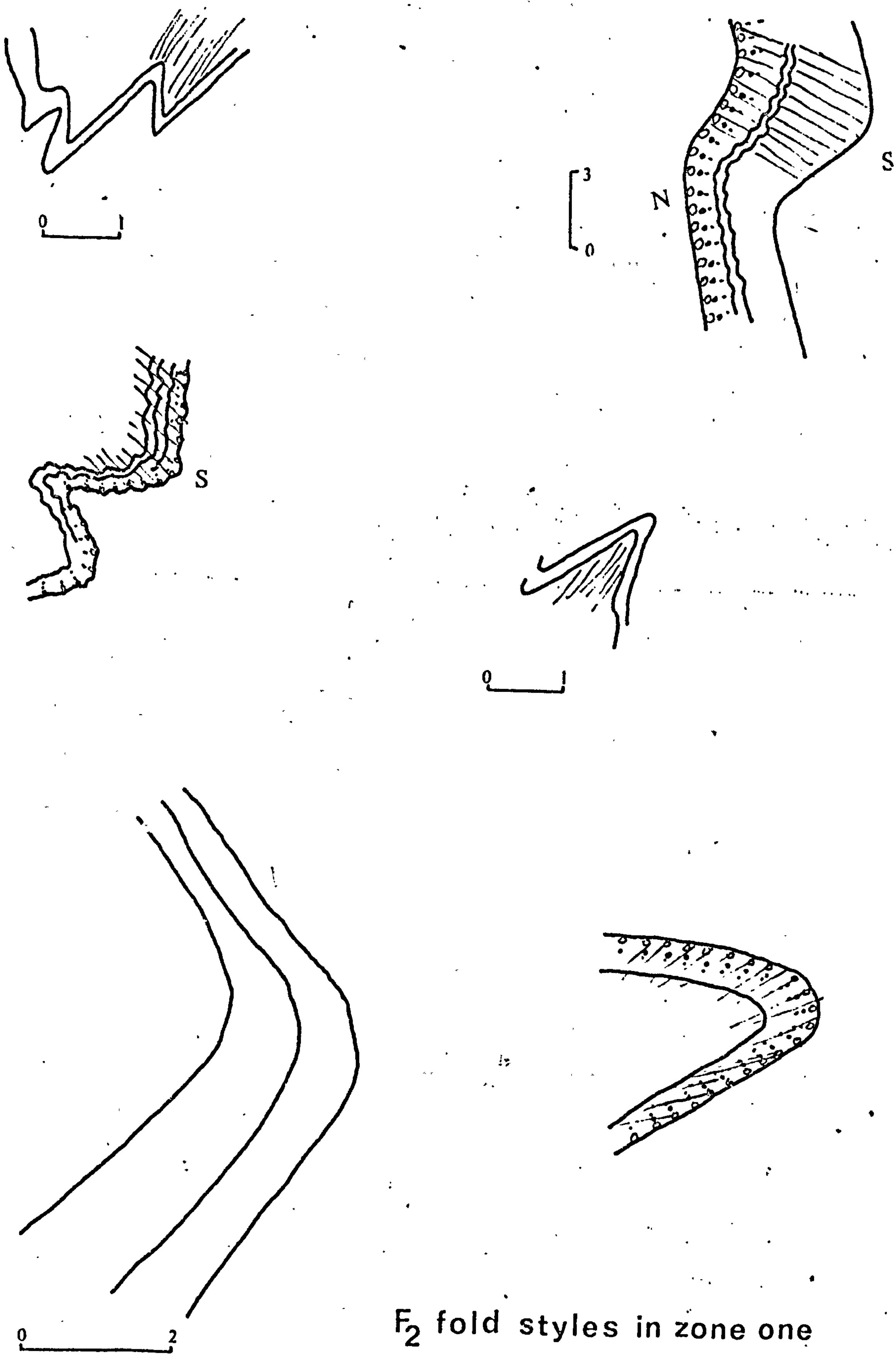


Fig 37



F_2 fold styles in zone one

Oa district

F_2 styles in the Port Ellen Phyllite in this zone are the same as those in the Jura Slate. Quartz veins appears in the phyllite where it has been folded in the F_2 styles, this suggests that:-

i The quartz veins are of pre-F_2 age

ii The quartz veins are the result of silica solution introduced into the sediments, or possibly produced as a result of re-crystallization of sandstone dykes.

Mushroom style F_2 folds have been recorded in the Port Ellen Phyllite (plate 43) (G.R. 3443). The mechanism of such folding is shown in (fig 36).

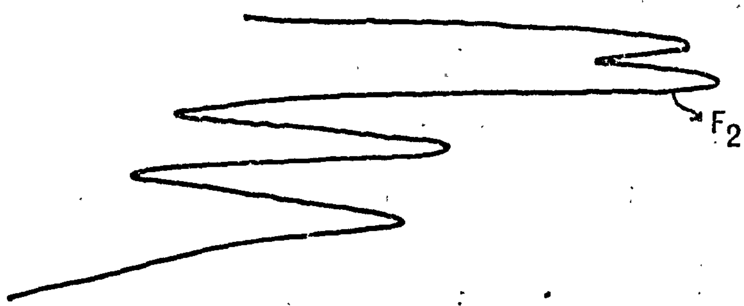
The fold developed as an isoclinal F_2 fold, and was distorted by the later F_3 deformation with a consequent rotation of each limb in the opposite direction, stage b.

In zone 2 the F_2 minor fold are isoclinal folds with detached limbs and thickened cores (fig 34) . Some of the competent beds in the phyllite preserve S_1 foliation which is folded around closures of the F_2 folds (fig34a). S_2 in this area is an axial plane foliation to the F_2 folds. Thin sections in the Port nan Gallan Phyllite, Kintra Phyllite and Baharradail Phyllite, show that S_1 is folded and S_2 is an axial plane to the resultant minor-folds (plate 57 & 58).

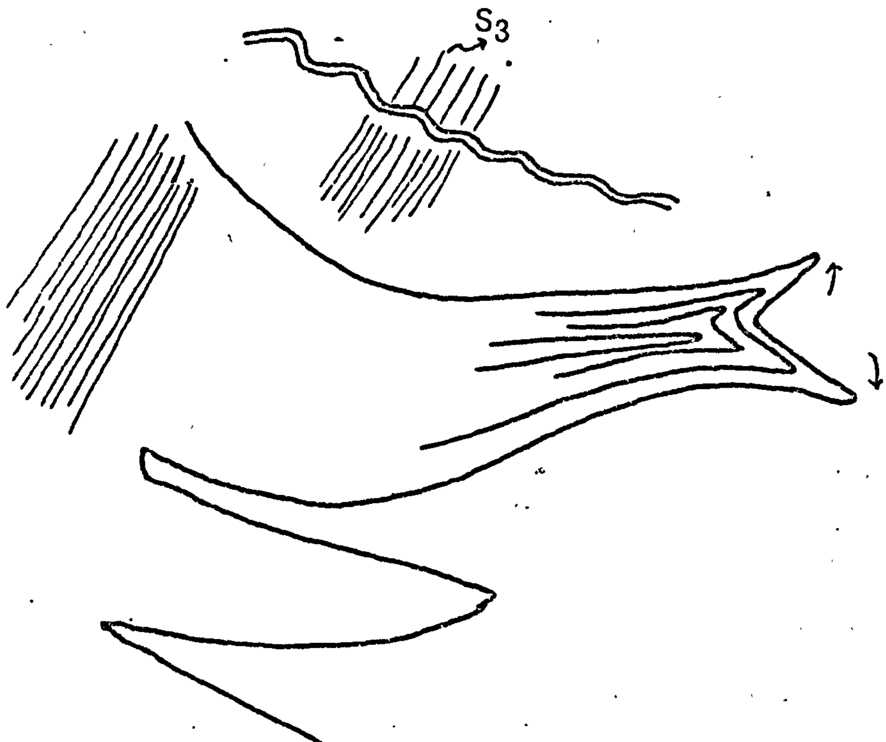
Zone 3 represent the western limb of the Islay Anticline, and western limb of the Oa Anticline, both limbs being overturned. The F_2 folds have varying axial plunges and directions. This is due to the greater effect of F_2 deformation, and the resulting from the Central Islay Slide. F_2 styles for this zone are shown in (pl. 42).

Fig 36

The development of F_2 mushroom fold



A



B

(b) Minor F_2 folds in Central Islay and Kildalton Districts

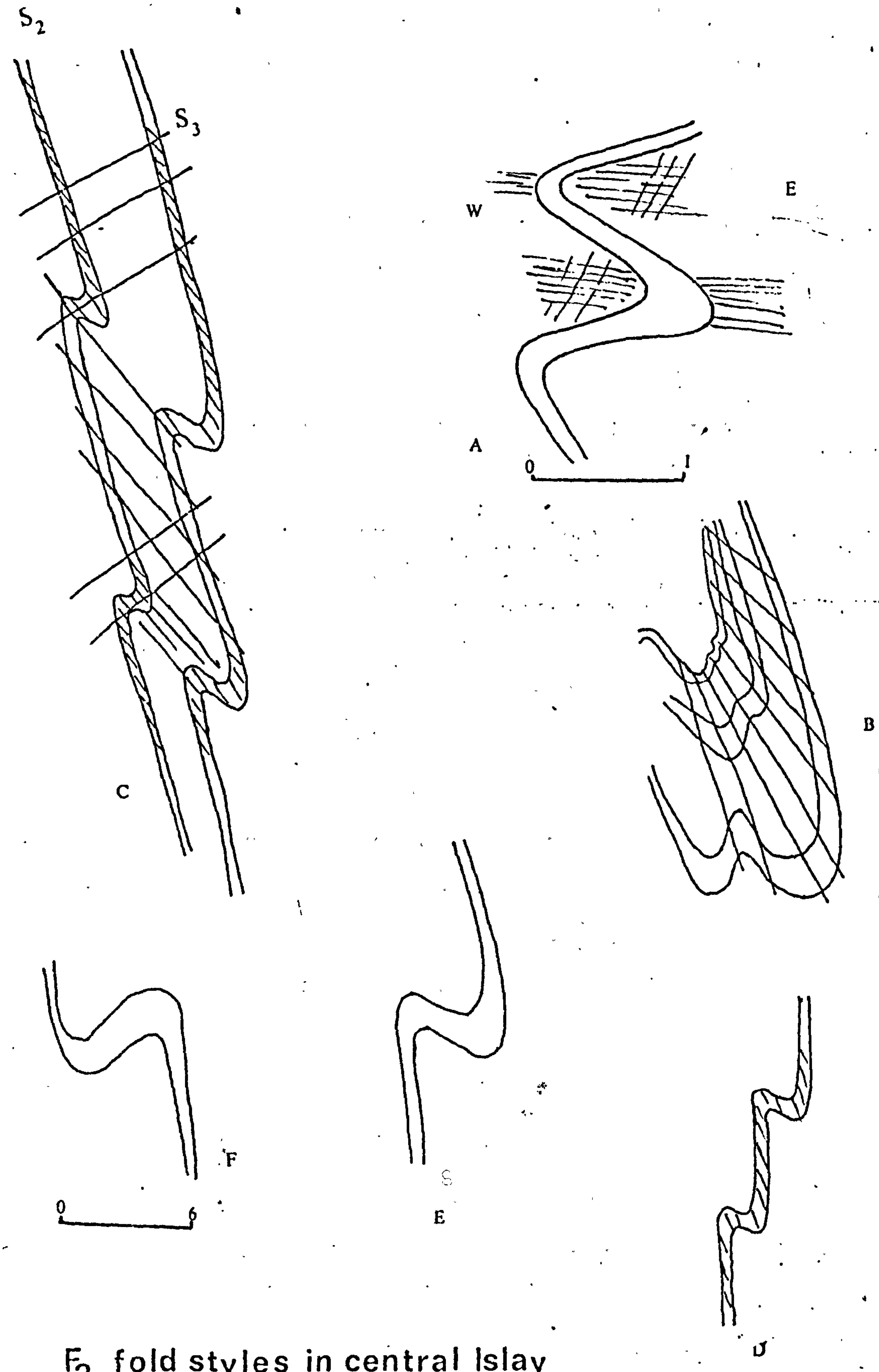
F_2 folds in Central Islay and Kildalton are similar to those in the Oa; in the latter locality the folds plunge steeply (50^o - 60^o) in the core of the Oa Anticline and 40^o - 50^o in the Central Islay Anticline. All the F_2 folds have been studied from the Core of those two Anticlines. The folds are isoclinal and the limbs are often detached with relatively thinner cores compared to those in the Oa. The rocks in Kildalton area are highly deformed, compared to the tocks surrounding it. This is due to the invasion of sills of epidionites. The folds are tight at the contact with the sills and are more open away from them (fig 38),

S_2 foliation.

The main schistosity (S_2) is cut across by closely spaced planes which are parallel to the axial planes of minute crenulation. In thin sections these planes are parallel to the limbs of the minor folds. The cleavage has produced parting of the rock along a zone where the micaceous minerals within the schistosity have been brought into parallelism on the fold limbs.

A microscopic study of some thin sections, shows an important structural feature of the rocks in the development of a stretching-direction. It is prominent, and is apparently controlled by lithology, being strongly developed in the more psammitic bands. In the latter it is indicated by quartz-fibres intercalating clastic grains of quartz and feldspar. In the more pelitic layers the stretching-direction is seen as fine quartz-fibres on micro films, elongate prismatic stock of stilpnomelane biotite and muscovite parallel to these fibres.

Fig 38



F_2 fold styles in central Islay

The minor folds in the Kintra Phyllite and in other phyllite rocks are, generally more open and, are thus unlikely to be first folds. Further, the early micro fabric shows interlaminated sercite mica between which detrital quartz of silt grade are flattened to form a penetrative fabric as in slaty cleavage (plate 60). Thus the dominent schistusity in the Islay Dalradian rocks appears to be S_2. In the field such foliation is easy to distinguish from an S_1, especially in the closure of the large scale folds. Veins of quartz and calcite represent S_2; in the former veins the quartz grains are stretched in the direction of S_2 (plate 63); in some thin sections quartz veins are cut by the S_3 slaty cleavage resulting in their off-set.

On either limb of the large folds, S_2 mica flakes while showing slightly differing sense of displacement, are generally sub-parallel to one another. Single S_2 planes, show no marked divergence in attitude. In thinly bedded layers S_2 sometimes fans round fold hinges, and an S_2 phyllite cleavage is often strongly refracted when traced from pelite into siltstone (fig 38b).

The great majority of minor folds seen in southern Islay are F_2 folds, since phyllite cleavages form their axial plane schistosities, and since S_1 in the competent rocks is folded round their hinges. Also the absence of large F_1 folds in southern Islay, suggests that all the folds observed are in fact F_2 folds. In the Kintra Phyllite, occupying the core of the Islay and the Oa anticlines, one prominent cleavage forms the axial plane of these folds.

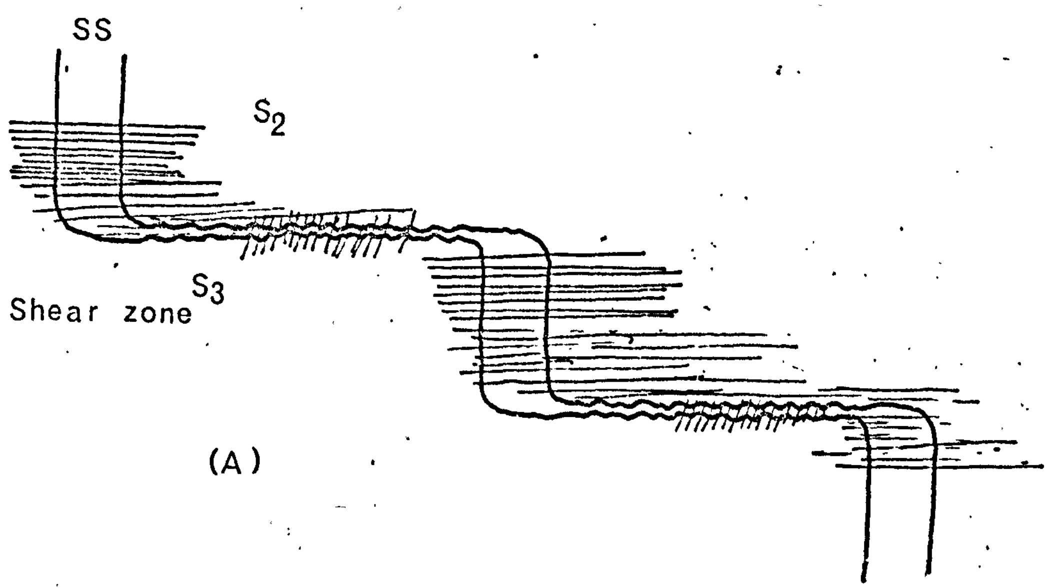
F_2 Slides

The two slides recognized in Islay, namely the Central Islay Slide and the Mull of Oa Slide, are not usually recognized by discreet planes of shearing; instead their presence can often be detected by sudden changes in fold geometry and stratigraphy. In one particular locality (G.R. 3148) the rocks are seen to be affected by the Central Islay Slide (plate 37). Here stratigraphy, fold geometry and the actual deformation are recognized. Shearing is well observed on a large scale (plate 37), and fold geometry and shearing are recognized on small scale (plate 38 & 39). F_2 folds are attenuated and thinned parallel to S_2 foliation whilst retaining normal thickness elsewhere. This is well recognized in the relatively competent rocks (Dolomitic Limestone). The attenuated fold limbs are not sheared or separated by shear zones, but have actually been thinned parallel to S_2, the minimum limb thickness being normal to S_2; this is attributed to the effect of the Central Islay Slide. The latter also is held responsible for the thinning of the Dalradian successions to the south-west.

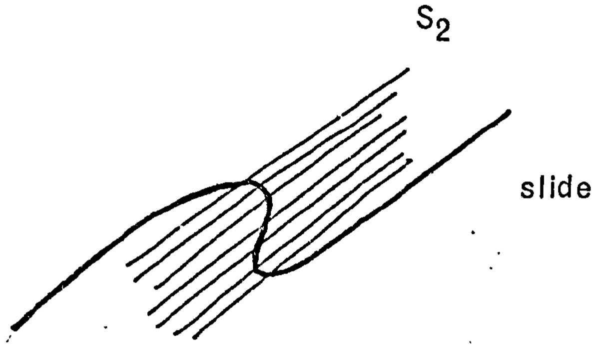
The two examples (plate 37 & 39) offer an illustration of plate 38) lamellae (dolomite, psamite and phyllite) following a zigzag pattern (step-shear), which is a repetition of the shear effect on the rock (fig 31). As a result of this shearing a change in the lamellae, resulted in thinning. The mechanism of such phenomena could be the product of simple shear if we ignore the volume change. In the example put forward there is evidence of shear zone, and what is observed is a thinning

Fig 40

Shear effect



(A)



(B)

without any deformation in the S_2 schistosity, which is parallel to the thinning zone, and normal to the surrounding unsheared lamellae. Ramsay and Graham (1970), proposed two alternative explanations for the relation between schistosity and shear zones:

i Schistosity forms parallel to the surface or (surfaces) of simply shear in the rock.

ii Schistosity forms perpendicular to the direction of greatest total shortening and it is widely held that it represents the XY plane of the finite strain ellipsoid with axes X Y Z.

In the examples they proposed they rejected the first theory on the basis that "Schistosity never forms parallel to the margins of the zone, it follows that it cannot be parallel to the shearing direction." Thus accordingly, the thinning of the lamellae (shear zone) which is in parrallel to S_2 schistosity cannot be the product of simple shear. The present writer is of the opinion that this phenomena presented in this thesis by examples (plate 39& 40) on the slide zone are not a simply product of simple or pure shear, but probably a result of both. This on the other hand can be explained as a product of a hetrogeneous deformation.

F_2 Thrusts

Beinn Bhann and Loch Skerrol's Thrust, are associated with asymmetrical folding, which in Beinn Bhann area trend parallel to the direction of major F_2 fold axes. Tectonic breccia and mylonization are found along its trace.
The Beinn Bhann Thrust to the south-east with a generally low angle, resulting in the disappearance of some units completely, and thinning out of the units along the strike toward the south-west. This Thrust is also responsible for the thinning of the Islay Quartzite and the Portaskaig Boulder Bed towards the north-east. The southern part of the Loch Skerrol's Thrust is almost completely covered by the superficial deposit (beet), but this does not preclude its continuation to the south-west. Since the Bowmore Sandstone outcrops in the Laggan Bay and there a slide must separate it from Dalradian rocks.

F_3 Deformation

F_3 phase of deformation in Islay generally has a small effect on the structure of its rocks. The folds produced by this phase have north-east to south-west trend with a gentle plunge 5 : 20. No large scale folds have been recognized in the area mapped. The effect of the deformation is greater to the south-west where it is best seen, and dies out towards the north-east.

Minor F_3 folds in the Oa Area

F_3 folds are best recognized in this locality and in particular on the cliffs extending from the Mull of Oa to the southern shore of Laggan Bay, where it forms a large tract of similar folds. The F_3 fold styles are gently open folds and isoclinal (fig 41 a & b). Lithological differences are recognized on the limb of folds; the lower limbs of the fold have been more deformed, and the rocks are more flaggy than the top limbs. This phenomena is best seen in the laminated Kintra Phyllite, and in the Kintra Limestone. A second visiable effect of the F_3 deformation are the complex disharmonic folds on the southern shore of Laggan Bay and on the cliffs of Lower Kelleyan Farm. Veins of quartz and calcite have cut through the cleavage, some of these veins of quartzite are of F_2 age, are seen to be folded in suspended folds.

F_3 Folds in Central Islay and Kildalton

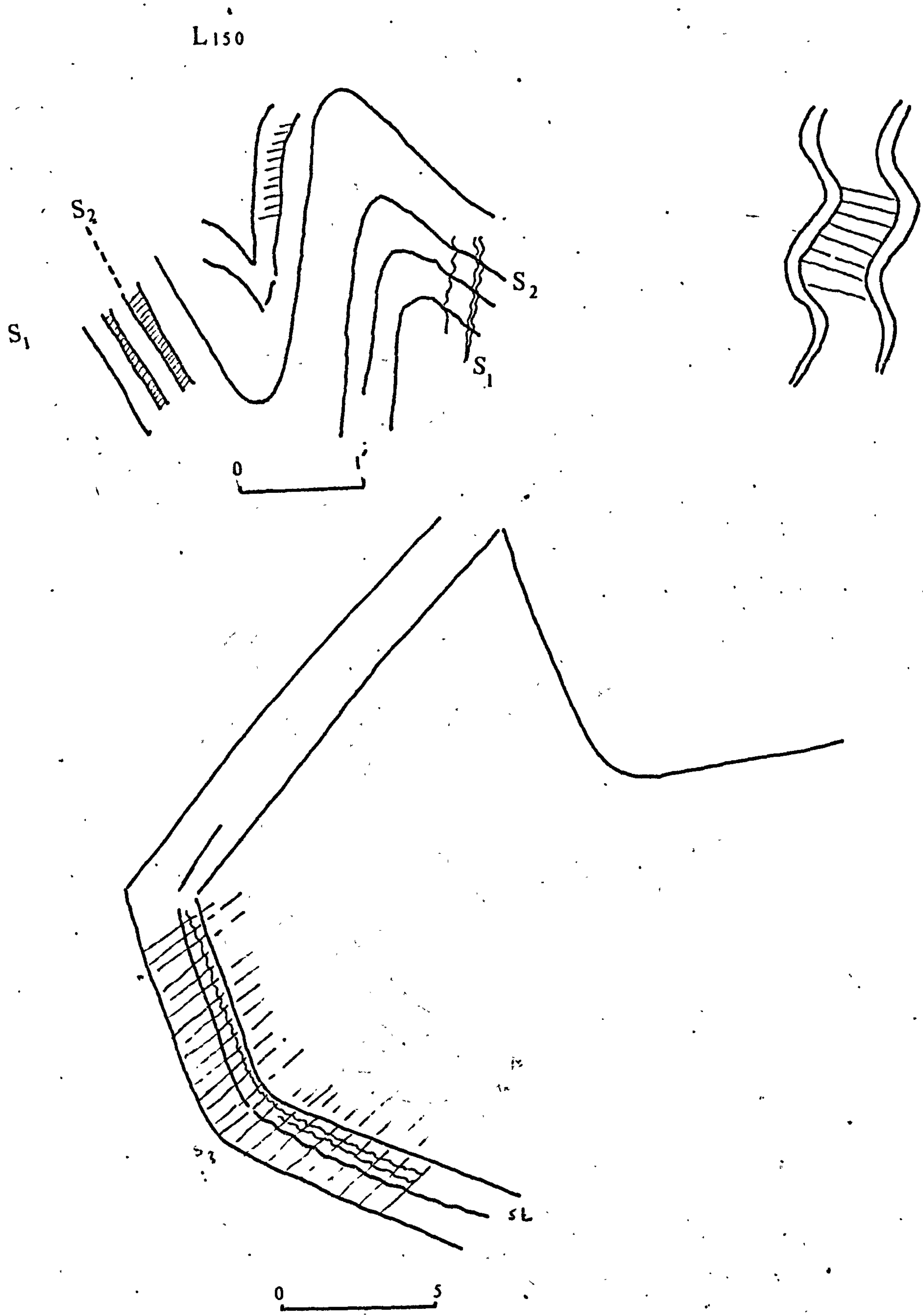
No major F_3 structures are recorded in either locality.

In Central Islay the F_3 phase affects the general structure by merely warping the limestone and the whole succession. Also the F_3 folds maintain the style described in the Oa district (fig 41a). In Kildalton the rocks are more highly affected by the F_3 phase than in any other district in Southern Islay. The slaty cleavage is highly penetrative and the folds are tighter (fig 41c). This phenomena is best seen in the phyllite near the Port Ellen Port.

Superimposed Folds

Small scale interference folds involving F_2 and F_3 folds are recorded from almost all districts of Southern Islay. This was produced by the superposition of F_2 and F_3 structures resulting in interference patterns (fig 36), producing superimposed folds on the small scale. Generally the early F_2 axes have been distorted so as to attain random directions. In one example the two axes F_2 to F_3 are having the same attitude with differences plunge direction (plate 44).

Fig 41a



F_3 fold styles in the district of Oa

Fig 41b

F$_3$ fold styles in central Islay

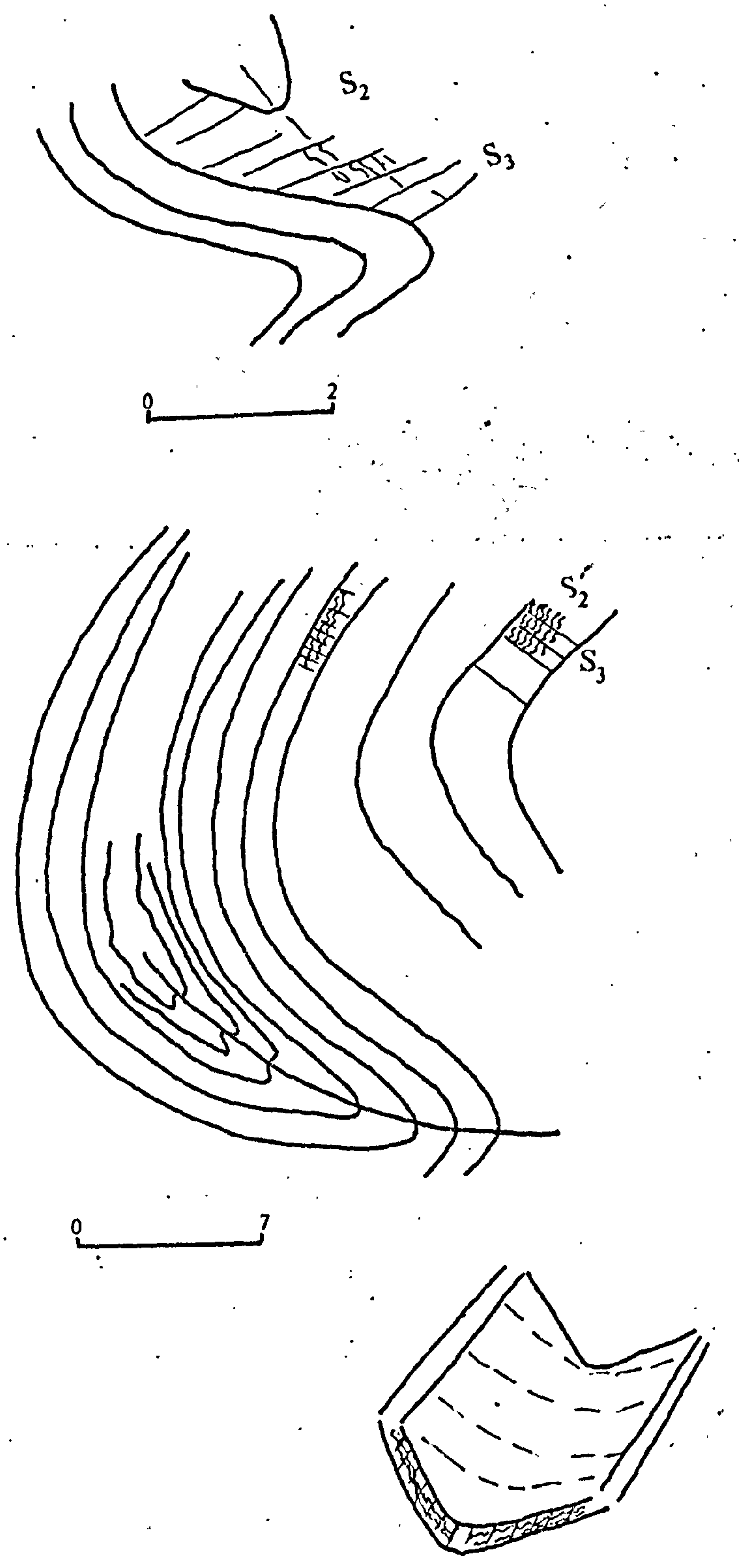
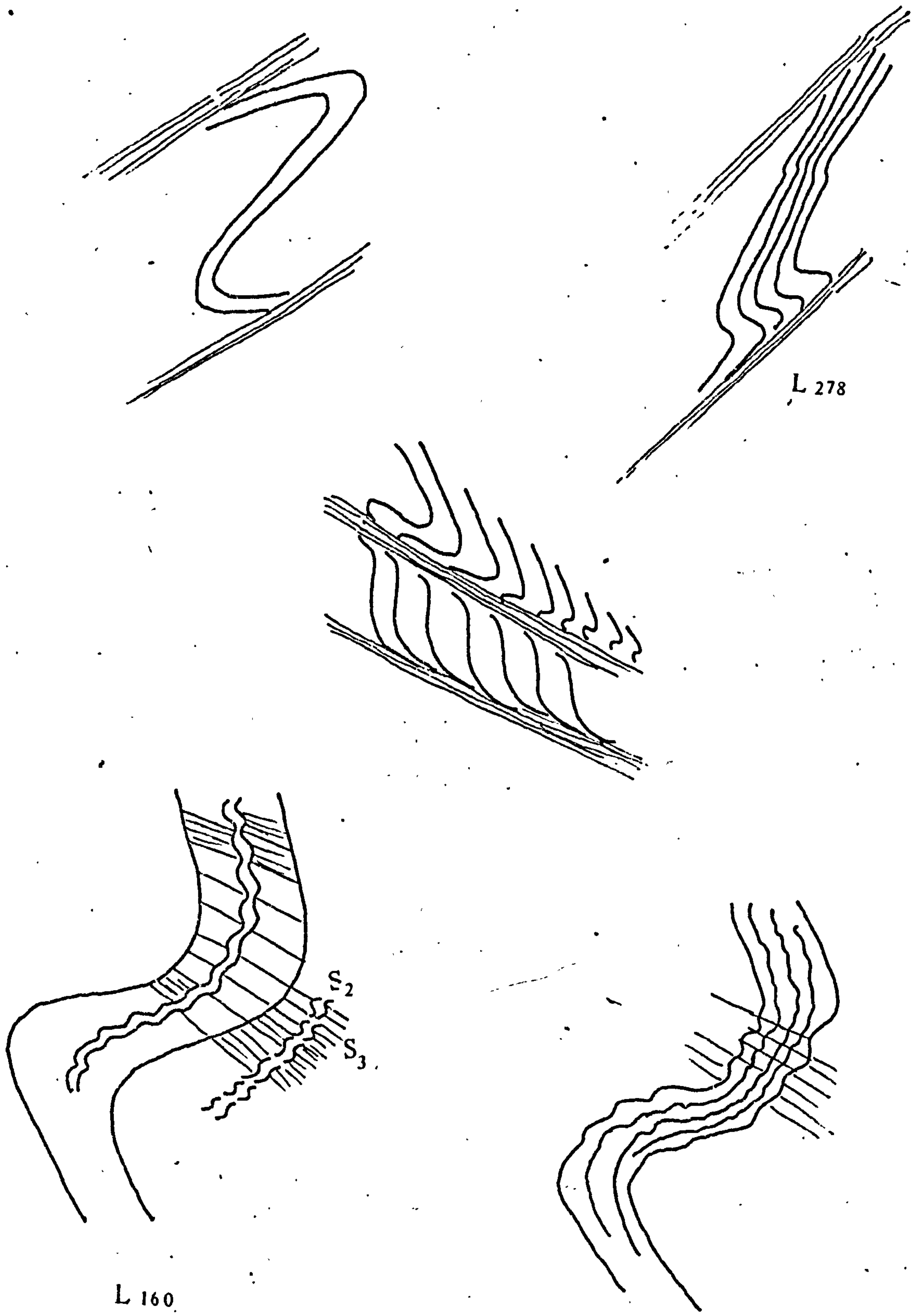


Fig 41c



F_3 fold styles in Kildalton

F_2 plunge steeply to the north-east with vertical axial plane, where as F_3 plunge to the south-west with a gentle plunge.

S_3 Cleavage (fig 45)

S_3 is generally crenulation cleavage (strain slip cleavage) and is found dipping shallowly to the north-west, at rather variable angles. This crenulation causes a strong tectonic rippling on S_3; excellent example of S_3 crenulations converting to actual S_3 cleavage occurs at Mull of Oa (G.R. 2744) (fig 46b). S_3 cleavage is constant in its strike all over the area mapped, with some exception, in the south-eastern limb of the Islay Anticline, where a change of dip to the south-east is recorded. Veins of quartz are associated with the trend of the S_3 having the same direction and dip (plate 6); this phenomenon is a result of the siliceous material penetrating along the cleavage and crystallizing. This also suggests that the temperature was a significant control in determining the development of the cleavage; temperature may have also controlled the type of cleavage developed.

A later F_3 deformation named F_3b with an S_3b cleavage, developed in the form of kink cleavage (fig41c). This is best seen in the Kintra Phyllite on the cliffs of the Oa (G.R. 2744), in Central Islay and in Port Ellen Phyllite (G.R. 3744), The kink cleavage which was best developed is axial planar to chevron folds.

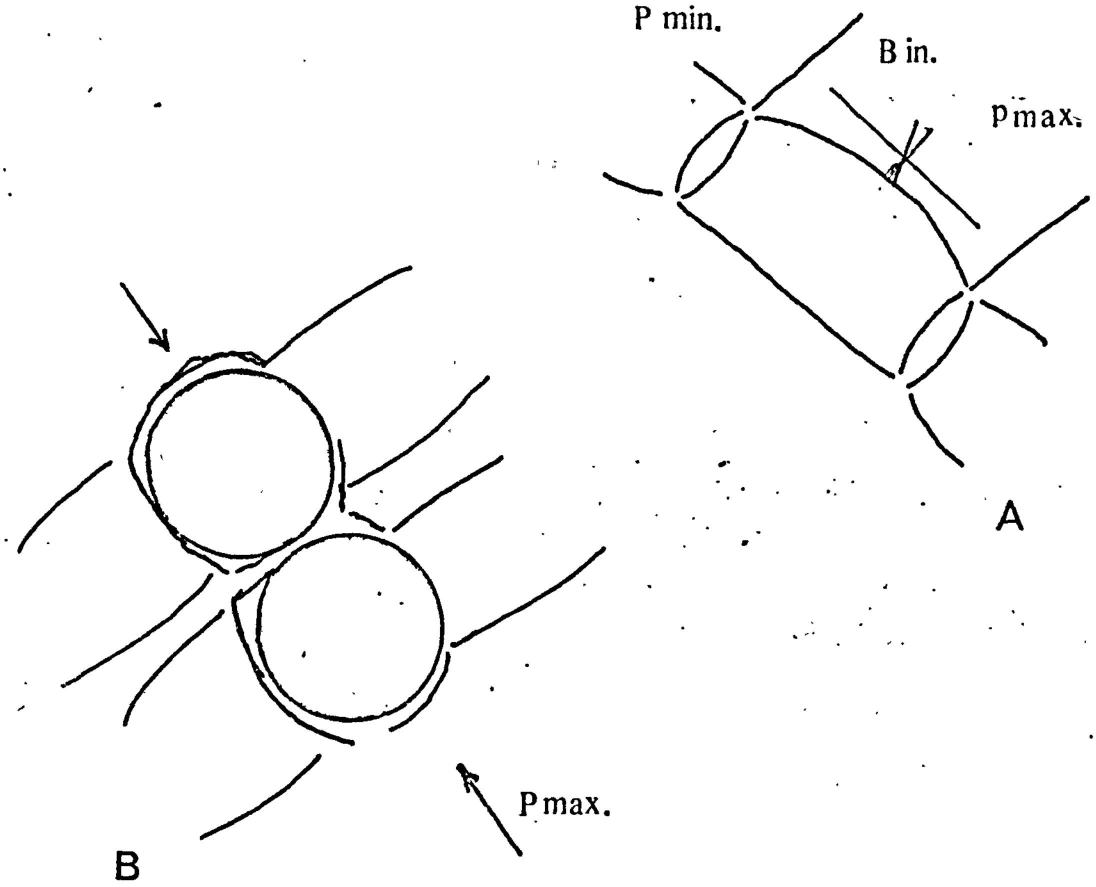
Boudinage

Boudinage structures are only observed in the south-western Islay (Oa district), and in particular occupying the south-eastern limb of the Islay Anticline. They are associated with a wide range of Islay rocks, e.g. limestone, epidiorites dykes and quartz veins. The boudinage belongs to two phases of deformation F_2 and F_3.

1. In the Port nan Gallan Bay (G.R. 2841), large boudinage is recognized on the steep exposure of the Port nan Gallan Limestone, between the Dolomitic Beds and the topmost flaggy limestones. The boudins have a width of about 4 meters and are separated by flaggy limestones. The boudinage is a result of compression normal to the layer, and shear movement, associated with the later phase of F_2 deformation. Strain slip cleavage S_3 cuts through the boudins, while S_2 cleavage is seen parallel to the bed inside the boudins (plate 44 and 50). Small scale boudinage in the same area is associated with the same features as mentioned above. The small scale boudinage has been folded by a later deformation. Also rotation in the boudins around their longitudinal axes is seen; the rotation occured in the direction of the strain slip cleavage. The rotation of the boudins as well as their folding suggests that the structures are associated with F_2 deformation. Detail of these structures are showmin (plate 51).

2. The development of boudinage in the dykes has been observed in the exposure (G.R. 3144), between the Ballygrant Limestone and horneblendic dyke. Here the dyke acted as the competent material, while the limestone was ductile, flowing around the boudin.

Fig 47



Development of the circular shape boudin

The boudins seen here are different in shape from any other seen in southern Islay. All the boudins described in the texts, to the best of the writer's knowledge, are either sausage or lozenge shaped (plate 54) in cross sections, while here the boudins are circular in cross sections, with the limestone beds surrounding them. This does not mean that the mechanism of such boudinage is different.

Three mechanisms are proposed for the circular-shaped boudins:

1. Early boudinage resulting from tension force of F_2 age, is followed by compression acting in the same direction as p<u>min</u> (fig 47). Such forces, are always observed, where there are several phases of deformation in the area.
2. The boudinage is of F_3 deformation and the compressional forces were more effective than the tensional ones.
3. Assuming that the shape of the boudinage is cylindroidal, then only a circular cross-section (2 dimensional) will be seen in the cliffs.

3. The third example is the development of quartz veins boudins in the epediorites (plate 52). This is seen in (G.R. 3443) the eastern side of the Oa. The boudinage is associated with an F_3 fold, affecting the epidiorite sill and having a wavelength of about 3 m. The orientation of the boudins in the closure of the fold does not indicate the direction of the folding axis with which they are associated.

Here the p min is at right angles to the direction of the fold axis. Details of the mechanism are shown in (fig 47).

This boudinage may have resulted from either of 2 mechanisms:

i The veins, regarded as pre-F_3 are deformed into boudins due to the competency difference between the epidiorites, quartzite and the surrounding phyllite, during the F_3 compression and subsequent tension on the limb fold. This possible mechanism is supported by the style of the boudinage around the closure of the fold (plate 52).

ii The boudinage itself regarded as pre-F_3, is refolded by F_3, evidence of this is that S_3 cut through the boudins, as well as the folding of the boudins (plate 53).

The present worker tends to support the second mechanism proposed above.

Mullion and rod structures

The mullion structures are only recognized in Central Islay (G.R. 3760). They are weakly developed in the Kintra Limestone, on the contact with the Kintra Phyllite (plate 15). The mullions generally have a steep plunge toward the east. Small scale folded rodding structures are also recognized (plate 47) in the Kintra Limestone, and in conformity with the Islay Anticline show a plunge of 40 - 50^{o} toward the north-east. Mullions and rodding are developed on the overturned limb of the Islay Anticline. Rods are also recognized in the Cnoc Don Quartzite (G.R. 3857) and in the Laphroaige Quartzite (G.R. 4755), where they are forms folded into cylindroidal folds (plate 46) with the same plunge as the Islay Anticline to the north-east.

F_4 Deformation

F_4 is represented by a strain slip cleavage, which simulates S_3 in the Port Ellen Phyllite near Port Ellen Port (G.R. 3745), and forms extensive small scale folding in that area. No F_4 has been detected in any other part of Southern Islay. Where F_4 is present in the Port Ellen Phyllite (Kildalton district) it is generally a gently dipping surface inclined to the south-east. F_4 is absent from the massive Lophroage Quartzite and the Ardmore Grits. The F_4 is the final episode in Islay history, no other phases such as F_5 and F_6 have been detected here, though Roberts in the south-west Highland (main land) (1963) reports F_5 and F_6, from various parts. The latter phases can be considered an equivalent of the secondary, or F_4 type of deformation which embraces all the strain-slip phenomena. The presence of F_5 and F_6 in the south-west Highlands suggest that the deformation increases toward the south-east and decreases toward the north-west.

SECTION 6

Discussion and Correllation with South-West (Mainland) Structures

The central argument of this section is that the second deformation in Islay Dalradian is the major phase. In this I differ from the view of the previous worker Bailey (1916), who referred to it as the F_1 deformation, and correllated it with the F_1 recumbent folds. Minor scale folds show that their relation to the major structures in Islay are thus one of strict parallelism, the relationship normally observed in folded rocks. This supports the major F_2 fold theory put forward in this thesis, since first folds have been recorded on the closure of the Islay Anticline, and having an axial plane trace trending to the south-east.

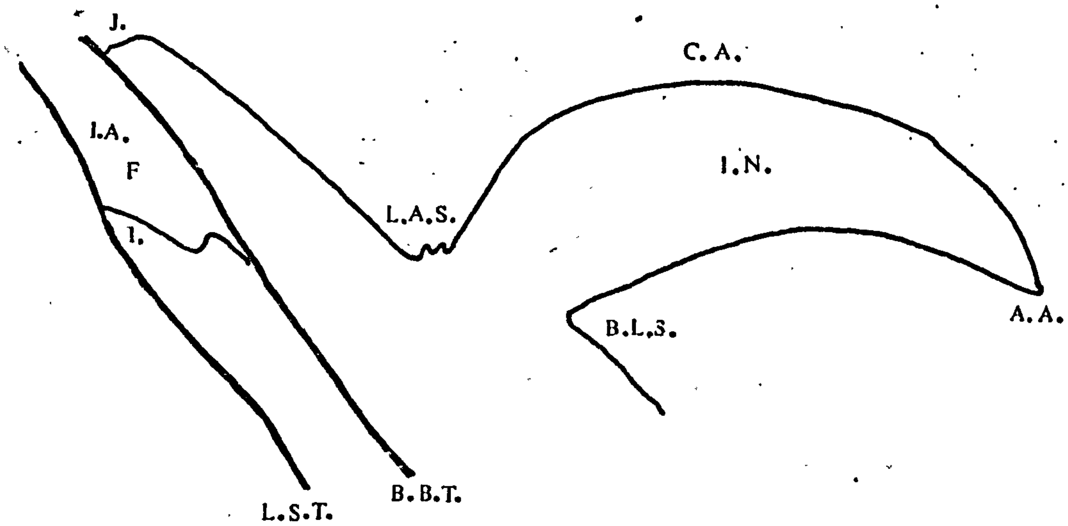
As previously described in this thesis S_1 cleavage is folded by S_2 (plate 56), which leaves no doubt that the Islay Anticline and the Oa Anticline and the other large structures have an axial plane trend of south-west to north-east with a plunge 40 - 60°, and are of F_2 deformation. Thus the trend of F_2 in Islay differs from that described by Rast (1958) where F_2 cross folds has an axial plane north-west to south-east. The change of axial plane between Central Highland and Islay can be explained as follows:

i. In the Central Highland F_2 cross-folds form recumbent folds.

ii. If we accept Bailey's suggestion (1916), that the Islay Anticline represents F_1 deformation, we face the problem of explaining the south-west to north-west trend of the structure which is incompatible with the Caledonoid F_1 deformation trend.

Fig 50

Section across Islay, Jura and the Southwest of Scotland



A.A. Aberfoyle Anticline
B.L.S. Ben Lui Syncline
B.B.T. Beinn Bhann Thrust
C.A. Cowal Antiform
I. Islay
I. A. Islay Anticline
I. N. Iltay Nappe
J. Jura
L.A.S. Loch Awe Syncline
L.S.T. Loch Skerrol's Thrust

iii In page 110 the present worker explains the sense of movement of the caledonoid phase on the light of block theory. We notice a striking coincidence in the relation between the axial plane trends of the three major deformations in the Dalradian rocks of Islay:

F_1 North-east to south-west

F_2 South-west to north-east

F_3 North-east to south-west, east-north-east to west-south-west.

This parallelism with its difference in plunge has suggested similar stress systems during the three phases of F_1, F_2; and F_3.

iv In Islay S_1, S_2 and S_3 cleavages occupy the same strike direction, although differing in dip. In south-east, in Jura and in Knapdale district Roberts (1959) describes folds having the same axial plane trend (south-west to north-east) as the Islay and Oa Anticlines with axial plane cleavage (S_2); however he refers these folds to the F_1. However according to Mr. Peter Gower (personal communication) in that area the S_2 cleavage acts as axial plane to F_2 folds; in fact all of the north-west Loch Awe syncline consists of F_2 folds.

Borradaile 1971 proposed a steeper original attitude to the Islay Anticline by unfolding the latter. This is due to a later movement of the monoform, if a later age of deformation for the monoform is accepted. The present writer rejects this theory unfolding the Islay Anticline as proposed by Dr. Borradaile (1971) would mean unfolding the Loch Skerrol's and Beinn Bhann thrusts which is impossible.

Correlation of Islay Structure with South-West (Mainland) Dalradian Structures

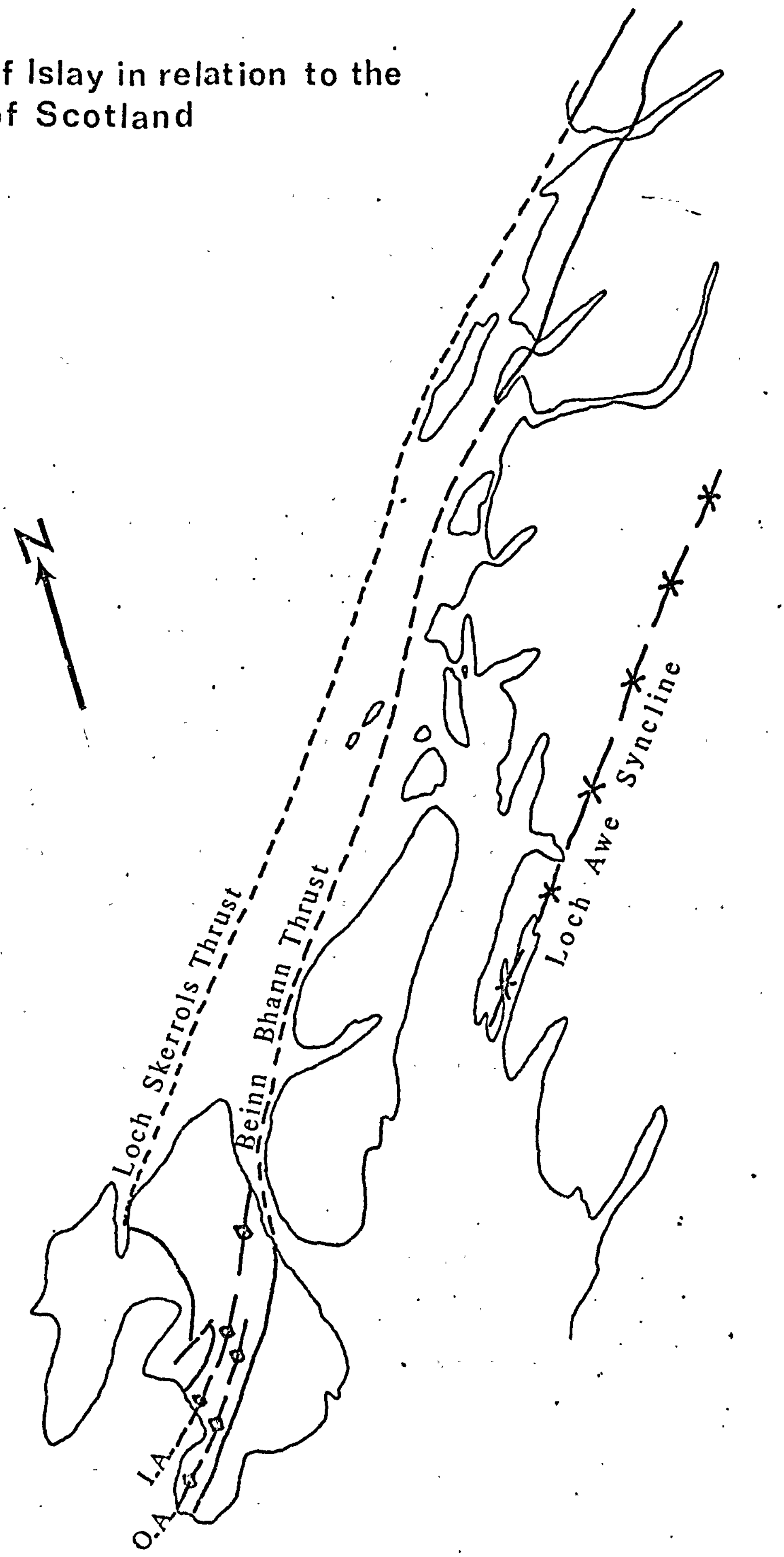
Many workers have tried to relate the Islay structures with structures of the mainland of Scotland, and Ireland, for example, Bailey (1916, 1922), Rast (1963), Shackleton (1957), Roberts (1963) and Litherland (1970). A general synthesis has been established by each. A detailed structural correlation followed by general synthesis is put forward here.

1. Loch Skerrol's Thrust

In this thesis the Loch Skerrol's Thrust have been considered to be the result of the F_2 deformation. Bailey (1916) correlated this thrust with the Moine Thrust, while Rast (1963) correlated it with the Iltay Slide. Recently Litherland (1970) correlated Loch Skerrol's Thrust with the Baltay Slide. The latter author has suggested the name Loch Skerrol's lag instead of thrust; by this he implies that it is an F_1 phase or part F_1. There is no evidence in Islay to support this suggestion, that the Loch Skerrol's Thrust is a lag. Further Litherland claims that the Loch Skerrol's Thrust follows the same course as the Baltay Slide, and occupies a position between the Portaskaig Boulder Bed and the Islay Quartzite (in the Ballachallish as well as in Donegal); also that both (Loch Skerrol's Thrust and Baltay Slide) are early gravity slope structures (F_1 deformation and earlier). No concrete evidence to support the contention that the Loch Skerrol's Thrust is a continuation of the Baltay Slide has been found. In fact in Islay Loch Skerrol's Thrust cuts through the Middle Dalradian and the Lower Dalradian, and no sign of an early gravity slope is detected in southern Islay.

Fig 49

Structure of Islay in relation to the Mainland of Scotland



Beinn Bhann Thrust

It has been shown that Beinn Bhann Thrust trends north-east to south-west through Islay, and is inclined. to the south-east. The thrust passes beneath the Islay Quartzite thrusting the Middle Dalradian over the Lower Dalradian. The Beinn Bhann Thrust continues to the north-east following the same course from Jura, Garvellachs up to the Ballachulish where it becomes the Baltay Slide. Further to the south-west Beinn Bhann Thrust may be present as the Knockateen Slide of Pitcher and Shackleton (1966), where it shows a similar searge of movement. A striking feature of the Beinn Bhann Thrust from Islay to Donegal to the south-west or Ballachullish to the north-east is the presence of the Portaskaig Boulder Bed along its course.

This correlation of Loch Skerrol's Thrust and Beinn Bhann Thrust with the Fort William Slide and the Baltay Slide respectively, explains the thinning of the Dalradian successions as a whole to the north-east, and the absence of Upper or Middle Dalradian from the western limb of Islay Anticline, as well as the dramatic thinning of Islay Quartzite and the Boulder Bed to the north-east (map 1).

Polyphase Deformation and Block Theory

After the previous interpretation of the structural synthesis of Islay put forward in section 5 and the establishment of the concept of Block theory in the Dalradian rocks of Islay and the South-West Highlands it is now necessary to review and interprete the polyphase deformation. The following observations have been made in Islay.

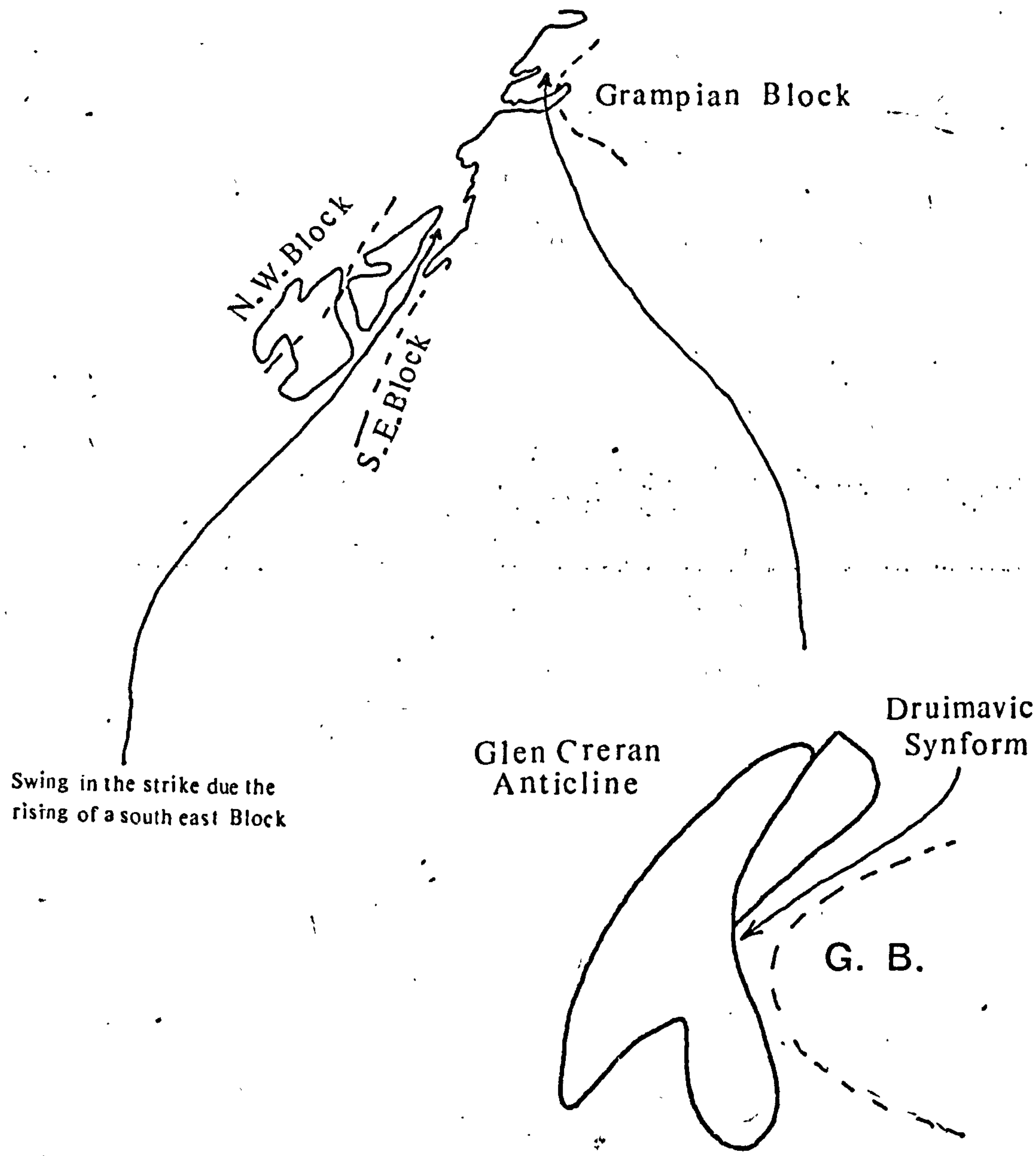
1. The most important phase of deformation is of F_2 age.
2. F_2 folds represents by Islay Anticline and the Oa Anticline having an axial plane trends of south-west to north-east.
3. F_1 folds generally have axial plane trends to the north-east to south-west.
4. F_3 folds are represented by open folds having an axial plane trending to the north-east to south-west.
5. Generally the cleavages recognized as S_1, S_2 and S_3 represent F_1, F_2 and F_3 phases of deformation and have analogous strikes, but differ in their dips; S_1 and S_2 dip to the south-east in general, while F_3 dips shallowly to the north-west.

The above mentioned points are of importance in the interpretation of the block theory to the polyphase development of structures.

<u>Firstly</u>: The F_1, F_2 and F_3 trends reflect the attitude of the north-west block. Thus F_1 and F_2 at least follow the same deformation in Islay. This also might be allowed for the F_3. The above mentioned conclusions are supported by the trend of S_1, S_2 and S_3 cleavages in Islay.

<u>Secondly</u>: F_2 folds are the result of buckling due to the compressive effect of two block, the second block having the same strike as the Grampian Block on the south-east of Islay (fig 51).

Fig 51



Sketch map for Block Defomation

<u>Thirdly</u>: Islay has escaped the F_1 deformation. This can be explained by the buckling around the margin of the Grampian Block and reveal a "corner" in the block outline, which is manifested as the Druinavuic Synform (Litherland 1970). The fold trends converge at Loch Awe, and this represent the south-western limit of the block. Thus the effect of the first plane decreases as it is developed away to the south-west, away from the Grampian Block. A new block to the south-west started to rise, resulting in the swing of the strike to the north-east of Jura, and Garavellach, which is a common case in orogenic belts. Thus at the Central Highland the F_1 phase is at its utmost as result of the upward movement of the Grampian Block, along deep faults initiated gravity flows at the south-eastern margin, where the interblock relief is greatest and buckling occurs at the north-west margin. Litherland (1970) defined the north-west Block as bordered by the Baltay Slide and in Islay by the Loch Skerrol's Thrust. As in Islay there is no evidence to assume that the Loch Skerrol's Thrust is the margin of the north-west Block. In this thesis the Loch Skerrol's Thrust is correlated with the Fort William Slide. Also this line in Islay is marked by two unconformities to the north-east and to the south-west (Section 3). Also the sedimentary evidence from the Lower Dalradian in Islay has shown that deposition during that period took place in shelf conditions. During

the Middle Dalradian however a new depression started to build up forming the Middle and Upper Dalradian Trough, to the south-east of Islay. The present position of Islay might coincide with that of the north-western block.

The relations between F_1 and the later fold phases has been discussed by Rast and Platt (1957); in general the phases represent decreasing fold amplitude and reflect a decrease in plasticity of sediments accompanied by increasing consolidation and recrystallisation Ramsay (1963). The latter phenomenon (recrystallization) is well seen in most thin sections in the form of microquartz veins. A problem has arrisen from the structural study in Islay - this is whether F_2 folds in Islay which has a trend to the south-west to north-east and F_2 (cross fold) of Rast (1958) which have north-west to south-east trend are equivalent. Such differances can be explained on the basis of the shape and style of the F_1 folds. In the Central Highlands F_2 folds are occupying the overthrust limb of large scale F_1 folds, resulting in major inflexion along the thrust or slide. As in Islay it is away from the effect of the first rise and compression and a second vertical block movement with interblock compression resulted in the second episode of deformation as It is in Islay trends to the south-west to north-east.

Within each block, deformation features such as fold, cleavage and interpenetrative distortion can only be explained by lateral compression generated between blocks (Rast and Crimes, 1968). This may be applied in

Islay to explain the same trends of folding recorded there. The folds in Islay have the same trend but different plunges: (F_1 - North-east to South-west; F_2 - South-west to North-east; and F_3 North-east to South-west); this may suggest that there are two or three blocks occupying the north-western, south-eastern and the north-east sides of Islay. These blocks were rising and subsiding vertically relative to each other, resulting in the three different phases of deformation (F_1, F_2 and F_3) with analogous trends, this does not eliminate the possibility of a deformation occuring with a trend normal to that of a previous deformation. Also a divergence of trend can result from the effect of tension on gravity.

SECTION 7

SUMMARY OF CONCLUSIONS

Summary of Conclusions

A stratigraphic and structural mapping has been constructed across the South Islay Dalradian rocks. With regard to the stratigraphy, the succession has been established in the Lower and all the Middle Dalradian rocks of Islay. The difference between this thesis and the previous works such as, the Geological Survey Wilkinson (1907), Bailey (1916), Green (1924) Gregory (1928) and Allison (1933) can be summarized as follows:-

1. The identification of, the Kintra Phyllite, Kintra Limestone, Cnoc Don Slate, Cnoc Don Quartzite, Cnoc Don Limestone Group, Baharradail Phyllite, Ballygrant Limestone, Port nan Gallan Phyllite and the Port nan Gallan Limestone of the Lower Dalradian, was made by breaking down the simple Mull of Oa Phyllite of Wilkinson (1907), This led to the confirmation of the existence of the Ballachulish succession in Islay. This in turn led to the correllation and joining of the Ireland Dalradian succession with its equivalent in Islay and the mainland of Scotland. A striking similarity is observed between the Kintra Phyllite, and its equivalent, 'Leven Schist' in the Ballachulish and of that of North Ireland. Other similarities are detected in the section of Cnoc Don area (Central Islay), where the stratigraphy follows the same sequence as its equivalent either in the Ballachulish or in Northern Ireland; that is the Cnoc Don Limestone group follow the same sequence as the Appin Limestone Group as follows:-

Phyllite - Calic Phyllite

Quartzite - Thick quartzite, interbedded with limestone

Limestone - Impure limestone

Table 7

Islay	Ballachulish	Blair Atholl
Port nan Gallan Limestone		White Limestone
Port nan Gallan Phyllite		Banded Group
Ballygrant Limestone	Lismore Limestone	Dark Limestone
Baharradail Phyllite	Cuil Bay Slate	Dark Schist

Overlie these are the

4 - White yellowish limestone

3 - Banded phyllite

2 - Dark blue limestone

1 - Dark phyllite.

Thus it is certain that in Islay, the Lower Dalradian sequence are uninterrupted from the Ballachulish into the Perthshire. The above four units of the top Lower Dalradian in Islay is clearly a reprezentation of the bottom part of the Blair Atholl series as well as the top part of the Ballachulish succession. Thus it is possible to say that the Lower Dalradian rocks are present in Islay without a major stratigraphic or tectonic break (table 7).

2. The identification of Kilbride Limestone, Kildalton Limestone, Ardmore Conglomerate and Ardmore Grits in the Middle Dalradian led to the establishment of a complete Middle Dalradian succession, and its correllation unit by unit with its equivalents in both Ireland and the mainland of Scotland. This is mainly due to the wide exposure of the conglomerate bed within the Portaskaig Boulder Bed in Islay and Garvellachs. Two rising blocks to the north-east and south-west contributed to the unconformity and the dramatic thinning of the Islay succession to the south-west and north-east.

A structural synthesis has been constructed for the Islay Dalradian rocks. Two major anticlines are recognized in Islay, namely the Islay Anticline and the Oa Anticline. The two anticlines were recognized from the stratigraphic repetition with aid of sedimentary structures and the cleavage bedding relationships.

Four phases of deformation, F_1, F_2, F_3 and F_4 were recorded.

On the basis of sedimentalogical interpretation, this thesis has demonstrated the shelf deposition of the shallow water Islay Dalradian sediments.

3. The discovery of unconformities in the Lower and Middle Dalradian is significant. The first unconformity between the Port nan Gallan Limestone, the Ballygrant Limestone and the Baharradail Phyllite (fig 11) is by a conglomerate zone. The second unconformity is within the Portaskaig Boulder Bed and is marked by a conglomerite bed 3 meters thick, and by the absence of some units recognized in the Garvellach succession Spencer (1966). The discovery of the latter unconformity, in the Boulder Bed, might record a large brake within the deposition of the Boulder Bed in Islay. The F_1, F_2, F_3 and F_4 planes are not intensive. The second phase is the strongest producing the present major folds with axial planes trend to the south-west to the north-east. Thus the Islay Anticline of Bailey (1916), and the Oa Anticline are of the second deformation and not of what has been suggested to be F_1 folds.

Two slides (Central Islay Slide and the Mull of Oa Slide) and Beinn Bhann Thrust are identified in Islay. All of these are associated with F_2 phase of deformation.

The establishment of the Lower and Middle Dalradian successions in Islay, makes it an ideal place for the study of the problems of structure, stratigraphy and sedimentalogy. The continuation from Lower to the top of the Middle Dalradian is unique to Islay and offers a promising terrain for further metamorphic and structural investigations.

Plate 37 Shear zone along the Central Islay Slide Port Alsaig west of Kintra Farm. The hummer marked the shearing zone.

Plate 38 General view for the small slide appear in the laminated phyllite west of Kintra Farm. Black line show the step slide as it appear. The folds are F_2.

Plate 39 and 40 Photo for the shearing zone (thinning of the lamellae). The match sticks are in parallel with the shear and S2 cleavage. F3 minor fold are developed along the shear zone.

Plate 40

Plate 41 The contact between the Jura Slate and Scarba Conglomerate "Port Ellen Lighthouse." F2 isoclinal folds in the Jura Slate, with S2 cleavage axial planes to the folds.

Plate 42 This is from the same locality as plate 41. The yellow pen marked the slide plane between the slate and the Scarba Conglomerate. Blue pen show the strike of the slate. Normal to the strike of the Conglomerate.

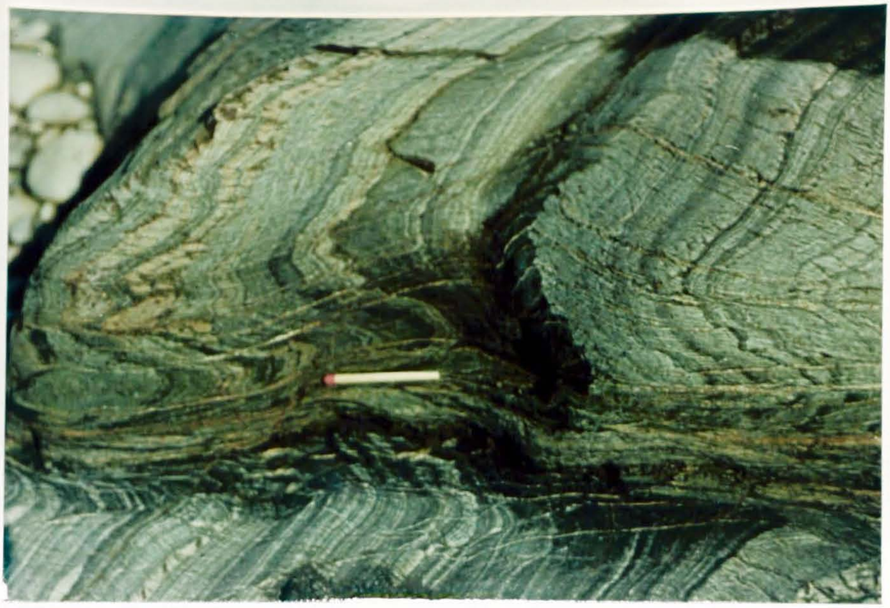


Plate 43 Mushroom style folds in the Port Ellen Phyllite. The match sticks marked the F2 mushroom folds, refolded by F3.

Plate 44 Superposed folds in the laminated Kintra Phyllite. F2 fold folded by F3, axial plane of F2 is vertical

Plate 45 Superposed folds in the Kintra Phyllites. Quartz veins have been refolded by F3. In the closure of the fold quartz veins show a rotational, and boudinage structure in the right hand side.


S3
F2

Plate 46 Mullion structures in the flagstone of the Port Ellen Group. The Mullions are plunged toward the north-east. Note the hummer and pen for scale.

Plate 47 Rodding in the Kintra Limestone Central Islay overturned limb Islay Anticline. The head hummer and the yellow pin pointing toward the plunge of the Rodding i.e. toward the north-east.

Plate 48 Ptygmatic F3 folds in the phyllites. Here S3 cleaned are more pronounced, also note the change in lithology on the lower limb left hand side. Quartz veins show boudinage which indicate elongation during F3 folding.



Plate 49 and 50 Large scale boudinage structure in the Port nan Gallan Limestone. These are of F2 age.

Plate 50

Plate 51 Enlargement photo to the small boudinage in the bottom of plate 52. Note the rotation in the boudins, which indicate pre F3 boudin structure deformation.

Plate 52 Quartz veins boudinage in the Epidiorite. Here the fold is of F3 age.

Plate 53 The quartz boudins in plate 53 show a rotation which indicate pre F3 boudinage. This also supported by the S2 cleavage which cut through the boudins.

S2

S3

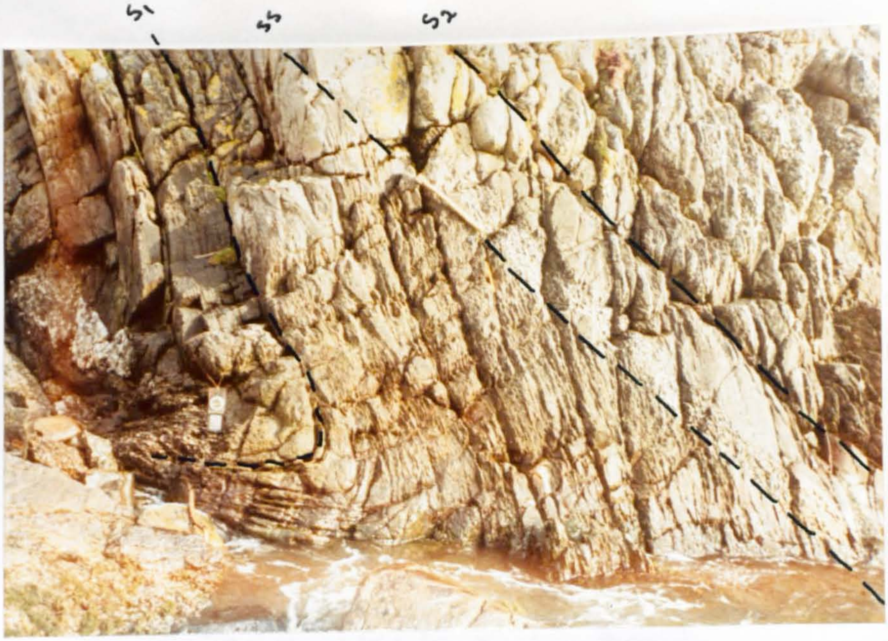
plate 54 Note the circular shape boudinage between the epidiorite and the Ballygrant Limestone. This is shown by the black line.

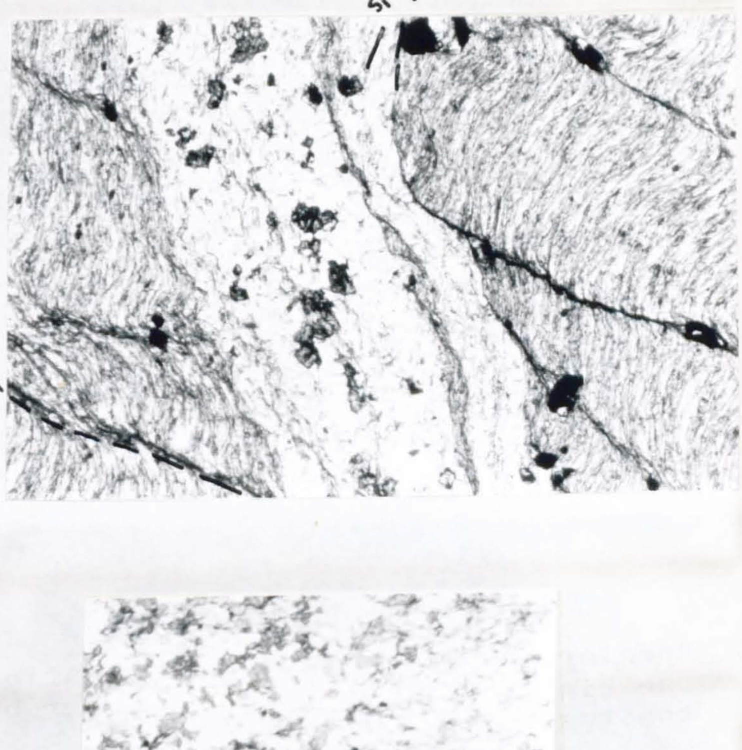
Plate 55 Epidiorite sills show F3 deformation within the Kintra Limestone. The hammer head pointed toward the F3 axial plane.

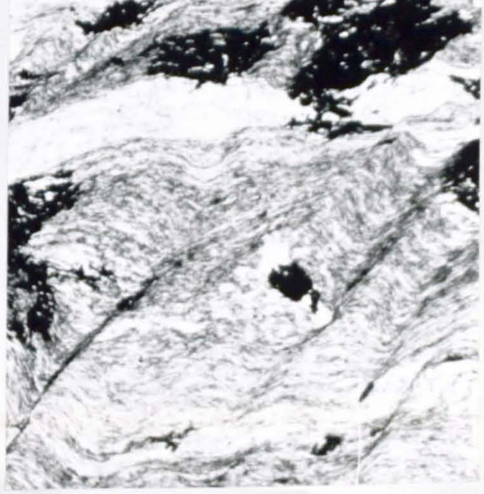
Plate 56. Note the relation between Ss, S1 and S2 cleavage. It shows that S1 has been folded and S2 are in parallelism with SS.

Plate 57. and 58. The plate shows the composite cleavage of S1, S2 as well as the bedding plane. In plate 57 incipient development of S3 cleavage is shown at the bottom of the plate.

Plate 58.


S1
S2


S1
S2
S3



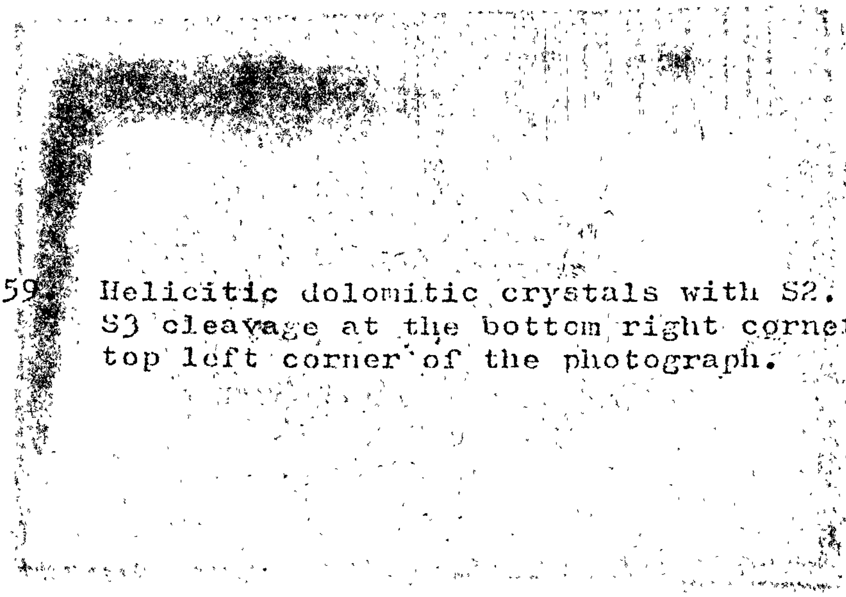


Plate 59. Helicitic dolomitic crystals with S2. Note S3 cleavage at the bottom right corner and top left corner of the photograph.

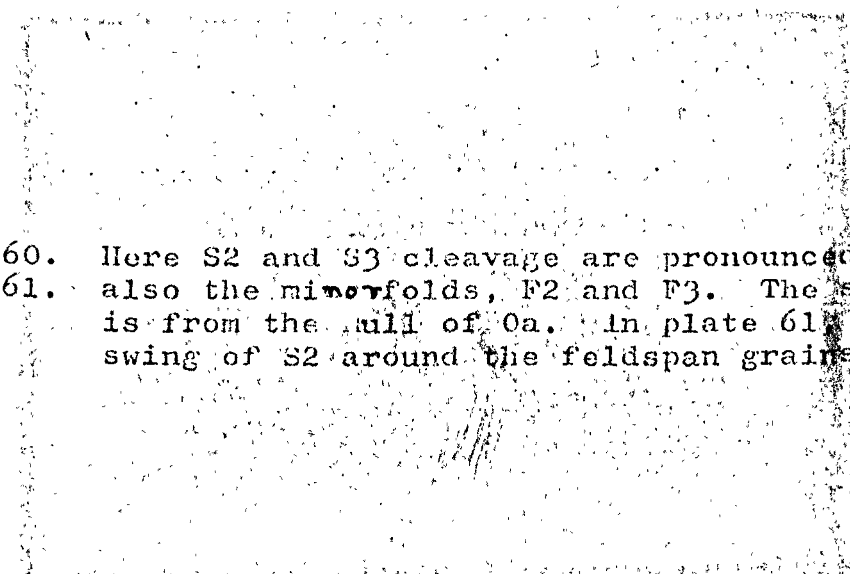


Plate 60. and 61. Here S2 and S3 cleavage are pronounced. Note also the minorfolds, F2 and F3. The section is from the hull of Oa. In plate 61 note the swing of S2 around the feldspan grains.

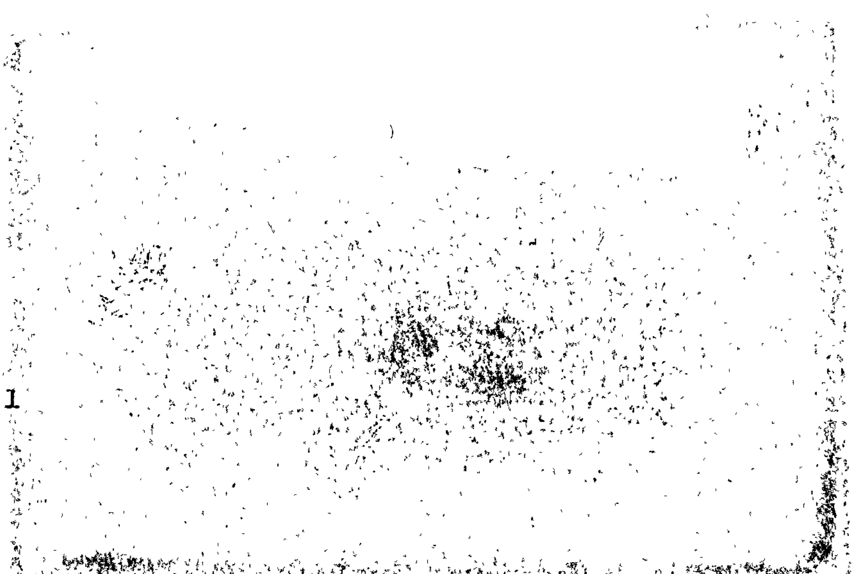


Plate 61

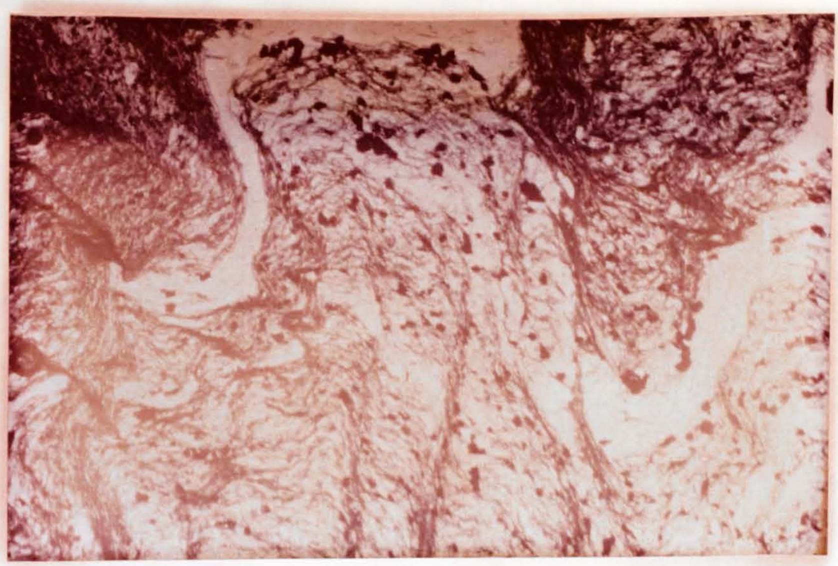
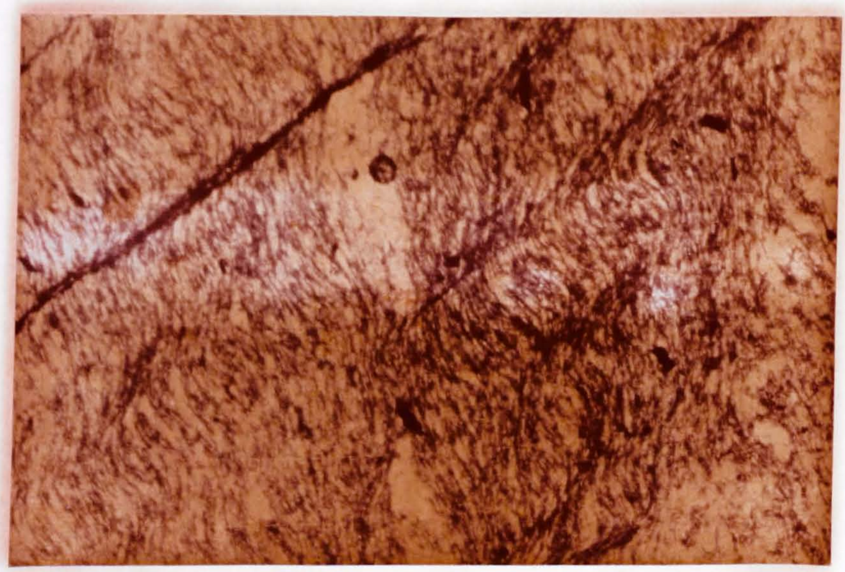
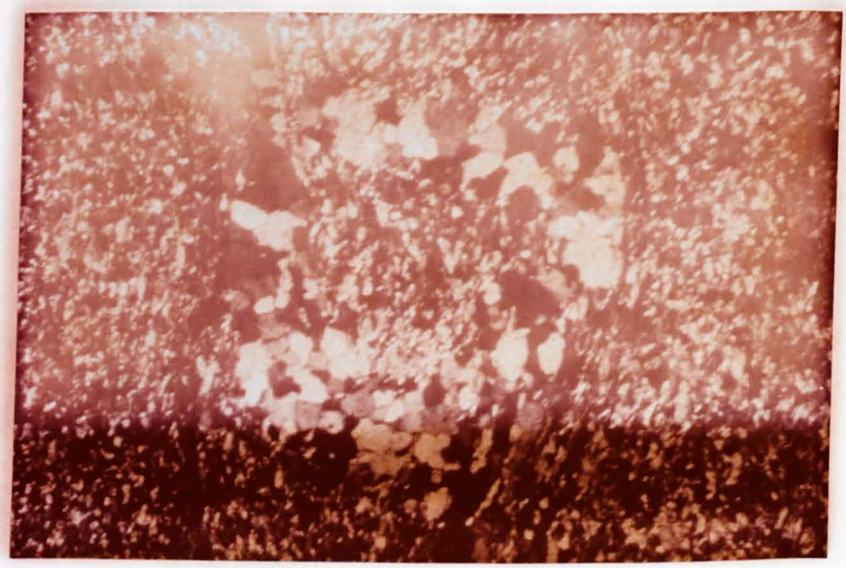
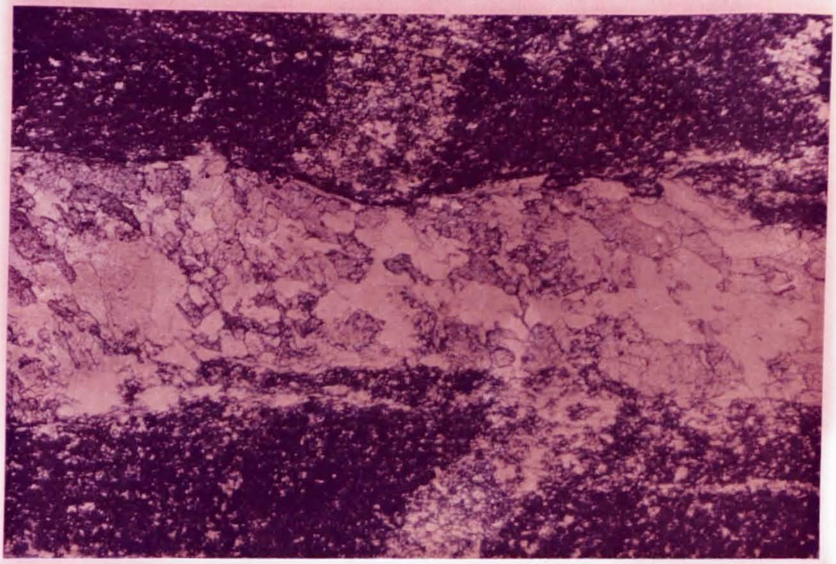




Plate 62 and 63. Quartz veins have been disrupted and cut by S3 cleavage. In plate 62, note the folded boudinage in the quartz vein.

Plate 63.

Plate 64. A quartz veins has been folded in a ring shape, which is rotated within the S2 cleavage.



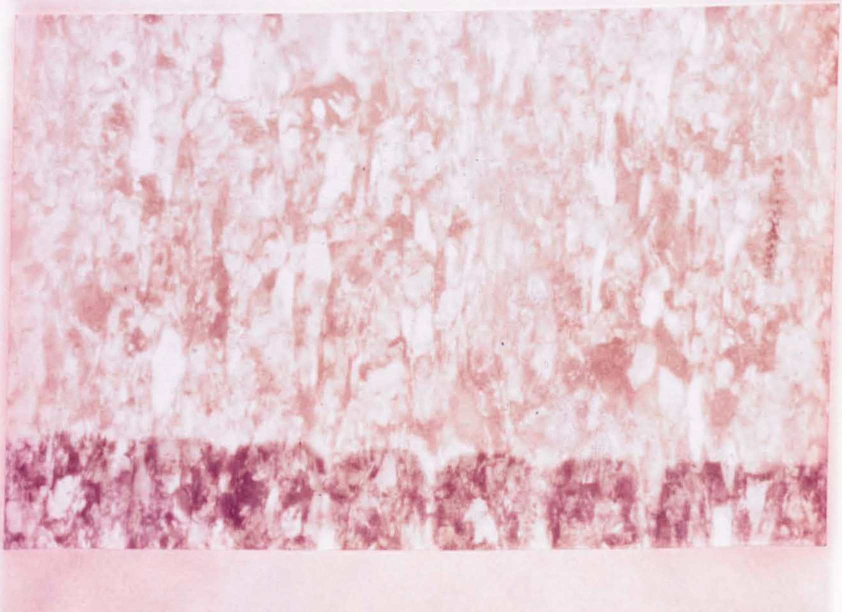


Plate 65. Calcite veins have displaced the bedding plane on the limb of microfolds (F2). These veins have the same strike as S2.

Plate 66. Quartz grains are elongated and orientated in the same direction as the S2 cleavage.

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REFERENCES

1. Allison, A. 1933 The Dalradian succession in Islay and Jura Quart. J. Geol. Soc. London. 89 125

2. 1940 Loch Awe succession and tectonics, Kilmartin - Tayvallish - Danna Quart. J. Geol. Soc. London. 96 423

3. Anderson, E.M. 1951 The dynamics of faulting 2nd edition Edinburgh. Oliver and Boyd.

4. Bailey, E.B. 1913 The Loch Awe Syncline. Qrt. J. Geol. Soc. 69 280

5. 1916 The Islay Anticline. Quart. J. Geol. Soc. 72 132

6. 1922 The Structure of the south-west Highlands of Scotland. Quart. J. Geol. Soc. London. 68 82

7. 1925 Perthshire Tectonics : Loch Tummel Blair Atholl and Glen Shee. Trans. Ray. Soc. Edin. 55 671

8. 1925 The metamorphism of the south-west Highlands Geol. Mag. 60 317

9. 1930 New light on sedimentation and tectonics Geol. Mag. 67 77

10. Clough, C.T. 1897 The Geology of Cowal. Mem. Geol. Surv. Scotland.

11. Cummins, W.A. and Shackleton, R.M. 1955 The Ben lui recumbent Syncline, south-west Highlands. Geol. Mag. 92 353

12. Elles, G.L. and Tilley, C.E. 1930 Metamorphism and structural in the south-west Highlands. Trans. Ray. Soc. Edin. 56 621

13. Green, J.F.N. 1924 The structure of the Bowmore-Portaskaig district of Islay. Quart. J. Geol. Soc. 80 72

14. 1931 The south-west Highland sequence. Quart. J. Geol. Soc. 87 513

15. Gregory, J.W. 1928 The sequence in Islay and Jura. Trans. Geol. Sur. Scotland.

16. Hackman, B.D. Knill, J.L 1962 Calcareous Algae from the Dalradian of Islay. Palaentology, 5 268.

17. Harris, A.L. 1963 Dalradian Geology of the Highland Border near Callander. Bull. Geol. Surv. U.K. 19 1

18. Howarth, R.J. Kilburn, G. Leake, B.E. 1966 The Boulder Bed succession at Glencolumbkille, County Donegal. Proc. Ray. Iris Acad. 65 117

19.	Johnson, M.R.W.	1969	The Dalradian of Scotland; in North Atlantic - Geology and Continental Drift. Ass. Am. Pet. Geol. Man. 12 309.
20.	Johnstone, G.S.	1966	The Grambian Highlands. 3rd edit. British Regional Geol.
21.	Kennedy, W.Q.	1948	The significance of the thermal structures of the Scottish Highlands. Geol. Mag. 85 229
22.	Kennedy, M.J.	1969	The structure and stratigraphy of the Dalradian rocks of north Achill Island County Mayo, Ireland. Quart. J. Geol. Soc. Lond. 125 1
23.	Kilburn, C. Pitcher, W.S. Shackleton, R.M.	1965	The stratigraph and origin of the Portaskaig Boulder Bed Series (Dalradian). Geol. Jour. 4, 343
24.	King, B.C. Rast, N.	1955	Tectonic styles in the Dalradian and moines of parts of the Central Highlands of Scotland, Proc. Geol. Assoc. 66, 243
25.		1956	The small-scale structures of south-eastern Cowal. Argyllshire. Geol. Mag. 93, 185
26.	Klein, G.	1970	Tidal origin of a precambrian Quartzite. The lower fine-grained Quartzite (Middle Dalradian) of Islay, Scotland. J. Petrology., 40, 973
27.	Knill, J.L.	1959	Palaeocurrents and sedimentary facies. of the Dalradian metasediments of the Craignish-Kilmelfort district, Argyll. Proc. Geol. Assoc. 70, 273
28.		1960	The tectonic pattern in the Dalradian of the Craignish-Kilmelfort district. Argyll. Quart. J. Geol. Soc. 115, 339
29.		1963	A sedimentary history of the Dalradian series: in Johnson, M.R.W. and Stewart, F.H. (editors), The British Caledonides; Edinburgh, Oliver and Boyd, 99.
30.	Knill, J.L. Knill, D.C.	1958	Some discordant fold structures from the Dalradian of Craignish Argyll and Rosguill, Co. Donegal. Geol. Mag. 95, 493
31.	Kuenen, P.H. Migliorini, C.I.	1950	Turbidity currents as a cause of graded bedding. J. Geol., 58, 91.
	Litherland, M.	1970	Unpublished Ph.D. Thesis The University of Liverpool

32. MacCulloch, J. 1814 Remarks on several parts of Scotland which exhibit quartz rock, and on the nature and connection of this rock in general. Trans. Geol. Soc. Lond. 2 450

33. 1819 A description of the western Isles of Scotland, including the Isle of Man Edinburgh.

34. Murchison, R.I. Geikie, A. 1861 On the attached rocks of the western island of Scotland and the north-western and Central Highland. Quart. J. Geol. Soc. 171

35. Peach, B.N. Kynaston, H. Maufe, H.B. 1909 The Geology of the Seaborad of Mid-Argyll. Mem. Geol. Surv.

36. and others 1911 The Geology of Knapdale, Ura and North Kintyne. Mem. Geol. Surv.

37. & Horne, J. 1930 Chapters on the Geology of Scotland, Oxford.

38. Pettijohn, F.J. 1957 Sedimentary rocks. Harper Bros. New York.

39. Pitcher, W.S. Shackleton, R.M. 1966 On the correllation of certain Lower Dalradian succession in north-west Donegal. Geol. Jour., 5, 149

40. Pulvertaft, T.C.R. 1961 The Dalradian successions and their relationship in the Churchill district of County Donegal, Proc. Royal Irish Acad., 61, 225

41. Ramsay, J.L. 1961 The effects of folding upon the orientation of sedimentation structure, J. Geol., 69, 84

42. 1962 The geometry and mechanics of formation of similar type folds. J. Geol. 70, 309

43. 1963 Structures and metamorphism of the Moine and Lewesian rocks of the north-west Caledonides. In Johnson, M.R.W. and F. H. Steward, 'The British Caledonides' Oliver and Boyd, Edinburgh.

44. 1967 Folding and fracturing of rocks. Intermostional series in the Earth and Planetry Sciences McGraw-Hill Book Company.

45. 1920

46. Rast, N. 1956 The Origin and significance of Boudinage Geol. Mag., 93, 401

47. 1958 The Tectonics of the Schichallion Complex. Quart. J. Geol. Soc. 114, 25

48. 1963 The structure and metamorphism of the Dalradian rocks of Scotland. In Johnson, M.R.W. and F. H. Stewart. "The British Caledonides" Oliver and Boyd, Edinburgh.

49. 1964 Morphology and interpretation of folds. A critical essay. Geol. J. 4

50. 1966 Recent trends in Geotectonics. Earth-Sciences reviews. I. M. Geol. Sci. 2

51. and Platt, J.I. 1957 Cross-Folds. Geol. Mag. 94, 159

52. and Crimes, T.P. 1969 Caledonian Orogenic Episodes in the British Isles and north-western France and their tectonic and chronological interpretation. Tectonophysics, 7, 277

53. Rast, N. Litherland, M. 1960 The correllation of the Perthshire (Iltay) and Ballachulish successions. Geol. Mag. p. 259.

54. Read, H.H. 1955 The Banff Nappe. Proc. Geol. Assoc., 66, 1

55. Roberts, J.L. 1959 Fold structures in the Dalradian rocks of Knapdale, Argyllshire. Geol. Mag. 96, 221

56. 1963 The Dalradian of the south-west Highlands of Scotland. Unpub. Ph.D. Thesis Univ. of Liverpool.

57. 1966 (a) The formation of similar folds by inhomogeneous plastic strain, with reference to the fourth phase of deformation affecting the Dalradian rocks of the south-west Highlands of Scotland, J. Geol. 74, 831

58. 1966 (b) Sedimentary affiliations and stratigraphic correllation of the Dalradian rocks in the south-west Highland of Scotland. Scott. J. Geol. 20, 200.

59. Shackleton, R.M. 1957 Downward-facing structures of the Highland Border. Quart. J. Geol. Soc. 113, 361

60. 1961 Contribution to symposium: some aspects of sedimentation in Orag-enic Belts, Proc. Geol. Soc. Lond. 1587, 75

61. Smith, A.J. Rast, N. 1958 Sedimentary dykes in the Dalradian of Scotland. Geol. Mag. 95, 234

62. Spencer, A.M. 1966 The Portaskaig Boulder Bed. Unpub. Ph.D. Thesis. Univ. of Liverpool.

63. 1969 Discussion of memoir 'late pre-Cambrian glaciation in Scotland' Proc. Geol. Soc. Lond., 1657, 177

64. 1971 Late pre-Cambrian glaciation in Scotland. Mem. of the Geol. Soc. Lond.

65. Spencer, A.M. Pitcher, W.S. 1968 Occurrence of the Portaskaig Boulder Bed in north-east Scotland. Proc. Geol. Soc. Lond. 1650, 195

66. Sturt, B.A. 1961 The geological structure of the area south of Loch Tummel. Quart. J. Geol. Soc., 117, 131

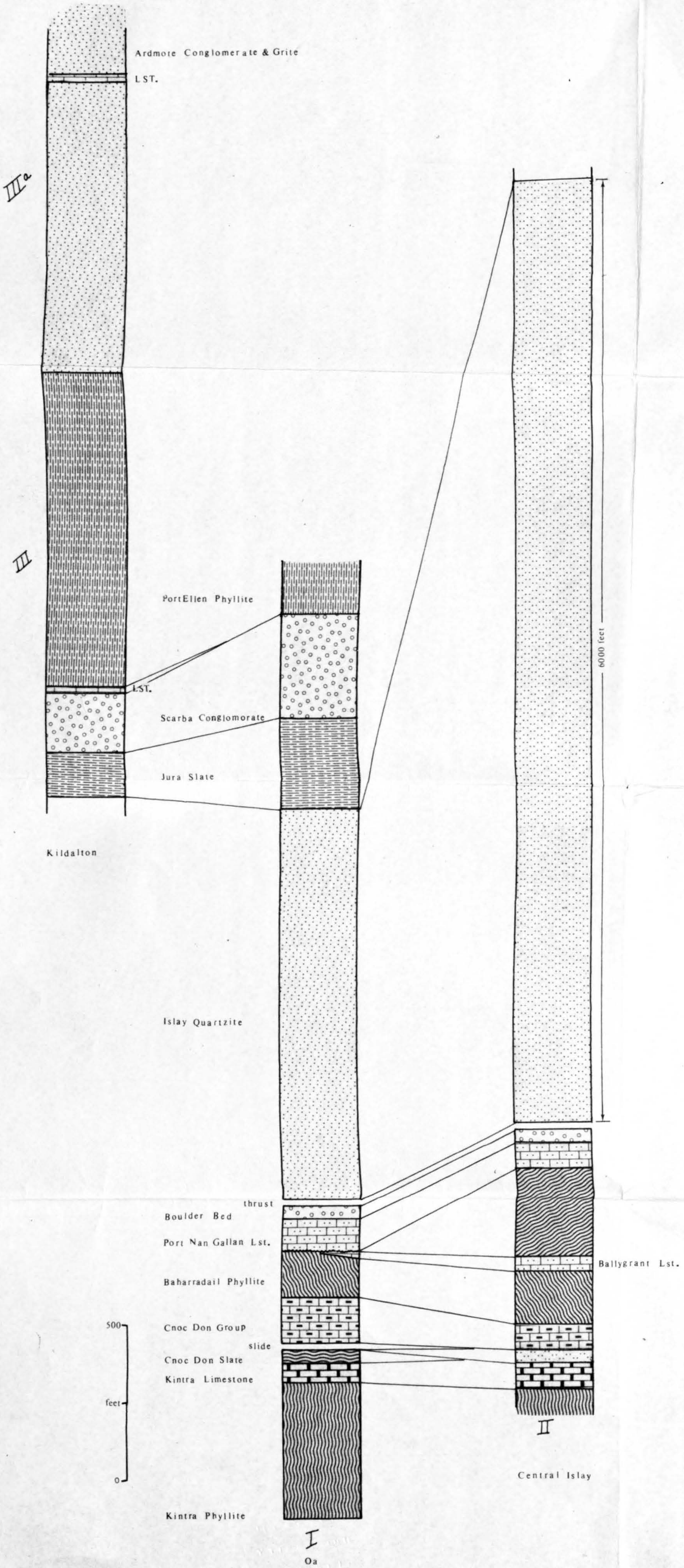
67. Sutton, J. Watson, J.V. 1955 The deposition of the Upper Dalradian rocks of the Banffshire Coast. Proc. Geol. Assoc. 66, 101

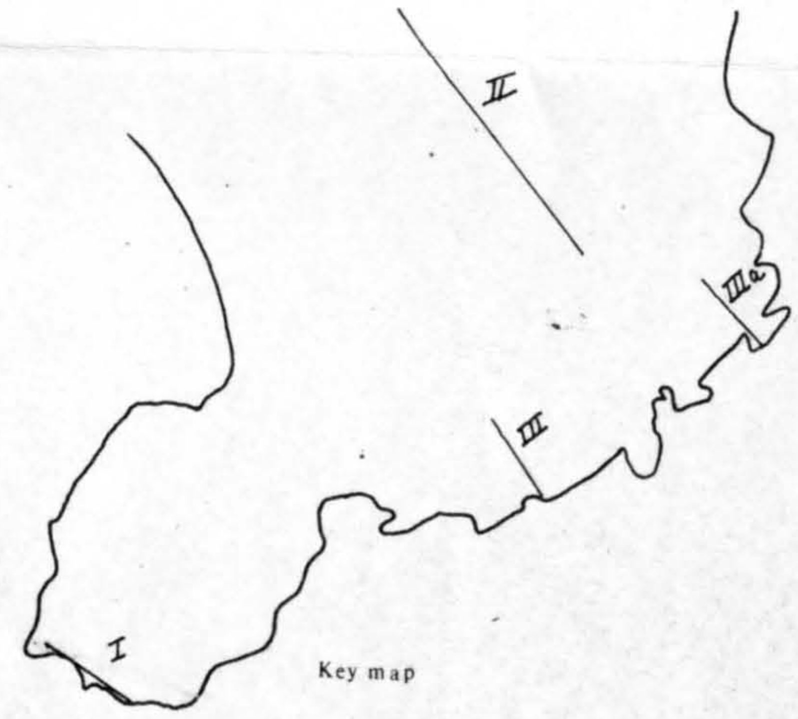
68. Taylor, W.E.G. 1968 The Dalradian rocks of slieve gamph western Ireland. Proc. Royal Irish Acad. 67, 63

69. Thomson, J. 1875 On the Geology of Islay. Mem. Geol. Surv. Scotland. 5, 200

70. Watson, J.V. 1963 Some problems concerning the evolution of theScottish Caledonides. Geol. Assoc. Proc. 74, 213

71. Wilkinson, S.B. 1907 The Geology of Islay. Mem. Geol. Surv. Scotland.





Key map

Stratigrphical Sections in The Lower & Middle Dalradian of Islay (Full explanation in section 2)


Serial Sections
Ardmore Grits d
Ardmore Conglomerate c
Kildalton Limestone d
Laphroaig Quartzite c
PortEllen Phyllite b a
Kilbride Limestone c
Scarba Conglomerate b
Jura Slates
Islay Quartzite b a
Dolomitic Group b
PortAskaig Boulder Bed a
Port Nan Gallan Limestone
Port Nan Gallan Phyllite
Ballygrant Limestone
Baharradail Phlyite
Cnoc Don Group Phyllite Quartzite Limestone b a
Cnoc Don Qurtzite
Cnoc Don Slate
Kintra Limestone a
Kintra Phyllite d c b a
Moal An Fhithich Qurtzite
feet 400 0
miles
N

N
Middle Dalradian
Epidiorite
AG Ardmore Grits
AC Ardmore Conglomerate
Ks Kildatan Limestone
LQ Laphraig Quartzite
PF Port Ellen Flagstone
PE Port Ellen Phyllite
KL Kilbride Limestone
SC Scarba Conglomerate
J Jura Slate
B A Quartzite
D group
BB Bolder Bed
Lower Dalradian
PL Port Nan Gallan Limestone
PP Port Nan Gallan Phyllite
B Ballygrant Limestone
BP Baharradail Phyllite
PC Phyllite
QC Quartzite
LC Limestone
Cnoc Don Group
CQ Cnoc Don Quartzite
CS Cnoc Don Slate
K Kintra Limestone
d c b a Kintra Phyllites
MQ Moal An Fhithich Quartzite
Vertical
S_0
S_1
S_2
Composite S_2 S_1
S_3
L
F_1
F_2
F_3
Fault
Slide
Thrust
Lithological boundary
Inferred lithological boundary
Younging
Tertiary dyke