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The sedimentology and palaeogeography of some Devonian sedimentary rocks in Southwest Ireland

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THE SEDIMENTOLOGY AND PALAEOGEOGRAPHY OF SOME DEVONIAN SEDIMENTARY ROCKS IN SOUTHWEST IRELAND

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This thesis is submitted to the Council for National Academic Awards in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

The research on which this thesis is based was conducted during tenure of a three year appointment as Research Assistant with the Department of Geology, School of Environmental Sciences, Plymouth Polytechnic. The Geological Survey of Ireland was a collaborating establishment. QU/DIG

While registered as a candidate for the degree for which submission is made, the author has not been a registered candidate for any other award of the CNAA or of a University, during the research programme.

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ABSTRACT:

The area investigated for this thesis is the western end of the Iveragh Peninsula, Co. Kerry, southwest Ireland. The rocks in the area are predominantly of Old Red Sandstone facies, totalling over 6600m in thickness, and were deposited near the northern fault-bounded margin of the extensive half-graben feature known as the Munster Basin. Towards the end of the basin's history, continental conditions were replaced by marginal marine as the sea transgressed into the area from the south.

The objectives of the study are to provide a description of the poorly known sedimentary facies from this part of the basin, to interpret these in terms of processes and environments of deposition, and to review and clarify long-standing issues arising from the poorly known age and correlative significance of the lower parts of the Iveragh succession. Mapping and detailed logging of selected sections have been carried out. A number of facies types are identified, and interpretation of these in the light of palaeocurrent and other evidence suggests a terminal-fan model for sediment deposition. Sediment transport was largely by unconfined episodic sheetfloods, with transport consistently from the north. Calcrete formation, although limited, suggests a semi-arid climatic setting.

Fish fossils and plant miospores date the basin-fill as Upper Devonian in age, possibly just extending down into latest Middle Devonian. Miospore assemblages allow regional correlation with other areas in the Munster Basin.

Minor igneous intrusive and extrusive rocks in the area have been mapped and described, and consist of contemporaneous acid pyroclastics as well as late or early post-Devonian intrusives. One dyke in the area is considerably younger, probably Tertiary in age. A thick tuff bed, the Keel Tuff Bed, is traced over part of the area, and may have regional correlative significance.

"It's not so much losing a thesis, as regaining the spare bedroom"

The assistance of people who have collaborated in certain parts of this study is fully acknowledged in the relevant sections dealing with that part of the work. I would like to take this chance to thank all the other friends and colleagues who gave freely of their time and advice; to John Graham, for showing reserves of patience he didn't even know he possessed; to Shona and Joan for finally typing it, and last but not least my wife Carol, who had to put up with it all.

VOLUME ONE

CONTENTS PAGE

CHAPTER 1	Introduction	2
	1.1. The location	2
	1.2. The geology	5
	1.3. Outline of the proposed investigation	7
CHAPTER 2	Methods and techniques	13
	2.1. Selection of sections	13
	2.2. Mapping	13
	2.3. Logging	14
	2.4. Palaeocurrents	14
	2.5. Facies mapping	15
	2.6. Computing	17
	2.7. Petrography	18
	2.8. Correlation	19
	2.9. Definitions	20
CHAPTER 3	Sedimentary facies	22
	3.1. Facies description.....introduction	22
	Old Red Sandstone succession	
	3.2. Conglomerate facies	24
	3.3. Sandstone body facies	32
	3.4. Rippled and laminated facies	49
	3.5. Sand-laminated siltstone facies	60
	3.6. Bioturbated facies	65
	3.7. Massive mudstone facies	67

Rossmore Sandstone Formation

3.8. Grey quartzitic sandstone facies 68
3.9. Grey siltstone facies 74
3.10. Sand-lensed grey siltstone facies 76
3.11. Heterolithic facies 78
3.12. Sedimentological model 80

CHAPTER 4 Palaeontology 93
4.1. Plant macrofossils 94
4.2. Plant miospores 95
4.2.1. Location of the spore samples 100
4.2.2. Microfloral assemblages 104
4.3. Fossil fish 114
4.3.1. Preservation and general occurrence 115
4.3.2. Fish material assemblages 118
4.3.3. Age and stratigraphic significance 119
4.4. Trace fossils 121
4.4.1. Burrow traces 122
4.4.2. Crawling trails 125
4.4.3. Identification and discussion 126
4.5. Algal pisolites 129
4.6. Palaeoecology 130

CHAPTER 5 Igneous activity 133

Intrusive rocks 135
5.1. The Valentia Harbour sill 135
5.2. Dyke intrusions 143

Extrusive rocks 148
5.3. Tuff Beds 148
5.4. Agglomerate 152
5.5. Summary and interpretation 156

CHAPTER 6	Stratigraphy	162
	6.1. Historical development of the regional geology - the Dingle Beds controversy	163
	6.2. Results of the present investigation	168
	6.2.1. The Atlantic Coast section	169
	6.2.2. The Eskine-Knocknagullion section	179
	6.2.3. The Sneem River section	189
	6.2.4. The Rossmore Island section	197
	6.2.5. The Valentia Harbour sections	201
	6.2.6. The Hog's Head sections	208
	6.2.7. The Lamb's Head section	218
	6.3. Local and regional correlation	223
CHAPTER 7	Structure	233
	7.1. Approach	233
	7.2. Background	233
	7.3. Folding	235
	7.4. Cleavage	239
	7.5. Faulting	243
	7.6. Jointing	247
	7.7. Tension gashes	247
	7.8. Summary	247
CHAPTER 8	Conclusions	249

VOLUME TWO

PLATES (1-120)

ENCLOSURE 1 Example of log recording form

2 Program listing - FILTER. FAS

3 Program listing - FILTER. GS

4 Program listing - SUMLOG

5 Program listing - MARX

6-10 Lateral facies diagrams (sandstone body facies)

11 Lateral facies diagram (rippled and laminated facies)

12 Reprint (Higgs and Russell, 1981)

13 Reprint (Russell, 1978)

14 Atlantic Coast section 6" map

15 Eskine-Knocknagullion section 6" map

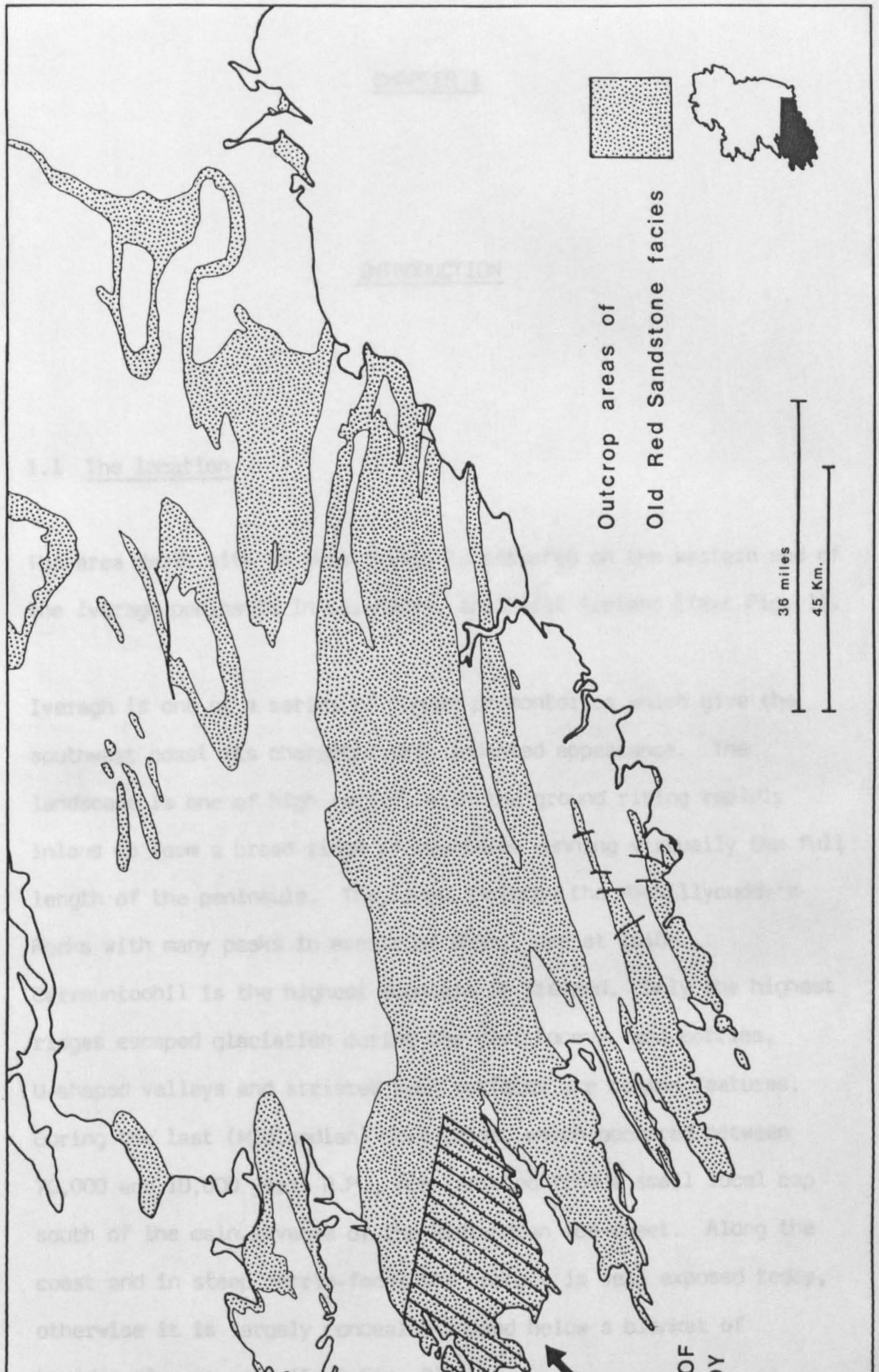
16 Sneem River section 6" map

17 Rossmore Island section 6" map

18 Valentia Harbour sections 6" map

19 Hog's Head sections 6" map

20 Lamb's Head section 6" map


Outcrop areas of
Old Red Sandstone facies
36 miles
45 Km.
AREA OF
STUDY

TEXT FIG.1

CHAPTER 1

INTRODUCTION

1.1 The location

The area dealt with in this thesis is situated on the western end of the Iveragh peninsula in Co. Kerry, southwest Ireland (Text Fig. 1).

Iveragh is one of a series of rugged promontories which give the southwest coast its characteristic indented appearance. The landscape is one of high relief, with the ground rising rapidly inland to form a broad ridge of mountains running virtually the full length of the peninsula. The ridge includes the MacGillycuddy's Reeks with many peaks in excess of 600m., and at 1040m. Carrauntoohil is the highest mountain in Ireland. Only the highest ridges escaped glaciation during the Pleistocene, and corries, U-shaped valleys and striated rock surfaces are common features. During the last (Midlandian) cold phase, which occurred between 70,000 and 10,000 years B.P., ice radiated from a small local cap south of the main advance of the Midlandian ice-sheet. Along the coast and in steep corrie-faces the bedrock is well exposed today, otherwise it is largely concealed inland below a blanket of boulder-clay or peat (Text Fig. 2).

TEXT FIG. 2

The view looking south across St. Finan's Bay, towards Ducalla Head. Along the coast a series of rocky platforms present a well-exposed continuous section, with bedding dipping almost vertically and striking normal to the coastline. The coastline visible in the photograph is approximately 8Km in length.

The landscape is one of outstanding natural beauty, a mosaic of small marginal farmsteads set in a broad expanse of rough hill and moorland. Traces of older races still linger in the fields and on the hillsides. Rough stone circles which today shelter or enclose straying sheep, mark the remains of 10th century stone huts. Ogham-inscribed stones and the remains of stone ring-forts obscured by gorse and briar date back to before the beginning of the 4th century.

The coastline is a combination of precipitous cliffs and wave-washed rocky platforms, and sandy beaches are rare. Along the western end of the peninsula in particular, the violence of the open Atlantic in winter is a constant factor of erosion, causing crumbling and retreat of the cliff-line. Access to coastal sections is reasonably easy in most cases, although some areas are impossible or should be attempted only with a companion and proper climbing equipment.

1.2 The geology

Good general discussions of the structure and geology of the region are provided by Naylor and Jones (1967), Sevastopulo (1981), Naylor et al. (1981) and Graham (1983).

The rocks of which the region is composed are predominantly of Old Red Sandstone facies. The area described by this thesis exposes an extremely thick sequence of these rocks, in which the grainsize rarely exceeds fine sandstone. They form a part of a thick prism of sediments cropping out over large areas of south and southwest Ireland, relating to a depositional feature known as the Munster Basin (Naylor and Jones, 1967). The basin is a half-graben structure, elongate in an east-west direction and fault-controlled along the northern margin (Ibid). A thickness in excess of 6600m. of red-bed sediments was deposited towards the central and north-central parts of the basin (Ibid). South of a line between Kenmare and Cork, the red-beds in the upper part of the sequence are replaced laterally by marine sandstones and mudstones (Naylor, 1969). Comparison between sections suggests that during late Fammenian and Tournaisian times, an irregular shoreline of the Old Red Sandstone continent retreated progressively northwards across the region (Clayton and Higgs, 1979).

Folding along a WNW-ESE axial trend took place during the Hercynian deformation, affecting the region south of the so-called 'Variscan Front' (a line running through Dingle Bay and continuing eastwards to the south of Killarney). The structural pattern imposed by the folding and associated cleavage development has strongly influenced the geomorphology of the region. Ridges and valleys run parallel to the axial traces of the folds. On the coast, the peninsulas are resistant ribs of older sandstone and slates brought up in the cores of anticlines, separated by long deep inlets where the sea has invaded along softer shales and limestones occupying the corresponding synclines.

The general outline of the Munster Basin, briefly described above, is now reasonably well established. In contrast to this, the nature of the material infilling the basin is at present very poorly known. This is because, with the exception of some well-exposed areas towards the basin margins, previous work has been confined to reconnaissance mapping. Even at that level, rapid lateral thickness and facies changes and a lack of diagnostic fossils have given rise to correlation problems, especially in the thick succession towards the basin-centre. The age and correlative significance of the lower part of the Old Red Sandstone succession on Iveragh has been a source of dispute since the earliest geological investigations of the area. A lack of detailed knowledge presently hinders a proper understanding of processes active during the evolution of the Munster Basin, and the time scale on which it occurred.

1.3 Outline of proposed investigation

The Iveragh peninsula is particularly interesting for the following reasons.

I. Over the last fifteen years revived interest in the geology of southwest Ireland has led to renewed investigation, concentrated mainly on coastal areas between Cork Harbour in the south and Kerry Head in the north. The Iveragh and Beara peninsulas, possibly due to the formidable thickness and apparent monotony of the sediments they expose, have been neglected by this new investigation.

II. Not much is known about the nature and origin of the fine-grained sedimentary rocks towards the centre of the Munster Basin. Published work indicates that the depositional centre of the basin (i.e. the centre of maximum deposited thickness) is situated on the Iveragh peninsula, in the vicinity of the MacGillycuddy's Reeks.

III. The basin is asymmetric and Iveragh lies close to the northern margin. Some evidence of the rapid lateral thickness and facies changes between basin centre and margin is to be expected on Iveragh itself.

IV. Previous published work (Capewell 1957, 1975) indicates that virtually the complete sequence through the Old Red Sandstone succession cropping out on Iveragh is well-exposed on coastal sections.

Objectives

The sedimentology and stratigraphy of the western end of Iveragh were investigated with three principal objects in mind.

1) To provide a detailed description of the sedimentary facies comprising the thick basin-fill succession.

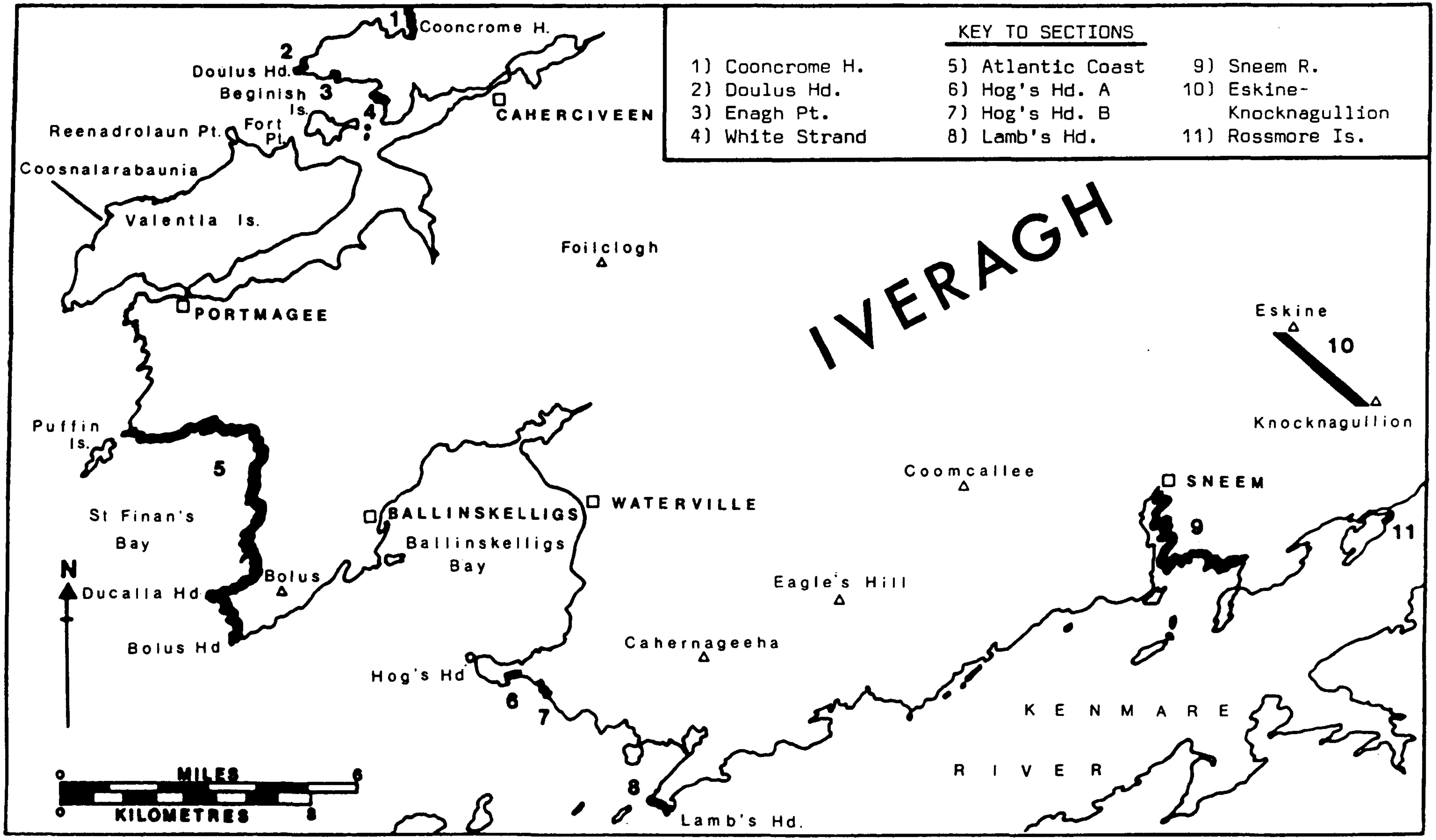
2) To interpret the above in terms of processes and environments of deposition.

3) To review and if possible resolve the long-standing debate on the age and correlative significance of the lower part of the succession on Iveragh.

Mapping and detailed logging of selected sections were used to build up a picture of the types and relative proportions of sediments involved. Locations of the selected sections are shown in Text Fig. 3. A number of distinct facies types have been identified and described using field-notes, photographs, and in some cases extensive diagrams to show how facies units behave laterally. Different lithologies were sampled and thin-sectioned for petrographic description and detailed identification. Clast counts were made for rare conglomerate lenses, and samples collected for provenance study. A large number of palaeocurrent readings were taken and analysed for use in provenance study and interpretation of transportation processes.

Several complete traverses were made through the succession to check for the presence of macrofossils. Previously unrecorded fossil fish material was discovered in moderate abundance, and considerable time spent in collecting, preparing and identifying the specimens. In addition to collecting macrofossil material, a large number of siltstone units were sampled during logging and mapping, for palynological processing by Dr. K. Higgs from the Geological Survey of Ireland.

Igneous activity played a role in the evolution of this part of the Munster Basin. Previous accounts were mainly descriptive and


KEY TO SECTIONS
1) Cooncrome H.
2) Doulus Hd.
3) Enagh Pt.
4) White Strand
5) Atlantic Coast
6) Hog's Hd. A
7) Hog's Hd. B
8) Lamb's Hd.
9) Sneem R.
10) Eskine-Knocknagullion
11) Rossmore Is.
IVERAGH
Cooncrome H.
Doulus Hd.
Beginish Is.
Reenadrolaun Pt.
Fort Pt.
Coosnalarabaunia
Valentia Is.
CAHERCIVEEN
Foilclogh
PORTMAGEE
Eskine
Knocknagullion
Puffin Is.
St Finan's Bay
N
Ducalla Hd
Bolus
Bolus Hd
BALLINSKELLIGS
Ballinskelligs Bay
WATERVILLE
Coomcallee
SNEEM
Eagle's Hill
Cahernageeha
Hog's Hd
KENMARE RIVER
Lamb's Hd.
MILES
KILOMETRES
0
6
0
8

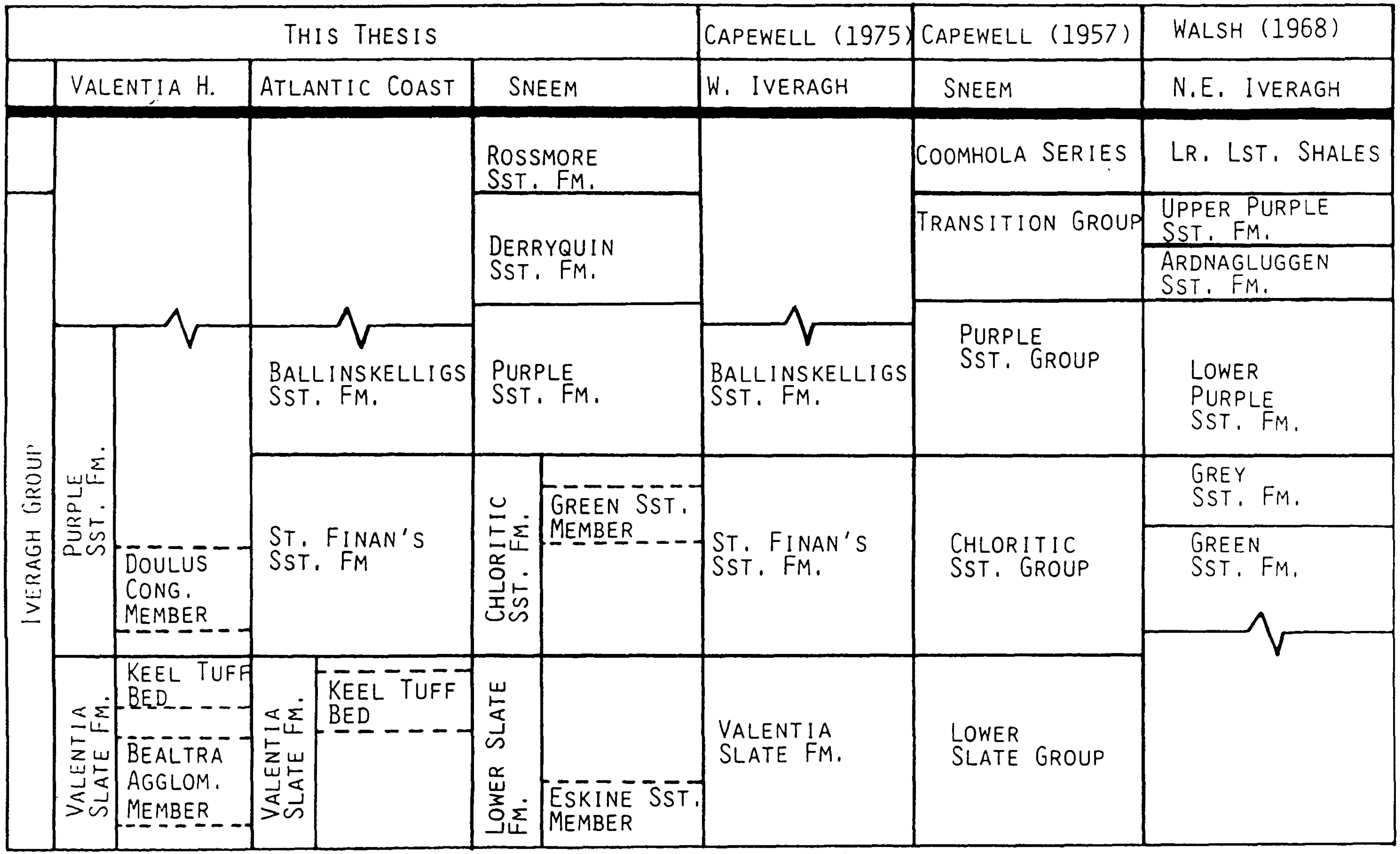
TEXT FIG.3

somewhat dated (Jukes et al 1861), or incomplete and superficial (Capewell 1975). Accordingly, considerable time was spent mapping agglomerate and basic intrusives in the Valentia Harbour area, and attempting to trace a thick tuff-bed across the area.

During the final field-season a brief geological traverse was made across the western end of the Munster Basin, visiting sections on the Dingle peninsula and along the west Cork coastline, in order to place the sedimentary succession on Iveragh in a proper regional perspective.

1.4 Stratigraphic Nomenclature

The stratigraphy of the area is discussed in detail in CHAPTER 6, where the nomenclature used in this thesis is justified. An outline of the scheme employed and its relationship to some other previous nomenclatures is given in Text Fig. 4.



TEXT FIG. 4 **Summary guide to stratigraphic units.**

CHAPTER 2

METHODS AND TECHNIQUES

2.1 Selection of sections

Aerial photographs and preliminary reconnaissance were used to select a number of coastal and inland areas for detailed investigation. The sections were chosen to give virtually complete coverage of the full Iveragh succession, as well as overlapping to investigate lateral facies changes.

2.2 Mapping

Each of the selected sections was initially mapped on a scale of six inches to one mile, to establish the structure and identify any major dislocation by faulting. Additional mapping was later carried out in the intervening areas to build up a picture of the geological structure and lateral behaviour of the sedimentary facies, and investigate features of particular interest such as the igneous rocks of the Valentia Harbour area. Field-sheets for all the logged sections are presented as enclosures 14-20.

2.3 Logging

Some examples of different log-recording methods were evaluated to develop a standard technique, which was then used to record all the selected sections. A log recording sheet (Enclosure 1) was used to ensure that the same details were recorded for each logging unit. A pocket grainsize scale was used to standardise identification of grainsize, particularly in the finer grained rocks. Logging units were identified to correspond with arbitrarily defined facies types (see CHAPTER 3), and averaged 1-2 metres in thickness. Breaks in exposure were recorded as estimates to the nearest metre. Where exposure did not allow direct measurement (e.g. sheer cliffs), distances were paced as accurately as possible and converted to true thickness using an averaged angle of dip.

2.4 Palaeocurrents

Palaeocurrent readings were recorded for small-scale cross-lamination, large-scale tabular and trough cross-bedding, and primary current lineation. In each case (where possible) the bedding orientation and plunge of bedding/cleavage lineation or local fold axes were also recorded.

Small-scale cross-lamination is only rarely sufficiently prominent and well-exposed to permit accurate measurement; in most cases bedding was restored to horizontal by eye and the orientation of current source assigned to one of sixteen sectors of the compass-rose. Rare well-etched cross-laminations in coarser grained rocks allowed proper measurement to be used as a check on the alternative method, showing it to be reasonably accurate.

Some difficulty was experienced in distinguishing planar from troughed cross-bedding. This was overcome by recording foresets only where there was evidence of reasonable lateral persistence of sets without signs of troughing. Since from observation, troughs tend to be relatively small, shallow and narrow features, the only orientation which will produce laterally persistent sets of cross-bedding is one parallel to the trough axis. Palaeocurrents measured from that orientation will reflect the true general flow direction, so that even if troughed cross-beds were mistaken for planar cross-beds a reasonable palaeocurrent direction would still be obtained. Obvious troughed cross-bedding was recorded only if it was possible to see two opposed sides of the trough, or if it was possible to measure the orientation of the trough axis.

Reorientation of palaeocurrent data was initially done using a stereographic net to remove tectonic plunge, followed by restoring bedding to horizontal. A computer program written by M.A. Cooper and J.D. Marshall was later used to reorient bulk data and draw graphic plots of current-rose diagrams (Cooper and Marshall, 1981).

2.5 Facies mapping

Vertical relationships between facies were recorded in the logs and later studied by Markov analysis (see Computing, below). Lateral behaviour of facies is also extremely important for interpretation, and a form of 'lateral logging' was used to investigate this.

For the 'sandstone body' facies (see CHAPTER 3 for definition), a grid of 2.5 x 1.5 metre graticules was laid down on a well-exposed sandstone body of considerable lateral extent. The grid was oriented parallel to a base line in the underlying (usually even-bedded) siltstone. The internal structures within each graticule were drawn to scale on A4 graph paper and the sheets later redrawn to a reduced scale as a large composite diagram. For the finer-grained 'rippled and laminated' facies (see CHAPTER 3 for definition) much less internal detail was present so a different method was used. A single baseline was laid down and a spaced series of vertical logs drawn at 3 metre intervals. Detail between the logs could then be sketched in by eye.

The remaining facies proved too fine-grained (i.e. full of extremely fine detail) to be recorded in either of the ways described above, and information on lateral behaviour was recorded as written descriptions in the field-book.

Orientation of the composite lateral-logs was in each case recorded in relation to:

a) overall trend of the facies unit (e.g. fining or wedging)
b) compass bearing

2.6 Computing

Three field-seasons produced large volumes of logging and palaeocurrent data, which (particularly in the case of the former) could only be manipulated properly using a computer.

PROGRAM FILTER (Enclosures 2 and 3). A program to draw stratigraphic logs, written by Dr. J.R. Graham, was extensively modified to deal with large amounts of log data. Logging units are clustered in groups of size 'N' and the dominant type identified for each group (using either grainsize or facies type as the criterion). By increasing the value of 'N', the resolution of the graphed profile may be reduced, thus smoothing unwanted variation and allowing large scale trends to stand out more clearly. Unusual parts of a sequence may be isolated and regraphed with a smaller grouping to increase the resolution. Examination of a series of plots at different values of 'N' is necessary to exclude apparent trends with a low level of significance. The starting point for defining group intervals should also be varied in case the selection of group intervals is 'out of step' with some pattern of cyclic variation. Examples of plots with a value of 'N' = 5 are used to show the overall trends for complete sections
while illustrative short sections from various members or formations are plotted with a value of 'N' = 1 and shown as text figures in CHAPTER 6.

PROGRAM SUMLOG (Enclosure 4). The bulk characteristics of an interval of logged section were studied by a program which draws a summary log profile. Each sedimentary facies is shown on a log profile (in order of decreasing grainsize) with the plotted thickness proportional to the percentage of the total section thickness which is represented by that facies. The profile is labelled with the name and percentage of each facies opposite the position it occupies in the profile.

PROGRAM MARX (Enclosure 5). A simple program was written to examine the logs for evidence of cyclicity, using methods for Markov analysis which are well-documented (Gingerich, 1969; Allen, 1970; Miall, 1973; Graham, 1975). The program calculates and prints the tally, probability, independent trials and difference matrices, and calculates the Chi-square values to indicate confidence levels that transition patterns are due to non-random processes.

2.7 Petrography

Rock samples of fine to medium grainsize were collected at regular intervals during logging for thin-sectioning and composition analysis, to check for any significant changes in the supply of clastic sediment.

Clast counts were carried out at two localities to study the composition of the conglomerates in the northern part of the area. Samples of different clast types (including metamorphic detritus) were collected for thin-section analysis. The technique employed for clast counting was to lay a section of fishing net over the exposed conglomerate and count each clast greater than 1cm in diameter at each point where the cords of the net intersected (PLATE 5). Over one hundred clasts were counted at each location.

Samples were collected from a number of suspected altered tuffs (thin creamy-weathering siltstones). These were compared with samples from a known tuff and ordinary siltstone samples, using X-ray diffraction. It proved impossible to distinguish between the samples due to diagenetic alteration which had strongly 'overprinted' the original compositional differences.

2.8 Correlation

Published accounts of the regional geology have shown that correlation between sections is a major problem. To try to overcome this the following approach was adopted.

1. During logging of the major sections, a large number of samples were collected from beds of fine-grained greyish or greenish rock.
   Each sample was located on the log and sent for palynological processing by the Irish Geological Survey.
2. The intervening areas between major sections were mapped to outline their structural relationship to each other.
3. Short logs were made on minor sections to check on lithological continuity across major fold axes. Attempts were made to trace a tuff 'marker bed' across the area.

4. During logging, the major sections were examined in great detail for any macrofossils which might prove useful in correlation.

2.9 Definitions

The terminology used in the following chapters is given below.

		Max. Grainsize (mm)	
GRAINSIZE	Conglomerate	256.00	cobble
(Wentworth size		16.00	pebble
classification)		4.00	granule
	Sandstone	2.00	very coarse
		1.00	coarse
		0.50	medium
		0.25	fine
		0.125	very fine
	Siltstone	0.0625	coarse
		0.0078	fine
	Claystone	0.0039	

SLATY CLEAVAGE: Refers to a closely spaced penetrative cleavage occurring in rocks not coarser than silt grade.

FRACTURE CLEAVAGE: Refers to an open spaced cleavage occurring in rocks of sand grade or coarser.

FOLDING:

Gentle	Interlimb Angle	> 120°
Open	" "	70°-120°
Close	" "	30°-70°
Tight	" "	1°-30°
Isoclinal	" "	0°

Monocline (Bedding flexure in which change in dip across the fold axis does not exceed 90°).

CHAPTER 3

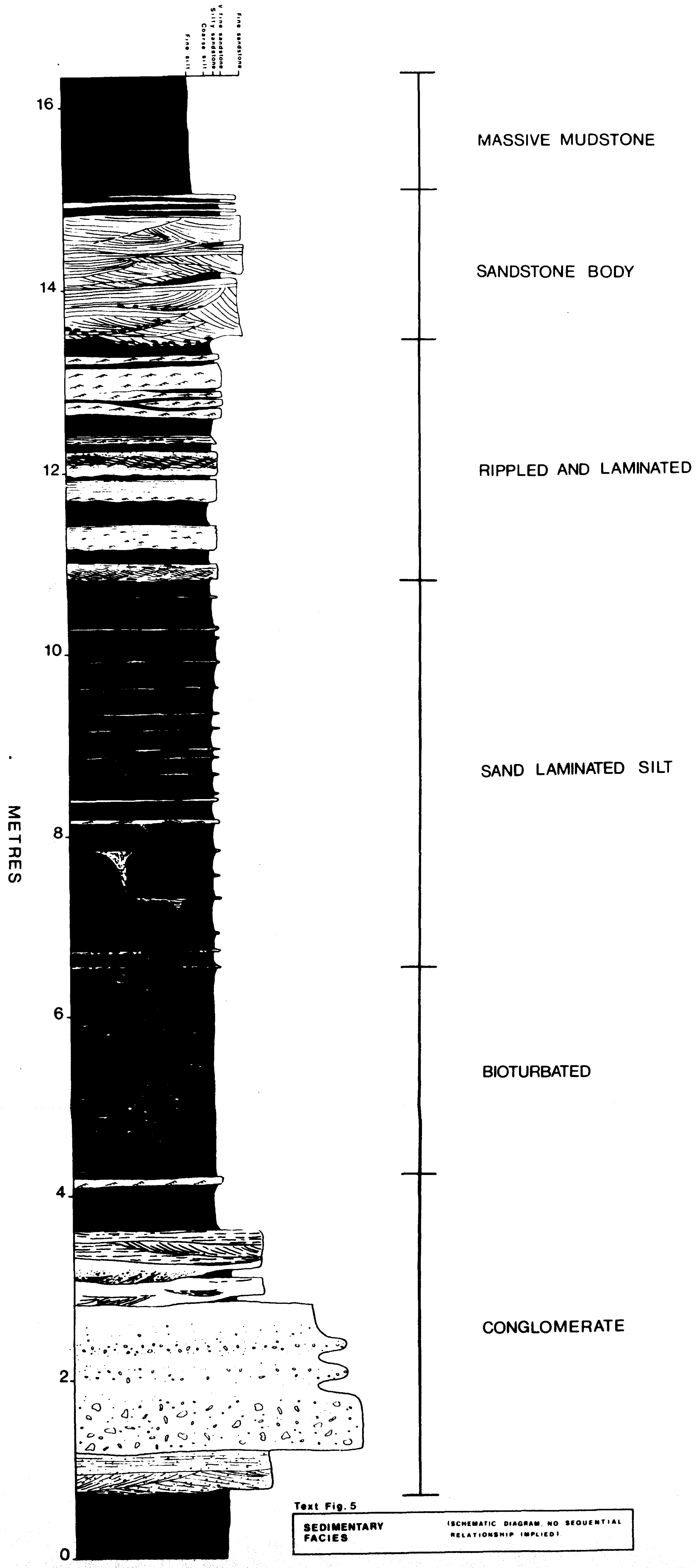
SEDIMENTARY FACIES

3.1 Facies description......INTRODUCTION

The lithology in the area varies in grainsize between claystone and medium sandstone, with rare conglomerate. A continuum of rock types has been divided into a number of 'end-member' sedimentary facies, chosen to reflect the most commonly occurring rock types observed in the field. Inevitably some 'transitional' rock types occur which are gradational between the designated facies. Such cases are infrequent enough to be arbitrarily assigned to the closest facies type without serious consequences.

Six facies are recognised within the Old Red Sandstone succession (Text Fig. 5)....

1) CONGLOMERATE FACIES
2) SANDSTONE BODY FACIES
3. RIPPLED AND LAMINATED FACIES
4) SAND-LAMINATED SILTSTONE FACIES
5) BIOTURBATED FACIES
6) MASSIVE MUDSTONE FACIES



Text Fig. 5

SEDIMENTARY FACIES (SCHEMATIC DIAGRAM, NO SEQUENTIAL RELATIONSHIP IMPLIED) and four facies are recognised within the overlying Rossmore Sandstone Formation (Text Fig. 6)....

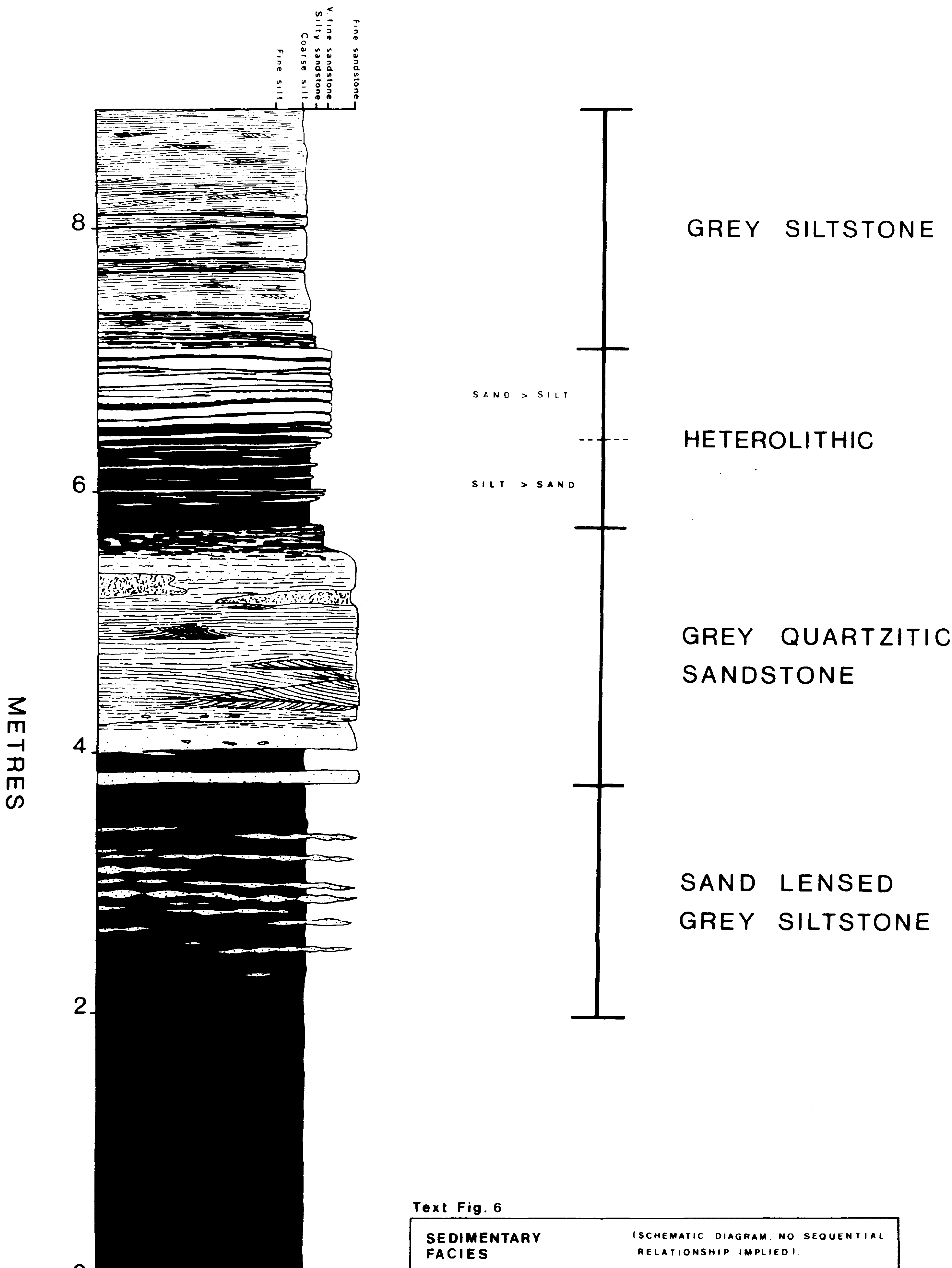
1) GREY QUARTZITIC SANDSTONE FACIES
2) GREY SILTSTONE FACIES
3) SAND-LENSED GREY SILTSTONE FACIES
4) HETEROLITHIC FACIES

In the following sections, each facies is described individually and interpreted in terms of the environment and processes associated with its deposition. Schematic log diagrams (Text Figs. 5 and 6) are a brief guide to help in visualising the various facies.

In referring to sedimetary facies the term 'UNIT' will be used to denote the uninterrupted vertical and lateral extent of a particular facies. In certain facies, distinct internal erosional surfaces divide the 'UNIT' into smaller divisions, which are here termed 'SUB-UNITS'.

3.2 The Old Red Sandstone Succession - CONGLOMERATE FACIES

This facies consists of granule to cobble sized clasts of exotic material, dominated by vein-quartz and metamorphic rocks (PLATES 7 and 8). The facies is very restricted in occurrence, and significant developments are limited to the northern coast of the peninsula.



Text Fig. 6

SEDIMENTARY FACIES (SCHEMATIC DIAGRAM. NO SEQUENTIAL RELATIONSHIP IMPLIED).

Three subfacies are recognised, each with characteristics suggesting a difference in the mode of origin, although all three appear linked by their relation to a common major environment.

Subfacies 'A'

This occurs as thin (1-2m) lenticular bodies of pebbly clast-supported conglomerate, usually overlying shallowly erosive bases (Plates 1 and 2). The lenses occur within poorly sorted pebbly and cross-bedded sandstones, and often fine rapidly upwards to fine sandstone. Although the conglomerate lenses are indistinctly bedded, traces of small to medium scale cross-bedding are sometimes picked out by thin sandy beds, or by pebble trains arranged on the foresets. Clasts range in size from approximately 1 to 5cm.

Subfacies 'B'

This takes the form of very poorly sorted massive beds up to 2m thick, containing matrix-supported clasts up to 15cm in diameter (Plate 3). The clasts are subrounded and no pattern of normal or reverse grading is observed within the beds. Although the majority of the clasts are equant, a few elongate clasts show weak alignment at a high angle to the planar upper and lower boundaries of the beds (Plate 4). The most likely cause of this is tectonic rotation of the clasts within a 'dirty' sand/silt matrix of fairly low competence, to parallel the subvertical regional cleavage (Plate 4). An alternative possibility is that the orientation is an original sedimentary fabric. The rarity of elongate clasts and limited extent of accessible exposure prevent measurement and statistical treatment of a large number of clast orientations, which would be required to detect any systematic difference in orientation from that of the regional cleavage.

Bed thickness ranges between 1 and 2m. The base of the beds is generally non-erosive, although in one case it is clearly shallowly down-cutting. The beds are much less lenticular than in subfacies 'A', although the cliff-face nature of exposure prevents tracing the facies laterally more than 15m.

Subfacies 'C'

This consists of interbedded sandstone and pebble conglomerate sheets approximately 1m or less in thickness, showing relatively much better sorting than subfacies 'A' or 'B' (Plate 6). The conglomerate beds are mainly clast-supported. Maximum clast size is less than 10cm, and the geometry of the subfacies units is sheetlike to gently lenticular (Plate 6). The frequent vertical changes in grainsize between sandstone and conglomerate are rarely sharply defined, although sandstone beds rarely show an abrupt erosive base and several shallow trough-shaped scours were observed. Tabular clasts show some orientation parallel to bedding but do not appear imbricate. Sediments of very fine grainsize are generally absent. Some beds within this subfacies show poorer sorting and appear to be intermediate between subfacies 'B' and 'C', with gravel beds varying from clast to matrix-supported.

Occurrence

Subfacies 'B' and 'C' are restricted to one exceptionally thick unit of conglomerate facies (at least 30m thick) cropping out on Doulus Head, on the extreme northern margin of the area mapped.

Subfacies 'A' is typically developed as much thinner lenticular conglomerates occurring at various levels in the succession, with the best developments restricted to the northern margins of the area studied.

An unusual conglomerate unit occurs in the vicinity of Bealtra Strand (V 433 800). It contains clasts of tuff and basic intrusive and extrusive igneous rocks (up to 1m in diameter) set in a fine matrix which is locally highly altered. The unit is an agglomerate, and is described separately in detail in the chapter on igneous activity.

Interpretation: (Subfacies 'A')

The coarse grainsize and poor sorting, basal erosive scours and clast-supported nature of these conglomerates are consistent with transport and deposition by an energetic flow of water. It can be estimated from a Shields diagram that clasts of 5cm diameter require a flow force of 500 dynes/cm^2 for entrainment (or on a Hjulstrom diagram a critical flow velocity of 200-300 cm/sec.). These estimates are only a general guide to the flow strength involved, since the minimum flow strength required will be lowered by the presence of finer sediment for larger clasts to move over, bed roughness to locally intensify flow velocity, and presence of flow eddies in turbulent flow conditions (Blatt, Middleton and Murray, 1972). Shield's criteria also neglect the effects of flow-depth, the packing of grains in the boundary-layer, entrainment due to slumping and bank collapse, and the fact that hydraulic conditions at deposition need not necessarily be the same as those required for entrainment (Church, 1978).

Poorly defined cross-bedding shows that the depositional surface had sufficient topographic relief to form inclined bedding-planes. The cross-bedded sets tend to be troughed and laterally impersistent, although repeated frequently both laterally and vertically. Large relatively persistent bedforms such as bars or sand-waves are unlikely to have been responsible. The lateral impersistence and relatively small set thickness are consistent with deposition by a migrating field of small dune bedforms, or repeated scouring and filling in a small braided-channel system.

The pebbly sandstone bodies with which the lenticular conglomerates intergrade laterally are abundantly cross-bedded with mainly trough cross-bedding. The conglomerates are closely associated with and show many features similar to these sandstones which represent deposition mainly in the upper part of the lower flow-regime. The latter probably represent stream-channel rather than sheetflood deposits; upper flow-regime plane-bedding is completely lacking although it is common in sheet-flood deposits and may comprise up to 90-95% of the bedding present (McKee et al., 1967), and the geometry is typically lenticular rather than sheetlike. Frequent trough-scours and rapid random lateral and vertical changes in grainsize and bedding suggest the pebbly sandstones were deposited by a system of small braided channels, with the conglomerate lenses deposited as localised lags in the bases of channel scours.

Interpretation: (Subfacies 'B')

The conglomerates of subfacies 'B' differ from those of subfacies 'A' in that they are very poorly sorted, appear massive, and the clasts are matrix-supported. The maximum clast size is also considerably larger (up to 15cm). The matrix-supported nature of the conglomerate excludes the introduction of matrix as a sieve-deposit event, so the conglomerate must have originally been poorly sorted at deposition. The maximum grainsize of the clasts would require a very high flow-competence if transported by water, which except in one case is not supported by presence of an underlying erosive surface which one would expect if such currents were involved. Better sorting would also be expected if tractive currents of water were the transporting medium.

An alternative transporting mechanism is required, capable of moving a large range of grainsizes without necessarily causing any sorting of the sediments or erosion of the underlying sediments. A high viscosity debris-flow (Bull, 1972; Steel, 1974) is capable of moving large blocks up to several tons in weight (Bull, 1968). The characteristics shown by subfacies 'B', i.e. poor sorting, large maximum clast size, presence of mud in the matrix, lack of internal structures, absence or rarity of erosive base, matrix-supported fabric, are all typical of debris-flow deposits (Fisher, 1971; Bull, 1972; Steel, 1974; Walker, 1975; Lowe, 1982).

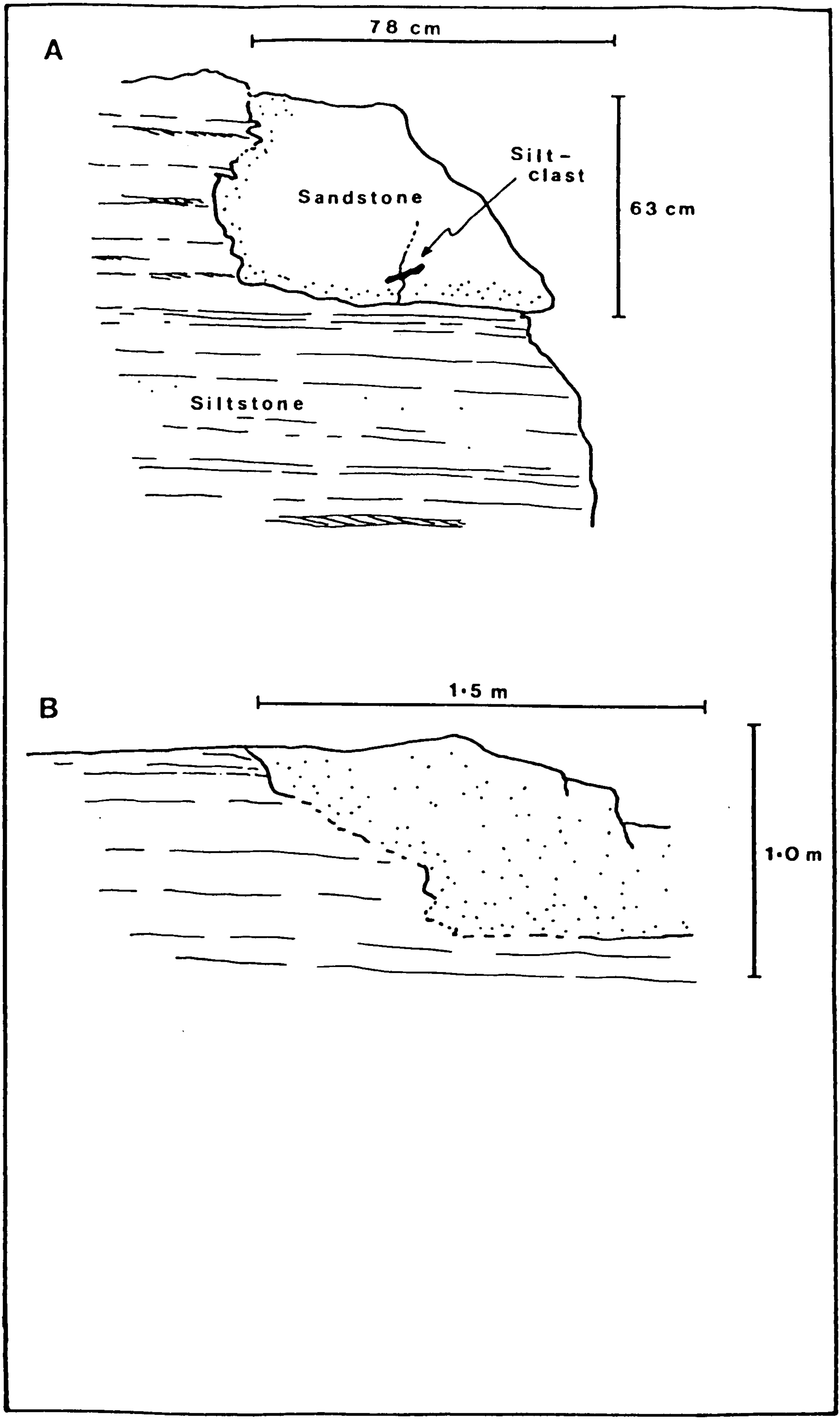
Steel (1974) noted the orientation of clast long-axes parallel with bedding in deposits interpreted by him as due to debris-flow. Bull (1972) states that in low viscosity debris-flows tabular clasts may become oriented parallel with or imbricate in relation to bedding, while high viscosity debris-flows show uniform clast distribution and tabular clasts tend to become oriented vertically normal to the flow direction. The weakly developed subvertical orientation of clasts in subfacies 'B' is attributed to tectonic rotation (fossil fish fragments and sandy mudcrack infills are similarly affected in siltstone lithologies), however the lack of grading may indicate that the debris-flow was of fairly high viscosity.

Interpretation: (Subfacies 'C')

The reduced maximum clast size, improved sorting and absence of extremely fine sediment favour interpretation of this subfacies as a water-laid deposit. The sheetlike geometry, dominance of horizontal bedding, and traces of shallow erosive scours suggest origin by sheet-flood deposition. Some beds showing similarities to subfacies 'B' are interpreted as flows where the ratio of suspended load to water was high enough to create low-viscosity debris-flows, or to cause rapid deposition of poorly sorted water-laid material (Bull, 1972). The gradational vertical changes from sandstone to conglomerate indicate that deposition took place under fluctuating flow conditions, occasionally becoming strong enough to cause scouring and erosion.

3.3 The Old Red Sandstone Succession - SANDSTONE BODY FACIES

This facies typically consists of very fine, fine and occasionally medium grained sandstone. Facies units are generally 2-3m thick, although rare cases of exceptional thickness (up to 20m) do occur. The base is typically abrupt and erosive, although scouring is rarely deeper than 30cm (Enclosures 6-10). Text Fig. 7 shows an exceptional case where a steep-sided scour at the base of a facies unit has eroded down at least 1m into the underlying siltstone. The base may be overlain locally by thin lenses containing medium to coarse sandstone, intraformational silt clasts and well-rounded carbonate fragments (of probable pedogenic origin). Such lenses may be repeated several times within the lower part of the facies unit, and where well-developed often show trough cross-bedding. Facies units are subdivided internally by frequent prominent erosional surfaces (Enclosure 7, H25 and G25) to give a stacked sequence of subunits, each averaging 10-40cm in thickness. Each subunit is defined by an erosive upper and lower bounding surface (except at the top of a facies unit where the upper surface may be gradational), and may vary from lenticular to sheetlike in lateral extent. Subunits may locally be separated by a very thin mudstone 'parting' which when traced laterally tends to wedge out or recur intermittently along a continuous erosional surface (Enclosure 10, F1 to F28 and Enclosure 6, E20 to E93). In some cases this feature



TEXT FIG. 7

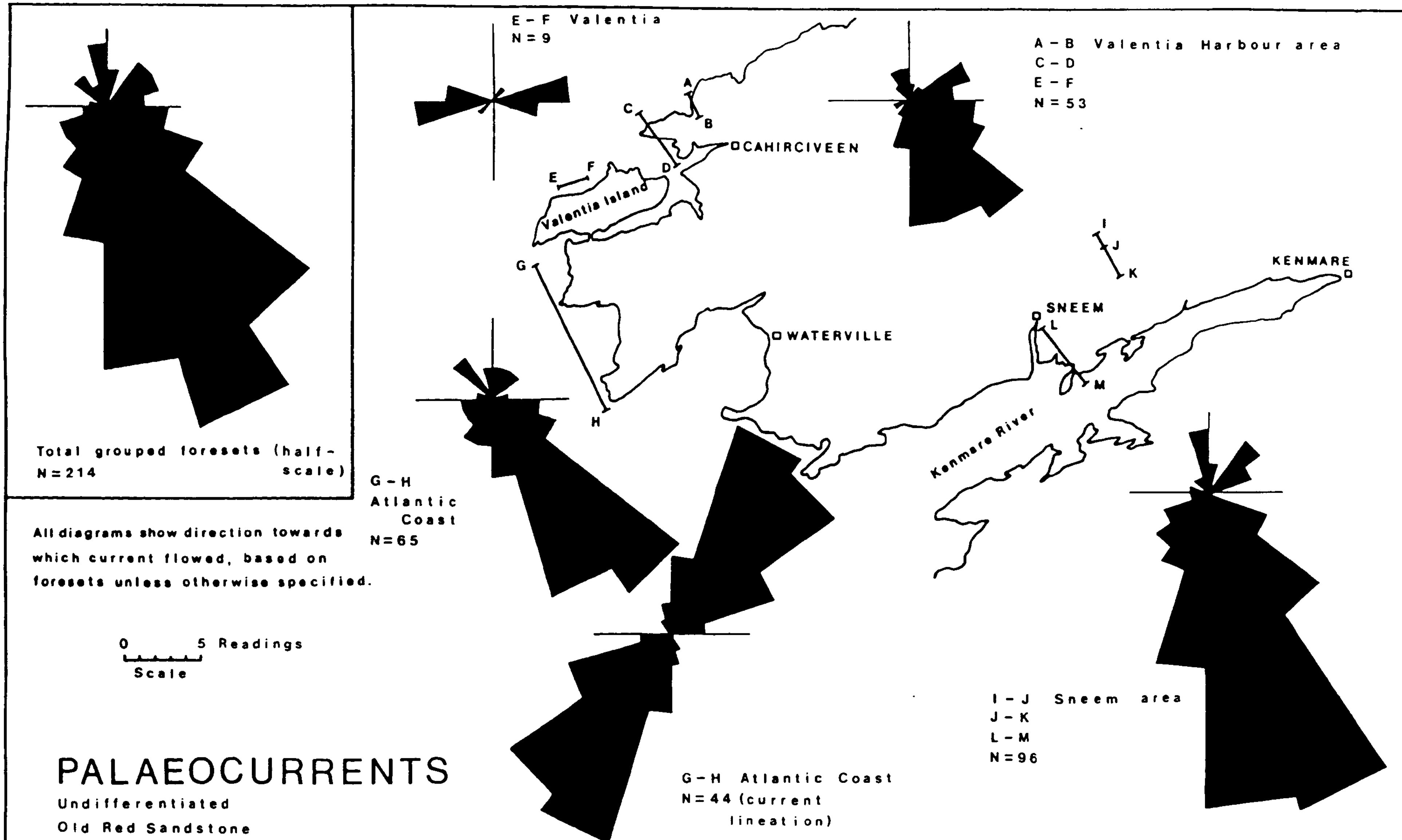
is quite strongly developed, while in others it is completely absent. The subunits tend to be dominated by a single bedding type, and are typically massive, cross-bedded or plane-bedded (Enclosures 6-10, and Plates 9-18). Some subunits are 'sub-horizontally bedded', a commonly observed situation in some plane-bedded sandstones where the plane-bedding is replaced laterally by bedding inclined at a very low angle (generally 10 degrees or less) to the base of the bed (Enclosure 7, D41 to D72). Plane-bedded sands often show parting lineation on exposed bedding plane surfaces (Plate 18). Cross-bedding is dominantly troughed (Plates 12 and 15), although tabular sets also occur (Enclosure 7, H1 to H42). Subunits tend to become finer at the top, sometimes developing small-scale cross-lamination. The subunits dominated by plane-bedding tend to be laterally extensive (Enclosure 6, E1 to E93), while those dominated by cross-bedding are markedly lenticular, usually wedging out over distances of less than 10m (Enclosure 7, G1 to G32).

Sandstone body facies units may consist largely of lenticular cross-bedded subunits (Enclosure 9), or sheetlike plane-bedded subunits (Enclosure 6), or a mixture of both. Although facies units tend to be coarser at the base and fine upwards into siltstone at the top, the main body of the facies unit shows a random vertical sequence of changes in grainsize and sedimentary structures. The thickness of the facies unit as a whole can remain reasonably constant over measured distances of at least 60m of strike section, even though the unit is composed of stacked subunits of varying lenticularity. In cases where facies units have been observed to terminate laterally, they do so by progressive wedging out of the lower subunits until the sandstone body eventually disappears (Enclosure 9), or by fining and developing siltstone interbeds to gradually pass laterally into rocks of rippled and laminated facies. None of the many units of this facies which have been observed show evidence of lateral accretion bedding, or terminate laterally with a clay-plug.

Palaeocurrent directions from this facies were obtained by measuring:

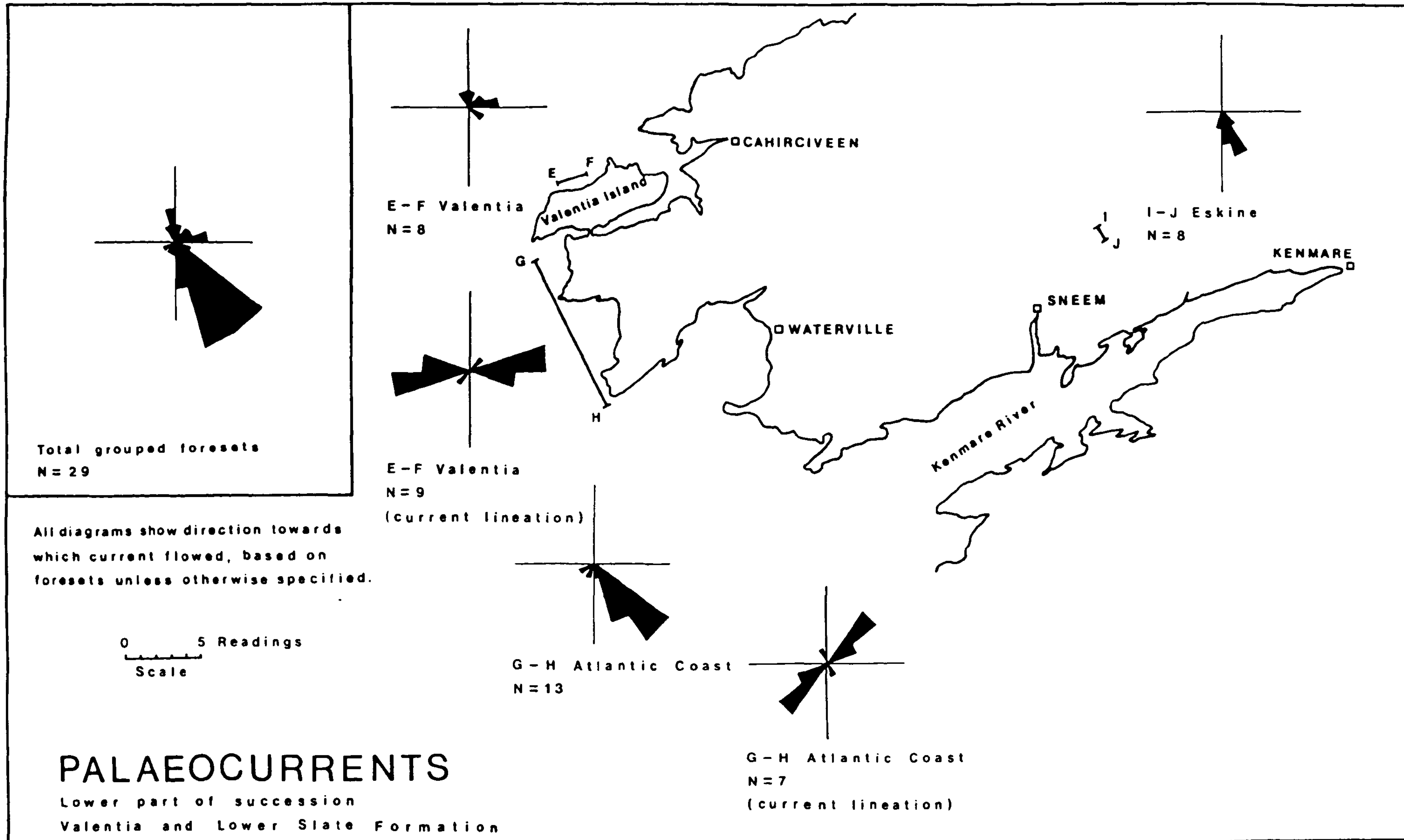
a) Tabular cross-bedding
b) Parting lineation
c) Trough cross-bedding where either the trough axis or both sides of the trough could be measured. The results are shown plotted in Text Figs. 8 to 11. In Text Fig. 8 palaeocurrent patterns are shown for undifferentiated Old Red Sandstone, plotted for individual sections and also grouped for the whole area. In Text Figs. 9 to 11, the palaeocurrents are separated to show the pattern for each of the stratigraphic units (see CHAPTER 6) within the Old Red Sandstone succession. The data are biased towards the middle part of the succession, since the sandstone body facies is virtually absent in the lower part and exposure of the upper part is restricted to two sections, one of which yielded comparatively few reliable palaeocurrents.

The plot shows a consistent pattern of foreset palaeocurrents flowing from the north and northwest, although there is some variation around this. Plotting the stratigraphic units separately does not show any systematic change in current direction within the

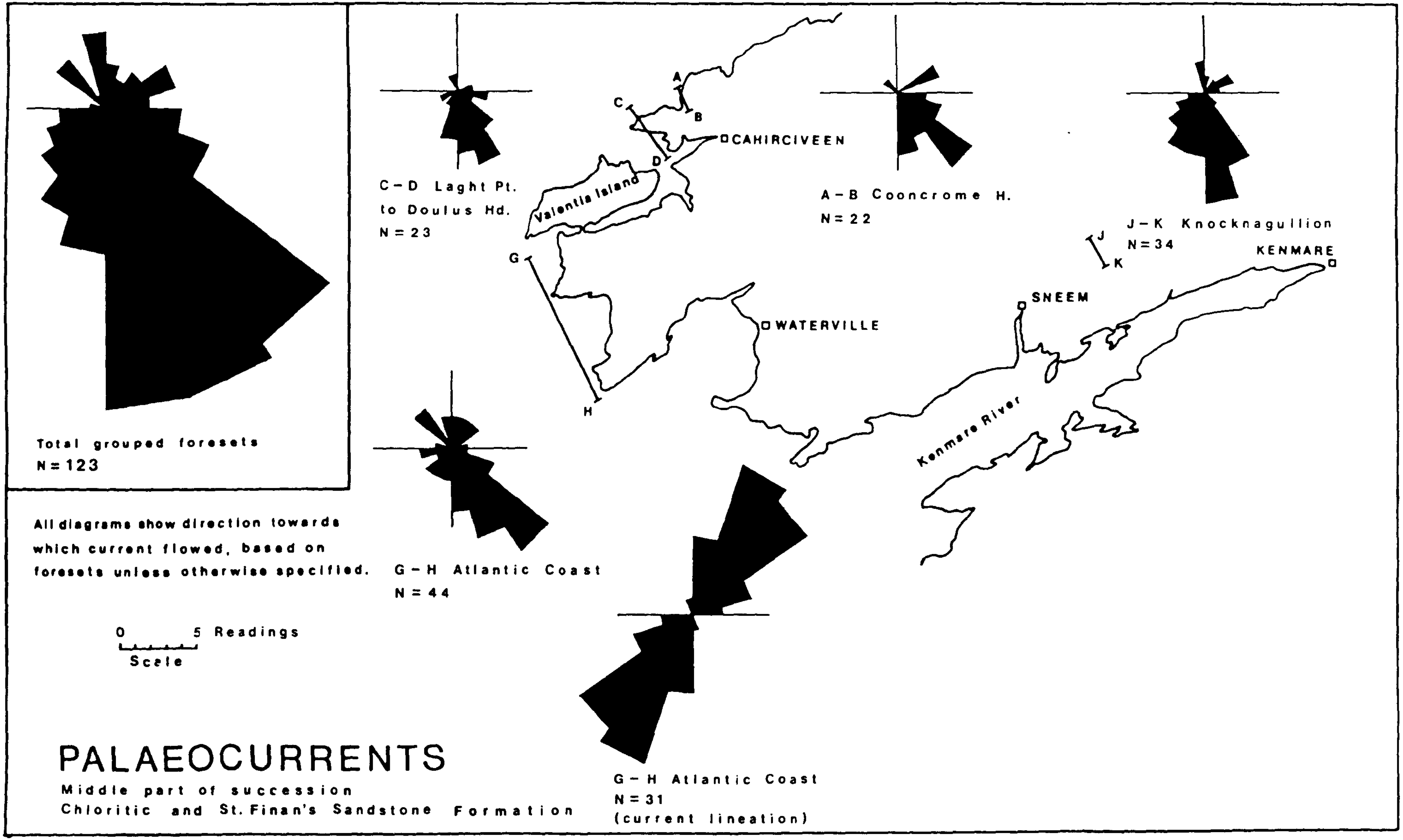


PALAEOCURRENTS
Undifferentiated
Old Red Sandstone
Total grouped foresets (half-scale)
N=214
All diagrams show direction towards which current flowed, based on foresets unless otherwise specified.
0 5 Readings
Scale
E–F Valentia
N=9
A–B Valentia Harbour area
C–D
E–F
N=53
G–H
Atlantic
Coast
N=65
G–H Atlantic Coast
N=44 (current lineation)
I–J Sneem area
J–K
L–M
N=96
CAHIRCIVEEN
Valentia Island
WATERVILLE
SNEEM
KENMARE
Kenmare River
A
B
C
D
E
F
G
H
I
J
K
L
M

TEXT FIG. 8

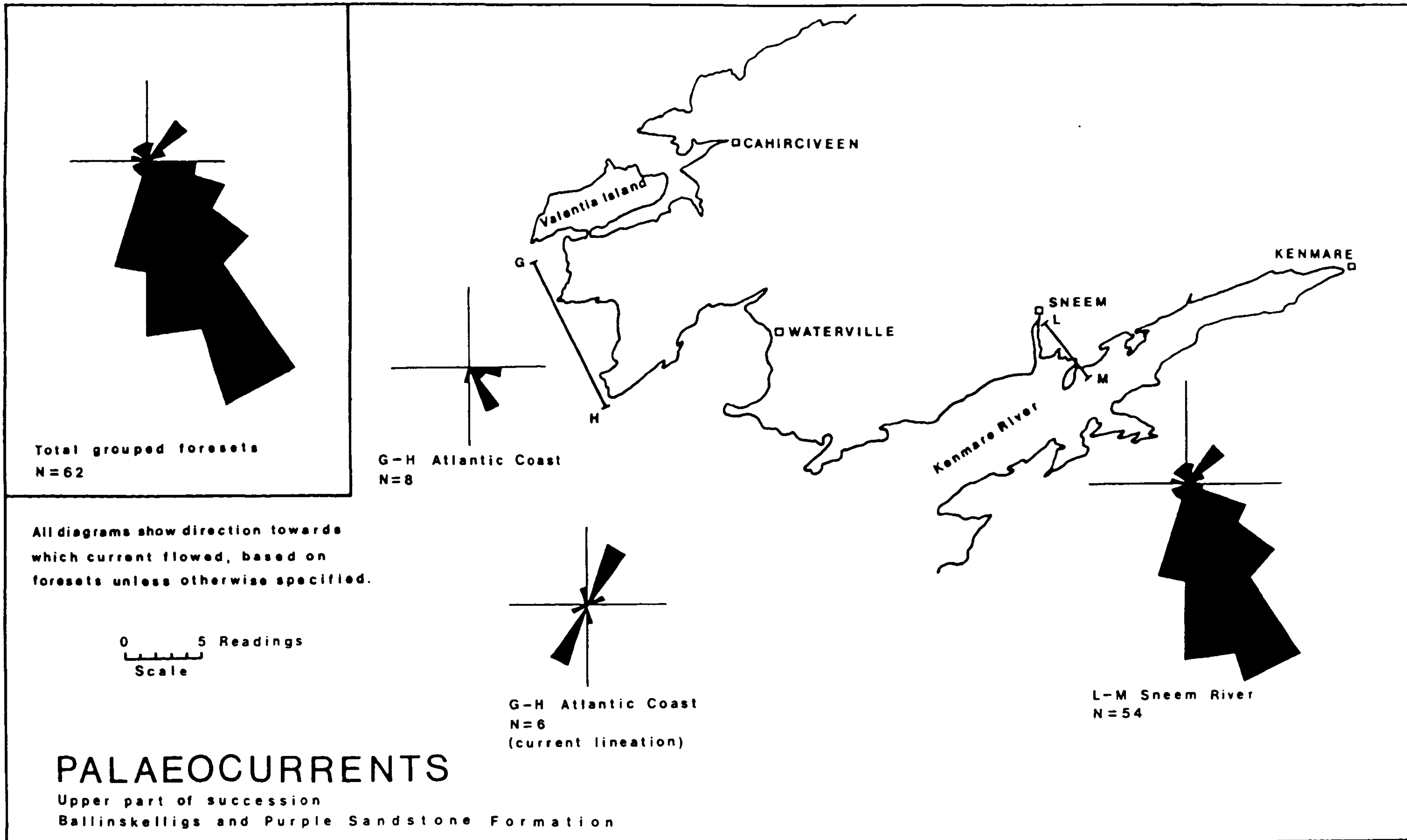

Total grouped foresets
N = 29
E – F Valentia
N = 8
E – F Valentia
N = 9
(current lineation)
G – H Atlantic Coast
N = 13
G – H Atlantic Coast
N = 7
(current lineation)
I – J Eskine
N = 8
CAHIRCIVEEN
Valentia Island
E
F
G
H
I
J
WATERVILLE
SNEEM
KENMARE
Kenmare River
All diagrams show direction towards which current flowed, based on foresets unless otherwise specified.
0
5 Readings
Scale
PALAEOCURRENTS
Lower part of succession
Valentia and Lower Slate Formation

TEXT FIG. 9



Total grouped foresets
N = 123
C – D Laght Pt.
to Doulus Hd.
N = 23
A
B
C
D
CAHIRCIVEEN
Valentia Island
A – B Cooncrome H.
N = 22
J – K Knocknagullion
N = 34
J
K
KENMARE
G
H
SNEEM
WATERVILLE
Kenmare River
All diagrams show direction towards
which current flowed, based on
foresets unless otherwise specified.
G – H Atlantic Coast
N = 44
0 5 Readings
Scale
PALAEOCURRENTS
Middle part of succession
Chloritic and St. Finan's Sandstone Formation
G – H Atlantic Coast
N = 31
(current lineation)

TEXT FIG. 10


CAHIRCIVEEN
Valentia Island
G
H
WATERVILLE
SNEEM
L
M
KENMARE
Kenmare River
Total grouped foresets
N = 62
G–H Atlantic Coast
N=8
All diagrams show direction towards which current flowed, based on foresets unless otherwise specified.
0 5 Readings
Scale
G–H Atlantic Coast
N=6
(current lineation)
L–M Sneem River
N=54
PALAEOCURRENTS
Upper part of succession
Ballinskelligs and Purple Sandstone Formation

TEXT FIG. 11

succession (Text Figs. 9 to 11), nor does there appear to be any overall pattern of geographic variation between different sections. The apparent switch to a westerly source for the lower part of the succession exposed on the northern coast of Valentia Island (Text Fig. 9), is based on a single facies unit traced along strike, and is not considered significant.

Parting lineation has only been observed on the Atlantic Coast section, and to a lesser extent on the northern coast of Valentia Island. The Valentia Island section (Text Fig. 9) has lineations with a predominantly E-W orientation, matching a weak foreset mode of palaeocurrents flowing from the west. In constrast with this, the Atlantic Coast section has NE-SW or NNE-SSW oriented lineations which are at an angle of almost ninety degrees to a strong foreset mode of palaeocurrents flowing from the NW.

In order to investigate the apparent divergence between foreset and parting lineation directions on the Atlantic Coast section, the sandstone bodies from which the measurements were obtained were revisited and examined in greater detail. The parting lineation observations come largely from a series of sandstone units in the lower part of the St. Finan's Sandstone Formation. Text Figs. 12 to 14 show a series of sketch profiles through these units, with palaeocurrent directions recorded wherever possible. A number of conclusions may be drawn.

KEY TO TEXT-FIGURES 11-13

The text-figures show a number of facies units of the sandstone body type, from the Atlantic Coast section (section G - H, Text-figs. 7 - 10). No particular sequential relationship is intended by the placing of sections within the figures.

↑ Palaeocurrent indication: pointing vertically upwards indicates due north (i.e. current coming from the south). Mid-point of arrow-shaft is opposite bed from which palaeocurrent has been taken.

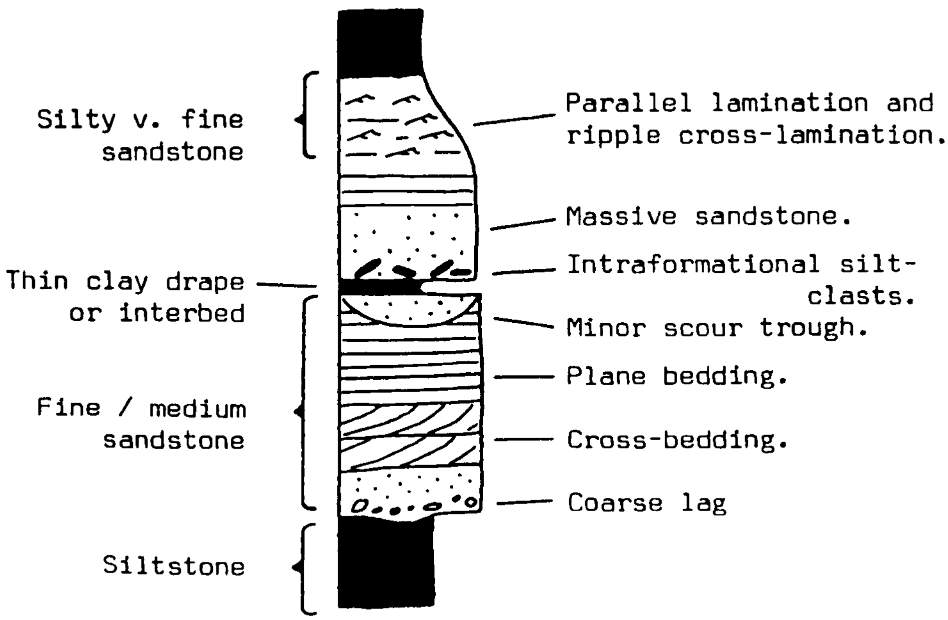
Palaeocurrents from foresets, parting lineations and trough axes have been restored to remove the effects of tectonic plunge and dip, using a stereo net. Ripple palaeocurrents are restored by eye and assigned to the nearest sixteenth of the compass-rose (i.e. N, NNE, NE, etc.)

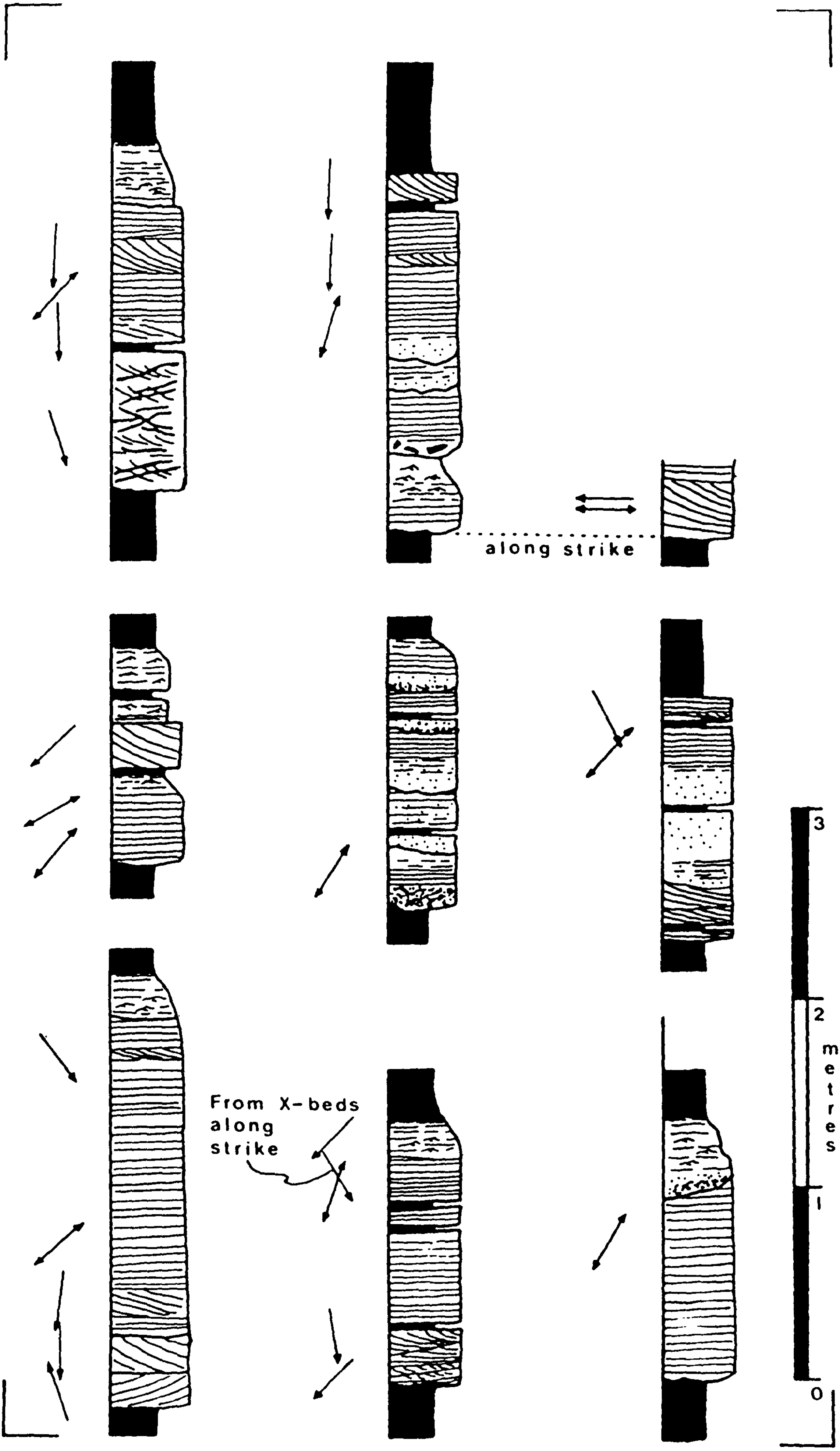
Ripple or foreset palaeocurrent.

Parting lineation palaeocurrent.

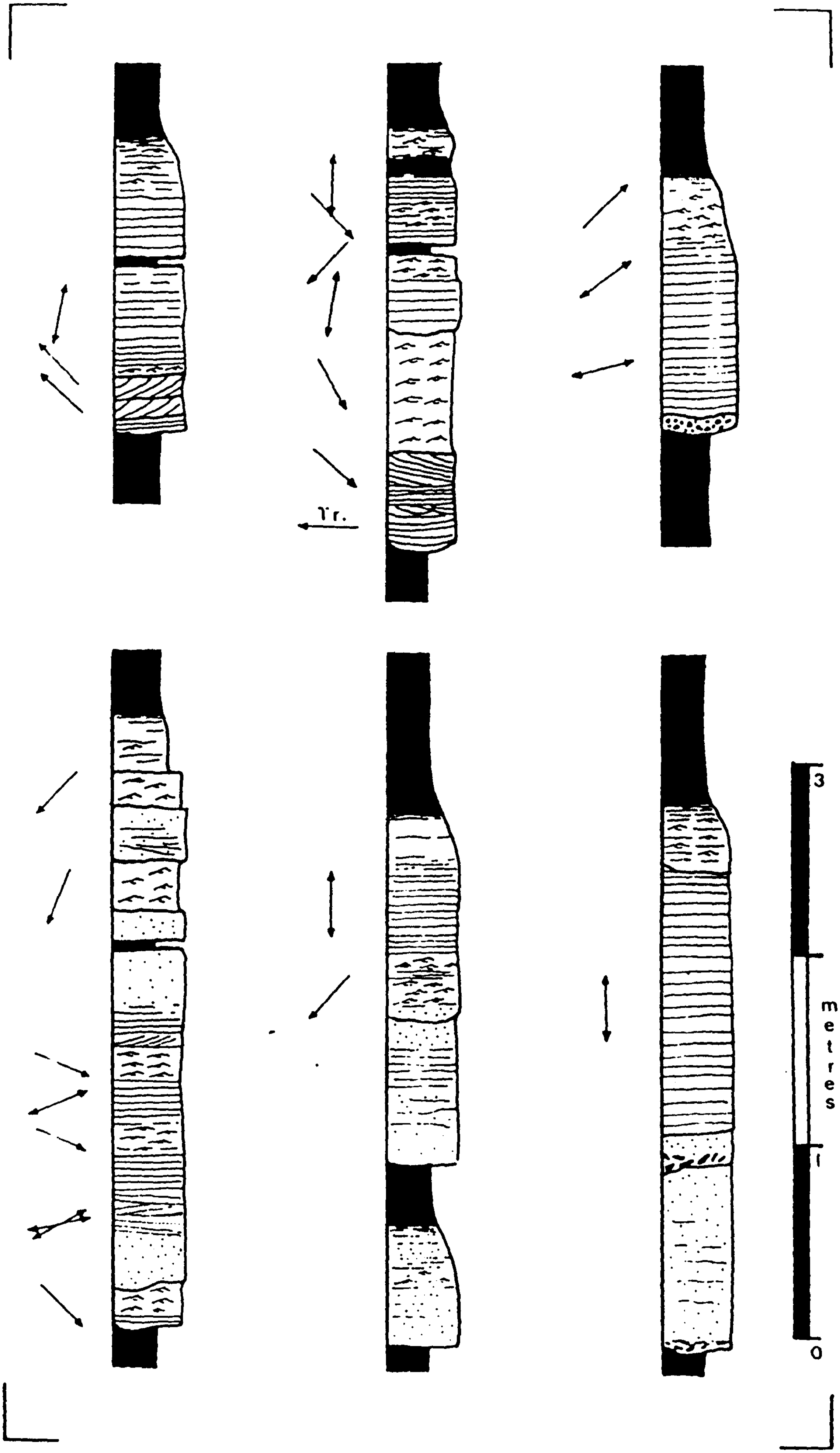
Trough axis orientation.

Trough axis where direction of current flow can be determined.

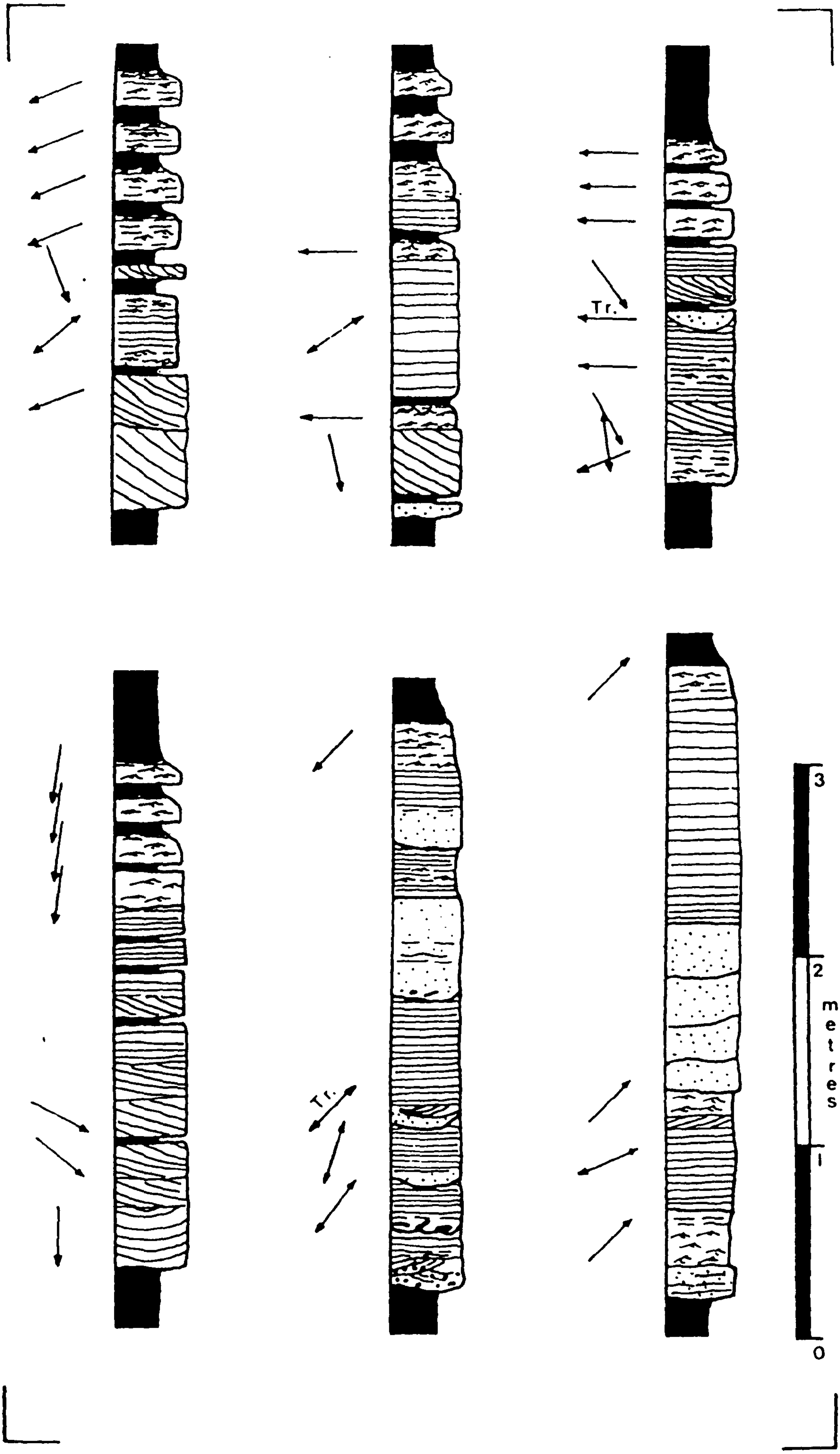




TEXT FIG. 12



TEXT FIG. 13



TEXT FIG. 14

1) In rare cases (e.g. Text Fig. 12, top right) the parting lineation is observed on the surface of low-angle trough foresets, but in general it is associated with thin (usually less than 1m) subunits of erosively based plane-bedded sandstone, sometimes separated by thin siltstone drapes or interbeds.

2) Where lineation is measured from repeated plane-bedded subunits within the same facies unit (e.g. Text Fig. 13, bottom left and top centre; Text Fig. 14, bottom centre), the orientation is consistent.

3) Where (lineated) plane-bedding is followed or follows cross-bedded or cross-laminated sandstones with no obvious break in sedimentation, the swing in palaeocurrent dirction varies from minimal (Text Fig. 12, top centre; Text Fig. 14, bottom right) up to forty-five degrees (Text Fig. 12, bottom centre; Text Fig. 13, bottom centre).

4) When considered in the context of other palaeocurrents within a single facies unit, parting lineation directions lie reasonably close to the overall pattern for the unit. Certainly they are not as strongly divergent as Text Figs. 8 to 11 would suggest.

Interpretation

The erosive base, pebbly lags, moderate sorting and sedimentary structures of this facies are consistent with transport and deposition by an energetic unidirectional current of water. A continental fluvial setting is indicated by intimate association with other facies in which dessication cracks and caliche horizons are developed (see sections 3.5 and 3.7). The identification of a particular style of fluvial system based on the features observed in an ancient example must be approached with caution (Collinson, 1978). The evidence for an incised permanent channel system is generally absent. Geometry is sheetlike, and the basal scour surface is generally flat. The majority of the units are only two to three metres thick which would imply a very shallow channel or else subsequent erosion. No examples of preserved channel margins are recorded, nor do any of the sand bodies terminate laterally in a fine-grained channel-fill. The facies units are internally poorly organised vertically, lacking a systematic upwards fining or decrease in the scale of bedforms, and no examples of lateral accretion surfaces have been identified.

The facies units show a complete range extending from the more sheetlike plane-bedding dominant type to the more lenticular cross-bedded type. Thin siltstone or claystone partings between subunits indicate that sedimentation occurred as a series of higher energy pulses (floods), between which fine-grained sediment was deposited.

The plane-bedding dominant units with associated current lineation are interpreted as vertically accreted sheetflood deposits, developing low-angle cross-bedding in places in response to decreasing flow strength or increase in water depth. The tops of some plane-bedded subunits are locally reworked by the waning flow into small cross-beds or ripples (Enclosure 10, D15 to D54). Each facies unit represents perhaps eight to ten individual flood pulses, with the lower and upper parts of the unit tending to show some cross-bedding formed as the flood builds up and then dies away.

The cross-bedding dominant units in contrast to this are made up of highly lenticular subunits with shallow scoured bases, indicating frequent localised scour and fill. The characteristics are similar to those of conglomerate subfacies 'A', and are interpreted as the results of a shallow braided-channel system. The larger planar cross-beds are interpreted as the product of lateral migration of cross-channel braid-bars. Enclosure 8 (B1 to B12) shows a migrating bar with several reactivation surfaces, and the bar top is locally incised by minor scour and fill structures which probably formed during low stage when the bar was not actively migrating. Some estimate of the flow-depth in which these cross-bedded subunits were deposited is provided by

1) The topographic relief of erosive bases underlying single subunits.
2) The maximum thickness of individual cross-bedded sets.

Although these are only minimum estimates, a water depth of just over one metre is indicated.

The close association between the shallow braided channel and sheetflood sandstones, often within the same facies unit, suggests that discharge was in the form of periodic flash flooding rather than a steady continuous flow. Hence there was no chance to develop a permanent incised channel system, instead small shallow channel systems controlled flow until the discharge became too great and flow spread out from the channels as a broad sheetflow moving over the floodplain.

Regarding the apparent contradiction of palaeocurrents from cross-bedding by those from current lineations, various authors have noted and considered the occurrence of current lineation oriented at a high angle to associated cross-bed foresets (Allen 1965, p. 149, 150 and 157; 1983, p. 246; Williams 1966, p. 744; Miller 1969, p. 19; and Cant and Walker 1976, p. 110). Where interpretations have been made, the patterns have mainly been explained by the sideways accretion of point-bar or bar bedforms in a direction normal to the overall channel flow direction. In the case considered here however, the profiles are dominated by stacked thin plane-bedded sandstones which are considered to have been deposited as sheet-floods rather than by channelised flows. Plane-bedding and the parting lineation represent the main depositing agent and transport direction for the sandstone bodies. The cross-bedding may have formed in response to some incision and greater water depths at the onset of flooding, while cross-lamination developed during waning stages when the flow-rate was reduced.

The general conclusion is therefore that the apparent divergence between parting lineation and foreset palaeocurrents on the Atlantic Coast section is the result of sampling heavily biased towards a small part of the succession in which transport was dominantly from the north and east. An overall transport direction from the north and west still applies to the succession as a whole, with the Valentia Island sequence and lineated sandstones of the Atlantic Coast as minor but real local variations.

3.4 The Old Red Sandstone Succession - RIPPLED AND LAMINATED FACIES

This facies consists of grouped or, rarely, solitary beds of coarse siltstone or very fine sandstone, in which small-scale cross-lamination and/or parallel lamination is the dominant internal structure (PLATES 19-28). Fine and coarse end-members are recognised, and are described separately below. The similarity between these end-members, and recognition of intermediate forms, shows that they are opposite extremes of a continuum.

For ease of description, in the following sections the terms 'rippled' or 'ripple-bedded' are used to denote small-scale cross-lamination.

Fine end-member

This typically consists of grouped beds of coarse siltstone or silty very fine sandstone, separated by subordinate interbeds of fine siltstone (Plate 19). In outcrop, the 'fine' interbeds tend to weather out, leaving the 'coarse' beds as ridges. The latter are generally 30cm or less in thickness, and are dominantly faintly ripple-bedded. The former tend to be rather thinner and are massive apart from slight traces of thin sandy laminations or textural mottling. Facies units rarely exceed 2m in thickness.

The base of a facies unit is that of the lowest 'coarse' bed, and is almost invariably abrupt and erosive. Within the unit, detail is obscured by the fine grainsize and closely spaced cleavage in the rocks. Where these are not too extreme the 'coarse' beds are seen to be current rippled, with troughed and planar foresets occurring in different cosets. Climbing rippled sets appear to be common. There is a tendency for the coarser grainsizes (very fine or silty sand) to segregate from the finer grainsizes (medium to coarse silt) and become concentrated in the foresets and crests of the ripple-bedding. Within individual 'coarse' beds erosional breaks are rare, and most if not all of the bed appears to represent a single depositional event. The tops of beds may be abrupt or gradational. Disturbed bedding is common (Plate 22), usually confined to just one or two of the grouped beds, or it may affect just part of a single bed. It appears to be a localised feature where it occurs, and disturbed beds may be traced laterally into undisturbed rippled beds. The top of the facies unit, where not erosively overlain by sandstone body facies, may pass abruptly or gradationally up into bioturbated, sand laminated siltstone or massive mudstone facies. In some cases the 'coarse' interbeds become thinner towards the top of the unit but this is not generally so.

Traced laterally, the facies unit remains constant in thickness over distances of up to 20m (the limit of continuously exposed section). The geometry of the 'coarse' beds is generally sheetlike, although locally some splitting and joining takes place where erosion by the overlying bed causes wedging of the intervening fine siltstone interbed (Plates 20 and 21).

Units of rippled and laminated facies may pass laterally into sand-laminated siltstone facies by thinning, splitting and fining of the 'coarse' beds, over distances of as little as 5 to 10m (Enclosure 11). In some cases the 'coarse' beds merge to thicken and coarsen, and pass laterally into sandstone body facies. In vertical sequences, sandstone body facies occasionally passes upward into rippled and laminated facies in a way which minimises the contrast between the two facies. The upper subunit of the sandstone body is fine-grained and dominantly rippled, and the lower part of the rippled and laminated unit is relatively coarse-grained, so that although erosive breaks are present, the overall impression is of a gradational vertical change.

Coarse end-member

This typically consists of grouped beds of moderately well-sorted fine sandstone, separated by very thin siltstone interbeds or prominent laterally persistent erosional surfaces (Plate 24). The thickness of individual sandstone beds ranges from 30cms to several metres. Facies units are typically 1-2 metres thick, with rare examples up to 5 metres thick.

The base of the facies unit is abrupt, often downcutting locally several centimetres into the underlying sediment. Thin (less than 5cm) lenses of coarse sand, intraformational silt clasts and rounded carbonate fragments are occasionally developed locally at the base of these units.

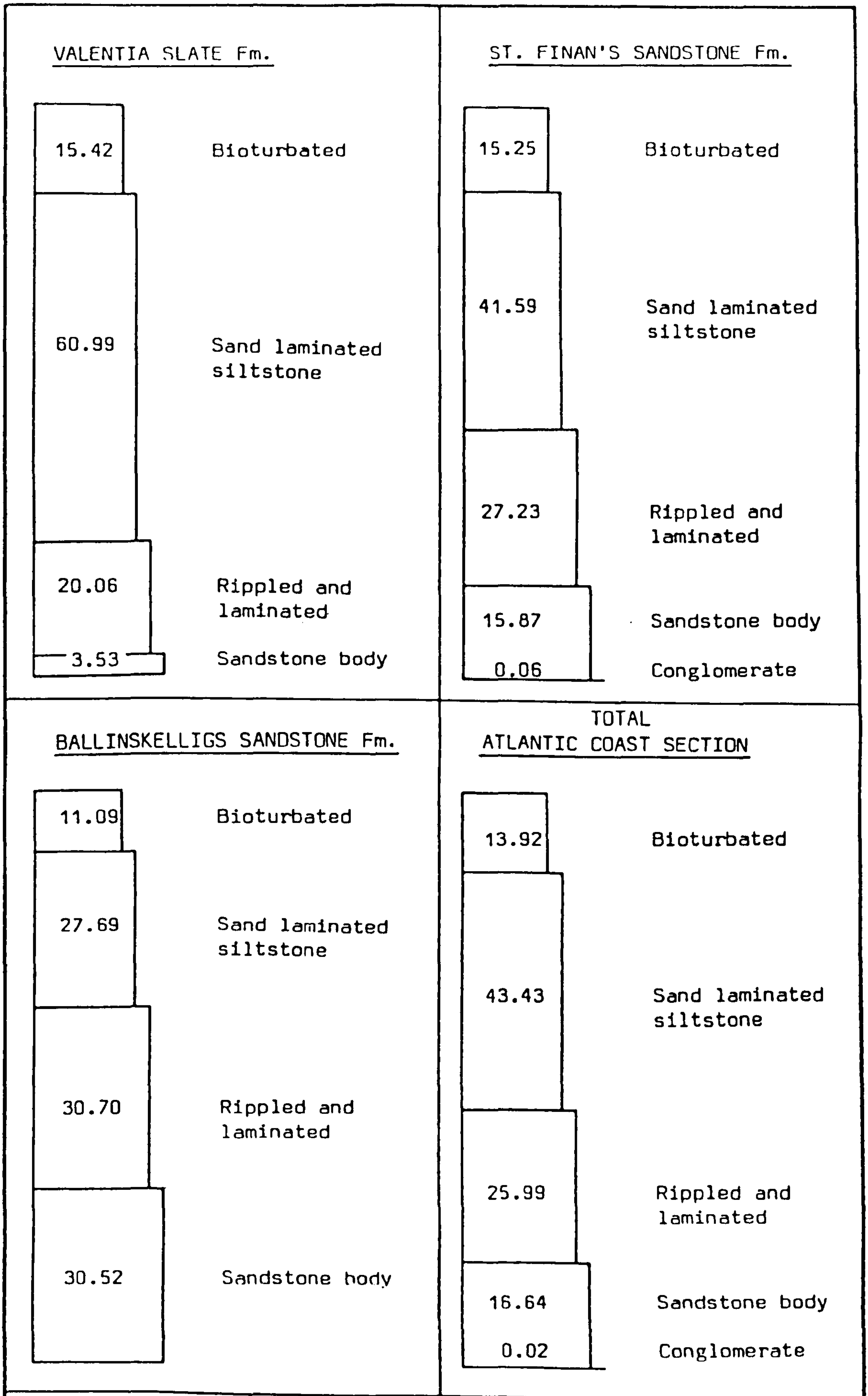
Within the facies unit, the individual sandstone beds also show shallowly erosive bases. As in the fine end-member, the sandstone beds are parallel laminated, rippled, or a mixture of both. Bedding is more discernible in this coarser end-member and in rare cases it is possible to see an upwards transition from parallel lamination, through ripple laminae in-phase (McKee, 1965) to climbing-ripple bedding, all within a single sandstone bed. Rippled beds are dominantly of climbing-ripple type (PLATES 23 and 25), with the angle of climb and degree of stoss-side preservation varying from one bed to another. Trough rippled beds also occur (PLATE 26) but are less common. Parallel laminated beds in which bedding planes are exposed may show weakly developed primary current lineation. The tops of sandstone beds may fine upwards and become silty, but more often they are abruptly overlain by a thin siltstone drape or are truncated by the erosive base of the sandstone bed above.

Thin interbedding with slightly coarser and better sorted fine sandstone can occur, accompanied by flat-bedding, small-scale cross-bedding or simply massive appearance, to produce strong similarity to the sandstone body facies. As already noted, a transition of this type can cause the rippled and laminated facies to pass laterally into sandstone body facies.

Both coarse and fine end-members tend to have an overall sheet geometry, and can be visually traced on vertical sea-cliff exposures for distances of at least 60 metres. Text Fig. 15 shows percentage thicknesses of facies from the Atlantic Coast section; the rippled and laminated facies comprises between 20% and 30% of the total facies volume. Palaeocurrent data for the facies are shown in Text figs. 16-18. Current lineation is too rare and poorly developed to be of use. Ripple-bedding from the Atlantic Coast and Sneem River sections was recorded as accurately as possible (see CHAPTER 2, section 2.4) and shows a dominant direction of transport from the north and north-west.

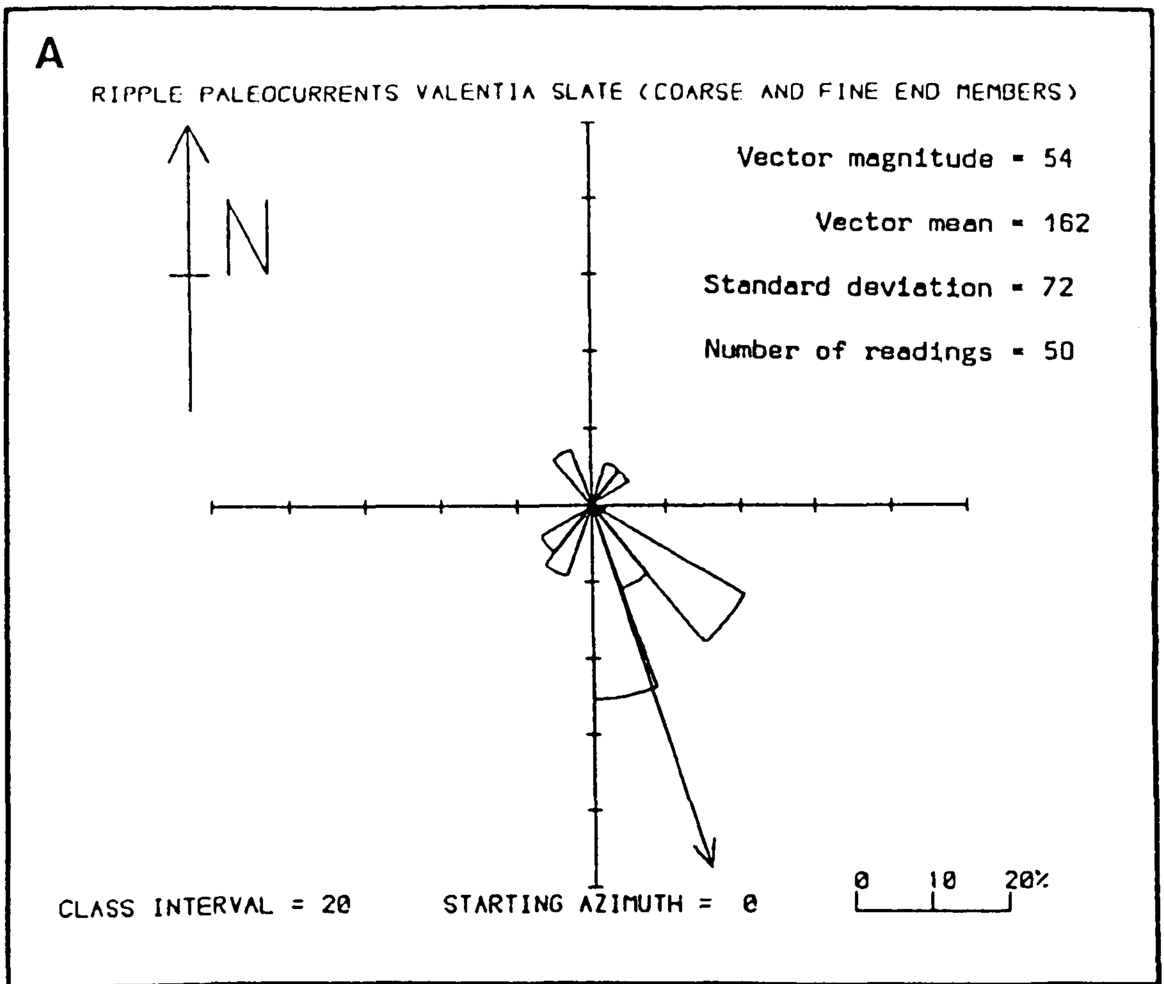
Interpretation

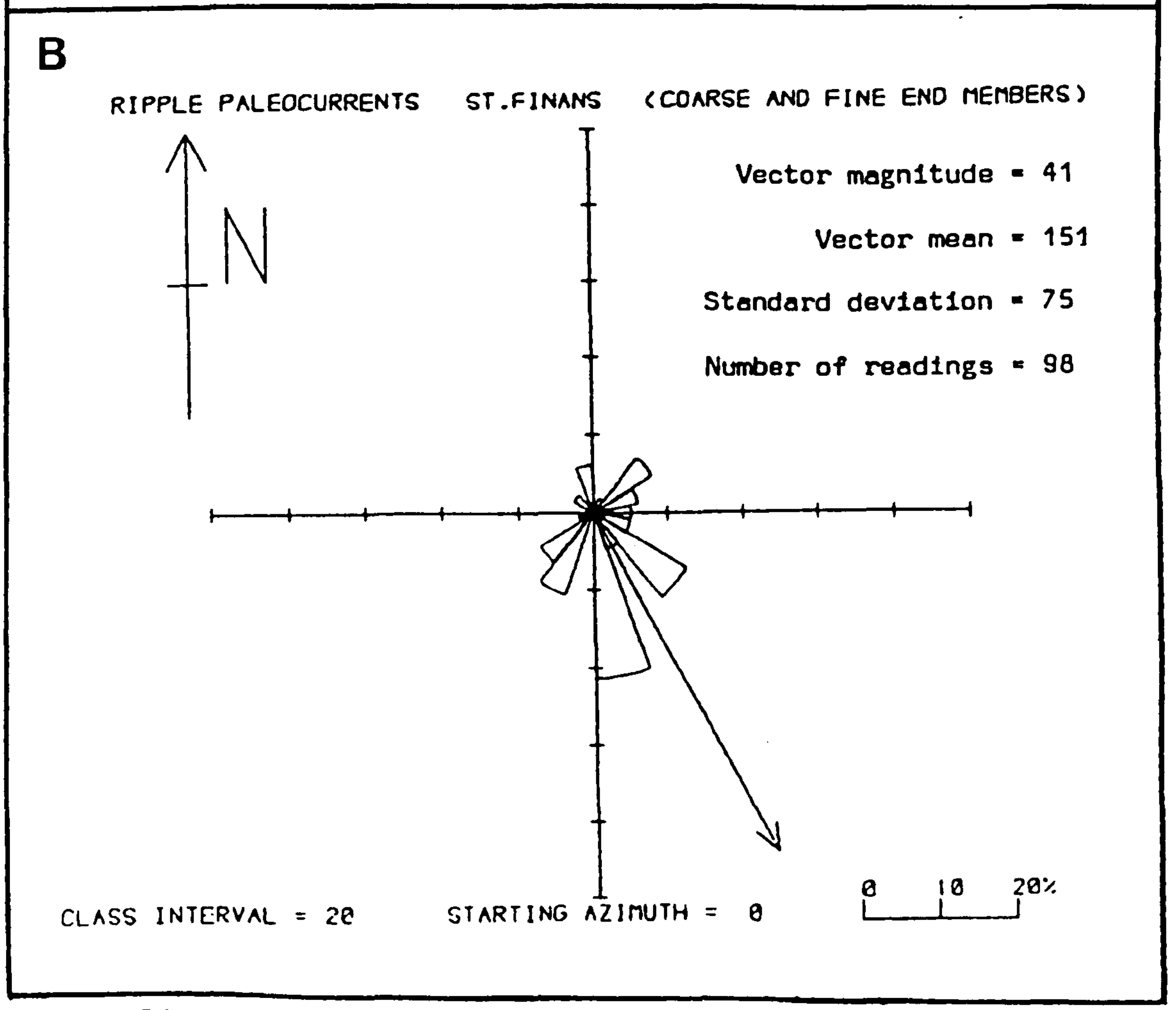
The sharp erosive base and locally occurring coarse basal lags in this facies indicate that deposition commenced following a relatively energetic flow event. The sediment grainsize and sorting, as well as sedimentary structures are consistent with a water-laid deposit. The flow was capable of eroding cohesive fine siltstones and transporting pebble-sized silt-clasts and granule to pebble-sized fragments of carbonate. The grouped arrangement of the coarser beds, separated by thin fine siltstone interbeds or claystone drapes, shows that each facies unit represents a series of flow pulses between which low-energy 'background' sedimentation was able to continue. Individual rippled beds often 30cms. or more in thickness contain no apparent erosive breaks and represent single depositional events. The predominance of current ripples and unimodal palaeocurrent patterns indicate deposition was by a



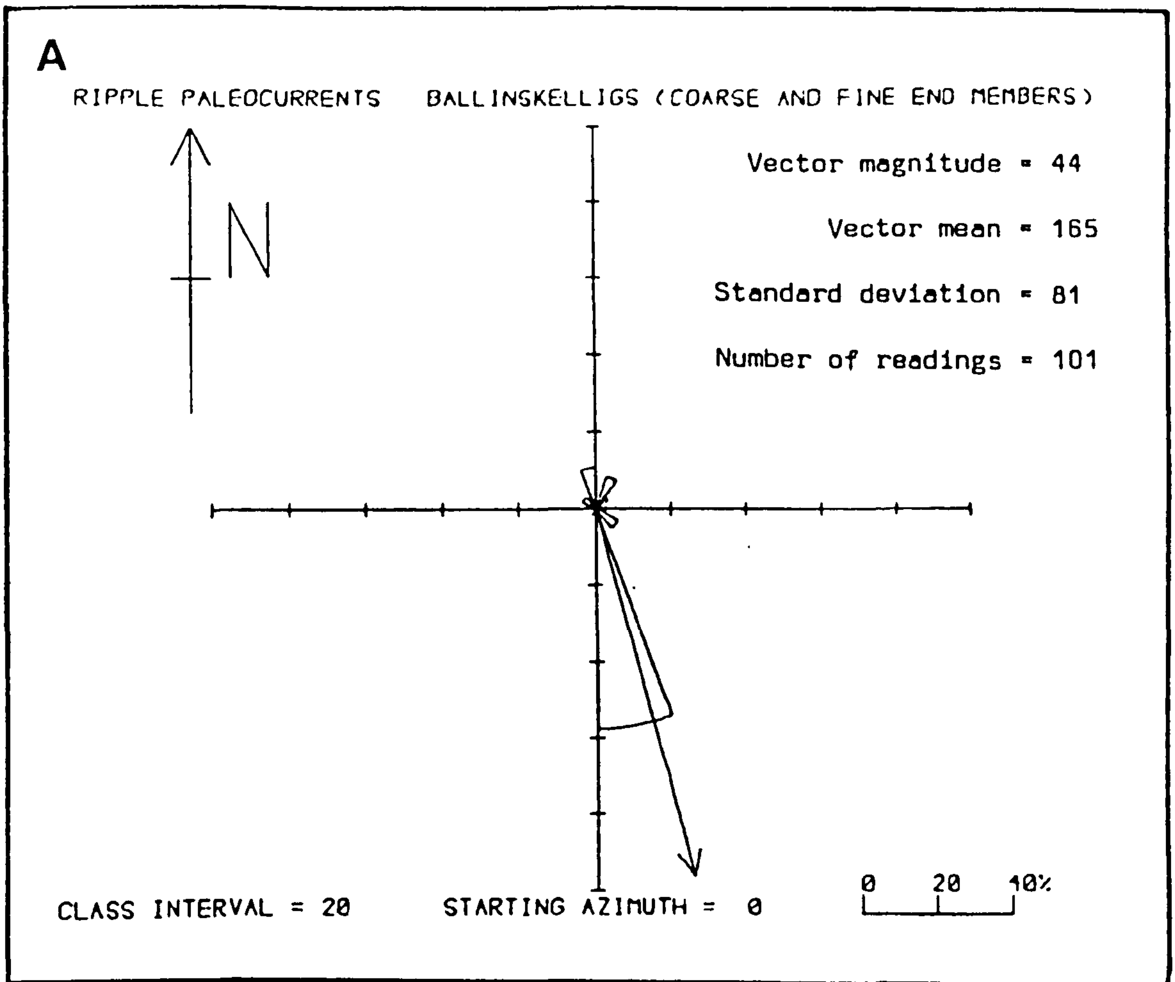
SUMLOG PROFILES from the Atlantic coast section.

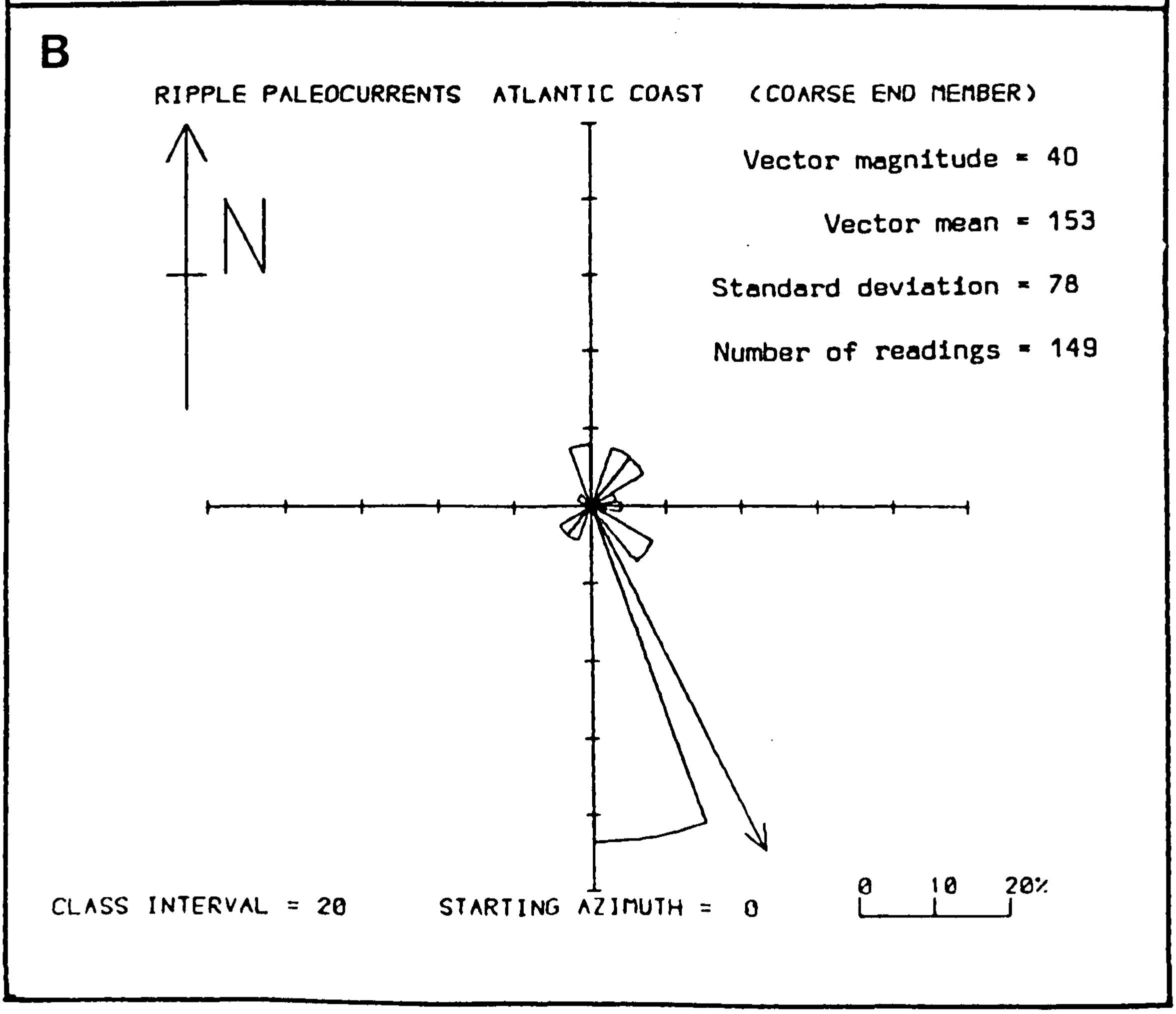
TEXT FIG. 15


A
RIPPLE PALEOCURRENTS VALENTIA SLATE (COARSE AND FINE END MEMBERS)
N
Vector magnitude = 54
Vector mean = 162
Standard deviation = 72
Number of readings = 50
CLASS INTERVAL = 20
STARTING AZIMUTH = 0
0
10
20%

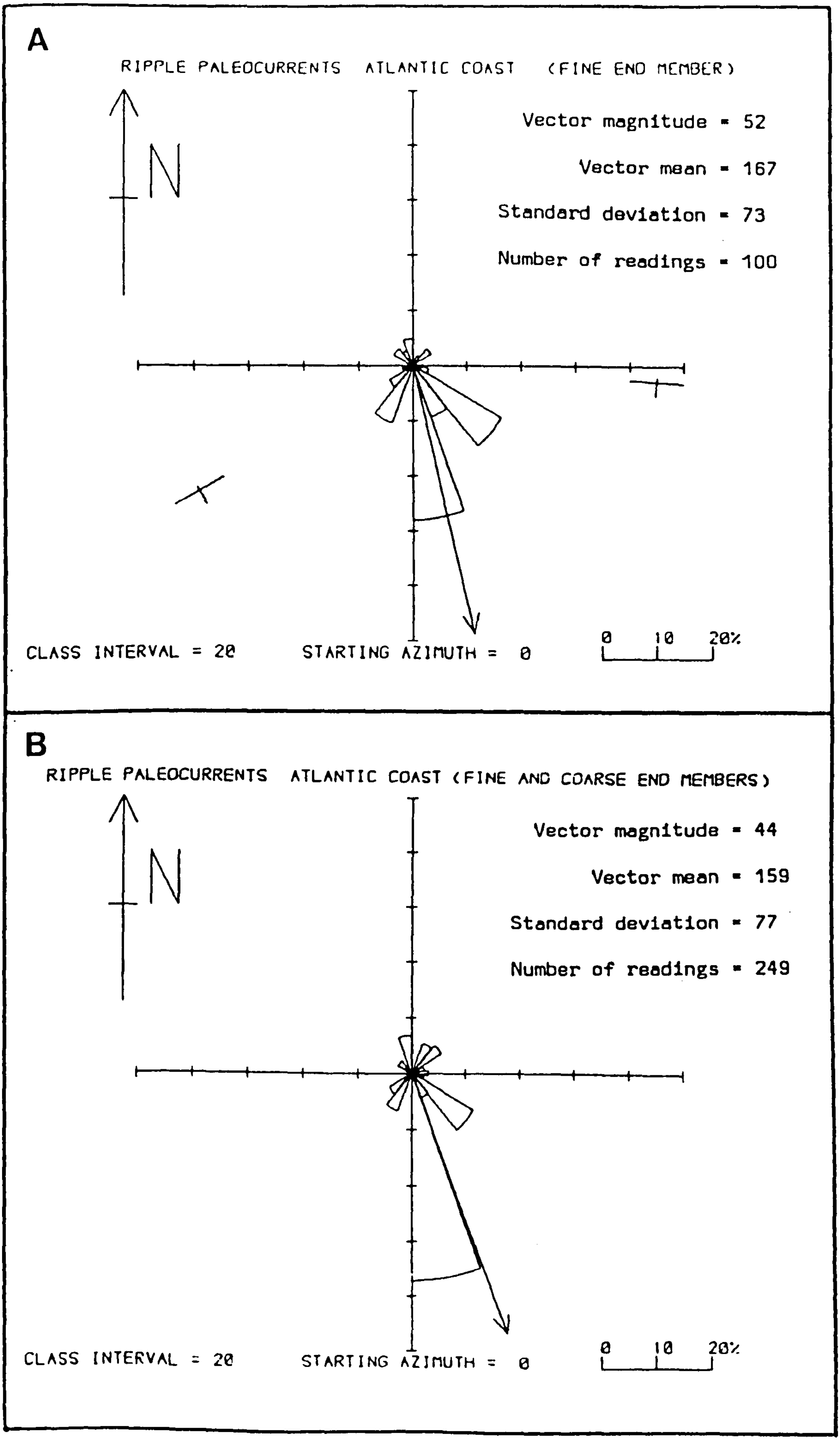

B
RIPPLE PALEOCURRENTS ST.FINANS (COARSE AND FINE END MEMBERS)
N
Vector magnitude = 41
Vector mean = 151
Standard deviation = 75
Number of readings = 98
CLASS INTERVAL = 20
STARTING AZIMUTH = 0
0
10
20%

TEXT FIG. 16


A
RIPPLE PALEOCURRENTS BALLINSKELLIGS (COARSE AND FINE END MEMBERS)
N
Vector magnitude = 44
Vector mean = 165
Standard deviation = 81
Number of readings = 101
CLASS INTERVAL = 20
STARTING AZIMUTH = 0
0 20 40%


B
RIPPLE PALEOCURRENTS ATLANTIC COAST (COARSE END MEMBER)
N
Vector magnitude = 40
Vector mean = 153
Standard deviation = 78
Number of readings = 149
CLASS INTERVAL = 20
STARTING AZIMUTH = 0
0 10 20%

TEXT FIG. 17


A
RIPPLE PALEOCURRENTS ATLANTIC COAST (FINE END MEMBER)
N
Vector magnitude = 52
Vector mean = 167
Standard deviation = 73
Number of readings = 100
CLASS INTERVAL = 20
STARTING AZIMUTH = 0
0 10 20%
B
RIPPLE PALEOCURRENTS ATLANTIC COAST (FINE AND COARSE END MEMBERS)
N
Vector magnitude = 44
Vector mean = 159
Standard deviation = 77
Number of readings = 249
CLASS INTERVAL = 20
STARTING AZIMUTH = 0
0 10 20%

TEXT FIG. 18

unidirectional flow. Common occurrence of climbing ripples implies a high rate of deposition (Allen, 1971). The upwards passage seen in some beds from parallel lamination with parting lineation to climbing ripples, clearly records a flow waning from upper to lower flow regime, accompanied by rapid dumping of the sediment load.

Palaeocurrent patterns from the Atlantic Coast section were analysed to see if there was any significant variation in results between fine and coarse end-members, or according to stratigraphic position (Text figs. 16-18). The conclusions are as follows:

1) Apart from a relatively stronger mode and lower variance in the coarse end-member, both fine and coarse end-members show a similar palaeocurrent pattern (Text figs. 17B and 18A).

2) When separated into lower, middle and upper parts of the succession there is no difference in palaeocurrent direction. The only change is a stronger mode and lower variance in the upper (Ballinskelligs Sandstone Formation) part of the sequence, due to the predominance of the coarse end-member in that part of the succession.

The facies initially suggested levee and crevasse splay deposits, based on interpretation as a series of waning flood pulses, together with the fact that it is laterally equivalent or follows after the sandstone body facies. Several points are now apparent to contradict this.

1) The sandstone body facies does not show the characteristics indicative of a permanent well-incised fluvial channel system (see section 3.3). Flow depths may have been quite shallow, and in many cases the flow appears to have been unconfined and sheetlike. In such conditions levee development would not form raised channel banks, and breaching to produce crevasse splays could not occur.

2) The palaeocurrent distribution for levee and crevasse splay deposits would be expected to show a wide variance, possibly weakly bimodal in directions normal to the main channel flow direction. Instead the palaeocurrent pattern shows the same overall direction as the 'channel' sandstone body facies.

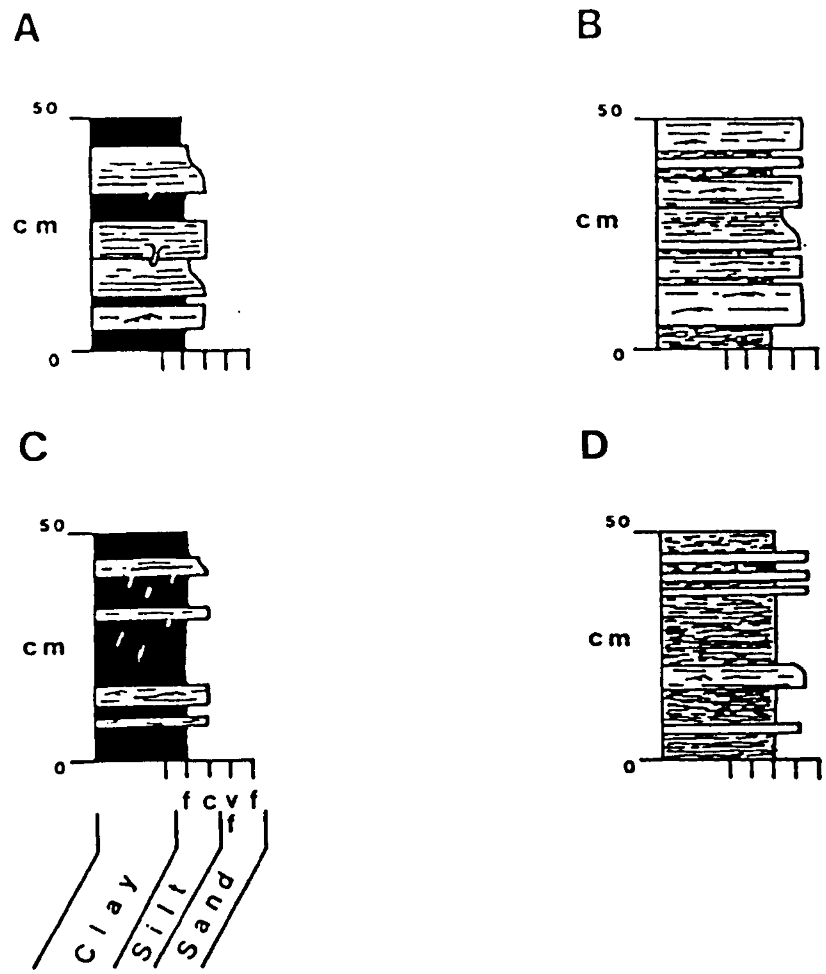
3) The geometry of the rippled and laminated facies is difficult to establish conclusively, due to the nature of the exposures. Units may however be traced as continuous sheets to the limits of visible exposure on cliff sections. Where access is possible, thickness and sedimentary characteristics are seen to remain constant.

In view of these points, and bearing in mind the evidence of unidirectional flow, flood pulses and rapid deposition of substantial volumes of sediment, the facies is interpreted as deposition from waning sheet-flows distally equivalent to those responsible for a large part of the sandstone body facies. The coarse and fine end-members are thus simply proximal and distal examples of the same process. The thicker fine siltstone interbeds in the fine end-member are due to more distal location in which high energy flood pulses are less frequent and probably less capable of erosion than in more proximal areas. The observed range of intermediate forms between fine and coarse end-members, and between coarse end-members and sandstone body facies, are not as surprising if all are linked to a similar process and variation is controlled simply by the energy of the flow and the distance over which the sediment has been transported.

3.5. The Old Red Sandstone Succession - SAND-LAMINATED SILTSTONE FACIES

This facies typically consists of a sequence of thinly alternating coarse and fine beds, in which individual beds are less than 10cms. thick and often less than 3cms. thick (Text Fig. 5, PLATES 29-36). The coarser beds tend to have abrupt bases and gradational tops, and occasionally show faint parallel lamination or rare ripple-bedding.

Text fig. 19 shows a range of variation within the facies. In the finer grained examples (A and C) the grainsize alternates between fine and coarse siltstone, or even between claystone and fine siltstone. Grainsize contrast is occasionally so low that the interbedding can be difficult to see, particularly since a strong cleavage is also present in the rock (PLATE 32). In the coarser examples (B and D) the alternation is between coarse siltstone and silty sandstone. Text fig. 19 also shows that either coarse interbed dominant (A and B) or fine interbed dominant (C and D)



RANGE OF VARIATION IN THE SAND-LAMINATED SILTSTONE FACIES

A Fine end-member, coarse interbeds dominant.

B Coarse end-member, coarse interbeds dominant.

C Fine end-member, fine interbeds dominant.

D Coarse end-member, fine interbeds dominant.

TEXT FIG. 19

versions of the facies may occur. All variations between A, B, C and D are observed in the field, but type B and type C are the most common.

Bioturbation textures and burrow traces are ubiquitous in this facies (Plate 33). Though varying considerably in intensity, bioturbation is never sufficient to obscure the primary bedding structures. Vertebrate (fish) material sometimes occurs as scattered fragments resting on a bedding plane (see CHAPTER 4 for more detailed discussion).

Mudcracks occasionally cut the fine siltstone beds in this facies, and are seen both in section (Plate 36) and as polygonal patterns on bedding plane exposures (Plate 35).

Small scour and fill structures are fairly common (Plate 33), rarely downcutting more than 30cm and less than 3m wide. The scour-fill is invariably of similar fine grainsize to the sediment in which the scour was cut. An unusually large scour is shown in Plate 29, 4m deep and at least 16m wide. This was the only example of this magnitude observed in the whole of the area studied. Jointing frequently exposes both N-S and E-W sections, so large scours are unlikely to have been missed due to preferred orientation of the exposures.

Units of sand-laminated siltstone facies are commonly 2-3m in thickness, but exceptional thicknesses of up to 20m may be developed. Apart from minor scours of the type shown in Plate 33, the thin alternating beds tend to be laterally extensive and sheetlike in geometry (Plates 30 and 31). Lateral intergradation with both bioturbated and rippled and laminated facies is common.

In the upper part of the Old Red Sandstone succession, the facies is generally a brighter 'reddish purple' compared with the dull purple-grey lower down. Coincident with this change, rare beds of concretionary carbonate nodules are developed similar to those shown in Plates 42 and 43.

No palaeocurrent data are recorded from this facies. Text Fig. 15 shows that in thickness the facies makes up between 27% and 60% of the sequence on the Atlantic Coast section.

Interpretation

The very fine grainsize and dominantly laminated nature of the sediments in this facies indicates low-energy deposition. The graded nature of coarser beds or laminae indicates vertical accretion by settling from suspension. Occasional horizons with polygonal dessication cracks reflect periodic subaerial exposure and drying out of moist sediments. Rare in-situ concretionary carbonates are interpreted as caliche horizons developed by soil-forming processes, in response to reduced sedimentation. Identification of associated facies as alluvial fan and channel or sheetflood deposits (sections 3.2 to 3.4) suggest deposition took place in the overall context of a fluvial plain setting.

The sheet geometry generally observed in this facies, together with an overall abundance of up to 60%, points to an environment with a broad uniform extent as well as reasonable preservation potential. In a fluvial plain setting such conditions are met on a sufficiently large scale by two different environments....

a) lacustrine

b) floodplain overbank deposition

The bulk of the evidence from mudcracks, rare concretionary cornstones, occasional minor erosional scours and the well oxidised nature of the sediment are entirely consistent with an overbank floodplain origin.

Criteria normally used to identify lacustrine deposits (Matter and Tucker, 1978; Picard and High, 1972) are absent. Fossil fish fragments are abraded and disarticulated suggesting energetic transport rather than mass mortality 'in-situ' due to shallowing or drying out of ephemeral lakes. No other diagnostic fossils are present. The sediments appear uniformly oxidised, and bedding laminations are not sufficiently fine or regular to suggest seasonal lacustrine processes. Matter and Tucker (1978) observed that wave ripples are common in lake sediments. The faint ripple structures which have been identified in this facies are all asymmetric. No characteristic evaporite minerals or mineral sequences are present, although thin or sediment-diluted evaporite horizons could easily be lost during diagenesis and absence is not proof that they never existed. Syneresis cracks, which in a continental alluvial floodplain setting would suggest lacustrine conditions, have not been observed. Finally, it is virtually impossible to identify a concentric arrangement of facies zones since good outcrop exposure is essentially limited to a narrow strip running along the coast.

To summarise, this rather enigmatic facies shows features which could be attributed to either of the two environments suggested. Positive evidence weighs in favour of a dominantly overbank floodplain mode of deposition, although accumulating some of the sediment in a standing body of water such as a pond or lake cannot be excluded as a possibility. Indeed, in a floodplain setting of the considerable extent suggested by the relative abundance of this facies, it is most likely that at least some shallow ephemeral lakes formed by ponding of floodwater.

The small-scale scour and fill structures observed probably represent ephemeral small drainage channels on the floodplain which formed after flood events and rapidly silted up again.

3.6 The Old Red Sandstone Succession - BIOTURBATED FACIES

This facies is defined as one in which textural mottling, usually accompanied by minor burrow traces, becomes the dominant internal structure (i.e. when less than fifty percent of the original sedimentary bedding remains intact) (PLATES 37 to 39). Original bedding remains only as 'ghost' traces, or is completely obliterated (Plate 37). Both sand-laminated siltstone facies and rippled and laminated facies may be detected through the textural mottling. The facies varies in grainsize from siltstone to silty sandstone. Facies units are up to 3m in thickness, and are seen to persist laterally over measured distances of at least 20m. The facies grades laterally into both sand-laminated siltstone and rippled and laminated facies. Upper and lower unit boundaries tend to be gradational.

Interpretation

The relict or ghost texture seen faintly through the intense textural mottling due to bioturbation, indicates that both the sand-laminated siltstone facies and rippled and laminated facies were locally subjected to severe biological reworking. Disruption of sediments due to intrasediment growth of salt crystals is known to occur in saline lakes (Hardie, Smoot and Eugster, 1978), but the way in which mottling follows irregular facies boundaries (Plate 38) and is coincident with increased abundance of burrow traces shows the influence in this case to be biological.

One can only speculate what must have been the control which dictated that bioturbation was kept in moderation for large portions of the finer grained facies, while other parts were very intensively reworked. Three possibilities are;

1. Some form of chemical gradient such as pH or high concentration of salts operated to discourage intense activity in certain parts.

2. Periodic low rates of sedimentation concentrated biological activity in certain horizons.
3. Localised ponding of floodwater provided extremely favourable environments for burrowing organisms in soft moist sediments adjacent to or below a standing body of water.

The first possibility would require a widespread distribution of saline conditions, since only twenty percent of the fine grained facies appears to have been strongly altered by burrowing. The second is reasonable, but there is no marked increase in bioturbated facies in the upper part of the succession where stronger oxidation reddening and local calcrete horizons suggest a general reduction in sedimentation rate. The third possibility, that where sediments locally remained moist for long periods biological activity was able to flourish, appears most probable. The true case is possibly a combination of more than one of these factors, with the availability of moisture as the main controlling influence.

3.7. The Old Red Sandstone succession - MASSIVE MUDSTONE FACIES

This facies typically consists of bright reddish purple massive mudstone (PLATES 40 to 42). It is restricted to the upper part of the succession and has only been observed in the sequences exposed along the Sneem River section. Its overall abundance, even for that section, is less than one percent.

The facies may be developed in units up to four metres in thickness. The base and top of units are typically planar and non-erosive. Pale green reduction spots are occasionally present (PLATE 41), and in rare cases a whole unit may change either vertically or laterally to become pale green. Rare horizons of pedogenic nodular carbonate are locally developed in the facies (PLATES 42 and 43).

Interpretation

The sediment is extremely fine-grained, varying between clay and very fine silt. There are no features such as intraclasts or a buried irregular surface to suggest a mudflow origin, and deposition is assumed to have occurred by settling from suspension. In a floodplain environment, which is indicated by associated facies, settling of fines probably occurred in areas of ponded floodwater where energy levels were at a minimum. The lack of bedding laminations could be due to complete biological reworking of the sediment, or simply a result of low grainsize contrast. Weathering occasionally produces slight 'benches' on outcrops, suggesting that some faint bedding may be present.

3.8. The Rossmore Sandstone Formation - GREY QUARTZITIC SANDSTONE FACIES

This facies consists of fine to medium-grained well-sorted sandstones occurring in units ranging between 20cms and several metres in thickness (PLATE 44). The sandstones are composed of clean-washed quartz sand, appearing pale grey on freshly broken surfaces and weathering to a distinctive white colour. Bedding may appear slightly flaggy due to the occasional presence of thin clay drapes lining the foresets. Internally, the units show parallel lamination, cross-bedding or appear massive. Ripple bedding may occur but is rare.

The sandstones show many features in common with the cross-bedding dominant variety of the sandstone body facies in the Old Red Sandstone succession (see SECTION 3.3). Most examples overlie a clearly erosive base, in some cases followed by a lag deposit containing material varying from limestone pisolites and pebbles of vein quartz, to rare fish fragments (PLATE 45). In one sandstone a branching piece of fossilised wood 30cm in length was found. The sandstones contain internal erosional surfaces, dividing the body into subunits approximately 20 - 30 cm thick, which may rarely be separated by thin lenticular grey siltstone beds (PLATE 46). Thin wisps and occasional small clasts of dark grey siltstone are sometimes found along the bedding planes in the sandstones, especially in the lower subunits. Some facies fine upwards slightly, and the tops of facies units tend to grade upwards into the overlying finer grained facies. Subunits within themselves show a better fining upwards tendency (PLATE 46) which is best developed in the finer grained examples.

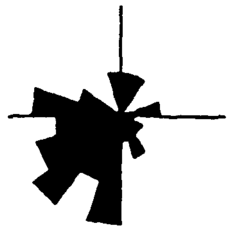
Subunits within facies units show similar lenticularity to the subunits in sandstone body facies of the Old Red Sandstone succession, while overall thickness of facies units appears to remain laterally fairly constant. Both trough and planar cross-stratification are developed. Set thicknesses average 15-20cm, although sets up to 1 metre thick have been noted (PLATE 44). The well-sorted and well-cemented nature of the sandstones renders identification of internal structures difficult on poorly weathered surfaces.

A peculiarity of this facies is rare development, usually in more massive parts, of irregular lens shaped patches (up to 1m in diameter) with a weathered and iron-stained decalcified appearance. Bedding can rarely be traced into the weathered lens, and except that it must originally have developed as a lens richer in carbonate cement than the surrounding rock, there is little compositional difference from the rest of the sandstone.

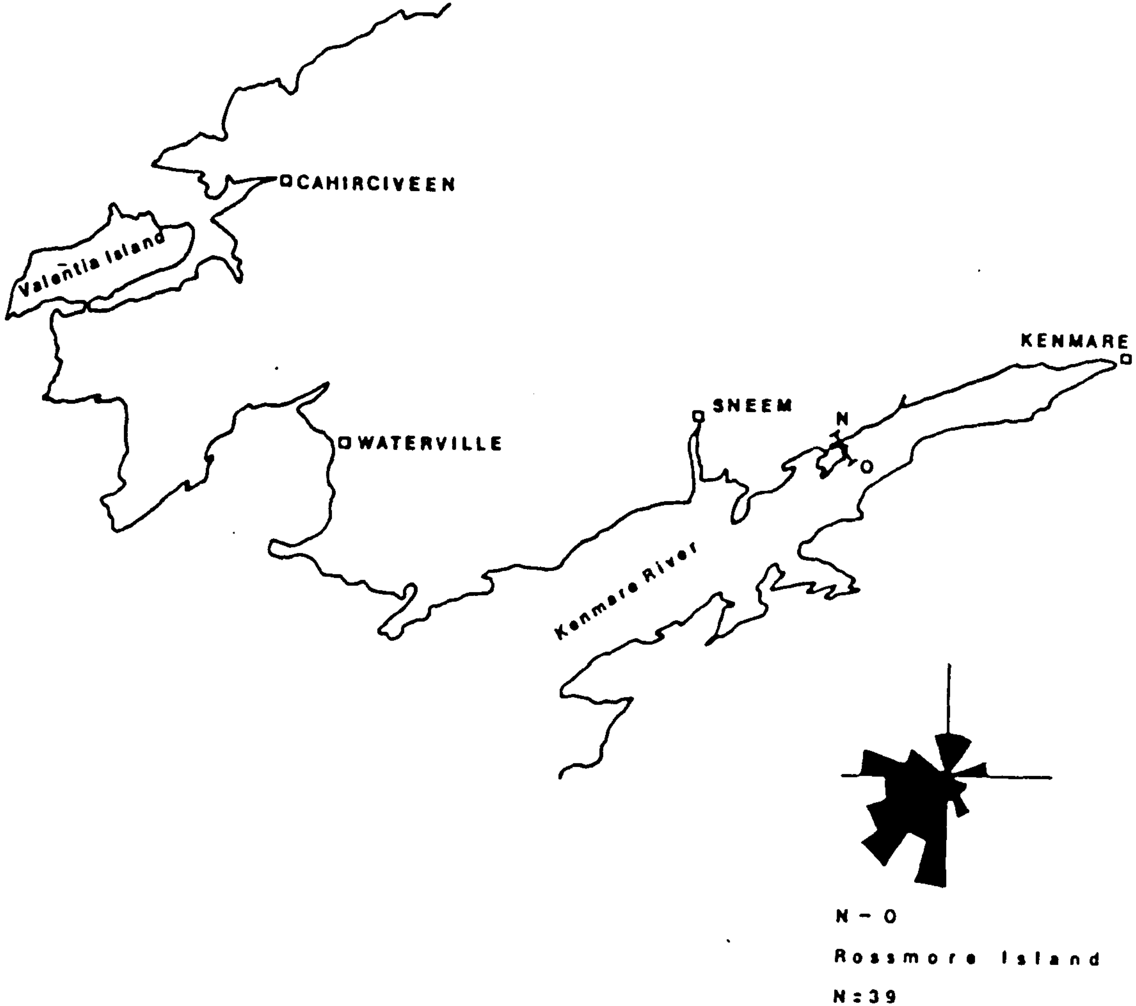
Palaeocurrent patterns from this facies show a fairly strong mode with currents coming from the north-east (Text. Fig. 20), although the spread of current directions is higher than for the sandstone body facies in the Old Red Sandstone succession.

<u>Interpretation</u>

The overall similarity between this facies and the cross-bedding dominant variety of the sandstone body facies in the Old Red Sandstone succession suggest that it may have had a similar channel-type origin. Unimodal palaeocurrents, scoured erosional surfaces overlain by cross-bedded lag deposits, and frequent occurrence of cross-bedding within the sandstone are most likely to represent high energy channel deposits, with cross-bedding forming



Total grouped foresets
N = 39



All diagrams show direction towards which current flowed, based on foresets unless otherwise specified.

0 5 Readings
Scale

PALAEOCURRENTS

Rossmore Sandstone Formation

TEXT FIG. 20

due to the migration of in-channel dune or bar type bedforms. Thin silty drapes suggest that flow strength was variable so that suspension deposition was occasionally able to prevail over that from bedload. The main features which distinguish it from the sandstone body facies are:

a) The lack of oxidised sediments, giving grey rather than purple colouration.

b) The composition, consisting of clean quartz sand in contrast to the sands of the sandstone body facies which contains appreciable amounts of clay/silt matrix.

c) The nature of the lag material. Grey silt clasts and pisolites are never found as lag material in the sandstone body facies.

d) Palaeocurrent patterns show a rather higher spread than those in the sandstone body facies.

e) Rare acritarchs are present in associated facies interbedded with the grey quartzitic sandstone facies (Higgs and Russell, 1981), confirming marine influence.

A mainly reducing environment with higher channel sinuosity is suggested by the lack of oxidised sediments and wider variation in palaeocurrent directions. Fine sediment was available since it occurs as wispy drapes on foresets and as thin interbeds, so the cleannesss of the channel sands must be due to a strong sorting process.

The pisolites (PLATE 54) show weak concentric lamination inferred due to an algal origin. Capewell (1957) interpreted the pisolites as representing deposition in delta-surface lagoons. However, all the pisolitic limestones observed consist of clearly reworked and transported material, often cross-bedded and overlying a scoured base, so therefore provide at most only indirect evidence of a pisolite-forming lagoonal environment somewhere in the channel catchment area at this time. An alternative possibility discussed in more detail in CHAPTER 4, is that the pisolites may have formed *in-situ* in a channel environment.

The same sequence in which this facies occurs is also exposed less than 8km to the south, on the Beara peninsula. There, similar facies overlies the Old Red Sandstone succession and is seen to pass up into shallow marine tidal sediments with thick heterolithic beds showing herring-bone cross-lamination, and thin lenses of crinoid and shell debris (Jones, 1974).

To summarise, the similarities with the sandstone body facies suggest a channel type origin. The change from reddish oxidised colour to greyish colours is interpreted as a combination of a higher water table and increased amounts of fine plant material resulting in dominantly reducing conditions. The change is believed due to a coast-marginal location where the low elevation resulted in more or less permanent water saturation, and vegetation was abundant compared to more arid and less hospitable inland areas. The spread of palaeocurrent directions suggests a greater channel sinuosity, which might reflect a change to a meandering or anastomosing distributary channel system (as defined by Rust, 1978; page 194). The difficulties of recognizing specific channel systems based on limited evidence (Friend, 1983) are acknowledged, and further refinement is not attempted. Interbedding with associated facies containing brackish marine indicators, and with lithologies suggestive of tidal-flat environments (see SECTION 3.10) suggests the grey quartzitic sandstone facies was at least partly influenced by tidal marine processes. Opposed cross-bed directions are observed in some cases (PLATE 44) but are not regarded as reliable proof of tidal current reversal. Thin clay drapes on foresets do suggest frequent alternation of high energy (bedload) and low energy (suspension) deposition which has been used as evidence of tidal origin (Allen 1981). The clean sorting of the sands supports the idea of winnowing and reworking of the sediment by tidal currents. The facies is thus interpreted as the result of in-channel deposition in the lower reaches of a coastal fluvial distributary system, where tidal influences extended some distance into the seaward end of the system.

3.9. The Rossmore Sandstone Formation - GREY SILTSTONE FACIES

This facies consists dominantly of pale grey silt-grade sediment, and never exceeds very-fine sandstone in grainsize. Bedding is a mixture of lamination and ripple-bedding but is typically faint and difficult to see due to a combination of low grainsize contrast and poor separation by sorting (PLATES 47 and 48). Poorly weathered or broken surfaces generally appear massive, but on smooth wave-polished or well-weathered surfaces (PLATE 48) one can pick out bedding more easily. Burrowing or bioturbation is not apparent. The facies may develop a slight flagginess in places due to improved grainsize separation. Where this tendency is very well developed the facies may pass gradationally into heterolithic facies (SECTION 3.11). The geometry within outcrop exposures is sheetlike.

Interpretation

The fine-grained nature of the facies, and its association with heterolithic facies containing acritarchs, suggest deposition in a low energy semi-marine setting. It occurs commonly in vertical sequence with fluvial distributary sandstones downcutting into it, and occasionally passes gradationally either laterally or vertically into heterolithic facies. There is no direct evidence such as dessication cracks to demonstrate subaerial exposure. It is suggested that the facies may represent low-energy inter-channel areas in which deposition took place mainly from suspension. The association with heterolithic facies suggests that this facies was a lateral equivalent, deposited in areas where wave or tidal processes were insufficiently strong to cause sharp segregation of sand and silt. Clifton (1983) describes mesotidal estuarine sediments from Willapa Bay, in which supratidal and upper intertidal flats are dominated by muddy sediments. Well-sorted fine sands become interbedded in the low intertidal flats and increase in a seawards direction. He notes difficulty in recognizing mud-cracks in these deposits, and states that bioturbation is inhibited in supratidal flats due to variable water saturation, and also in upper intertidal flats due to anoxic conditions caused by decomposing algal material.

The grey siltstone facies lacks diagnostic features, and interpretation must be based largely on inference from the associated facies. In view of the semi-marine context, and similarity to features described by Clifton (Ibid), a supra- or intertidal setting for this facies seems reasonable.

3.10 Rossmore Sandstone Formation - SAND-LENSED GREY SILTSTONE FACIES

This facies consists of grey siltstone alternating with thin (1-15cms) beds of clean well-sorted fine sandstone (Plate 49). The siltstone may be massive, laminated or rippled and typically occurs as subordinate very thin interbeds separating the sandstone beds. The sandstone beds have abrupt upper and lower contacts with the siltstones. The former rarely show faint traces of lamination or ripple-bedding, but more often appear massive due to good sorting. The beds tend to be strongly lenticular, sometimes over distances of less than 2m. Where lenticularity is well developed, the sandstone beds commonly show 'pinch and swell' structure (Plate 50). Facies units are up to 5m thick, and may contain occasional thicker (0.5m) sandstone beds which are cross-bedded or massive and are laterally persistent over distances from 10m to over 20m. Facies units may pass gradationally (laterally or vertically) into either heterolithic or grey siltstone facies by gradational change in grainsize separation and/or bed thickness. No direct evidence of subaerial exposure has been observed in the facies.

Interpretation

Ripple-bedding is not very distinct, and it has not been possible to gain an impression of whether the bedding is current or wave dominated in origin. The facies shows similarities in the scale, grainsize and general geometry of bedding to the lenticular and flaser style of bedding described from intertidal flats (Reineck and Singh, 1973) and classed as sand-dominated heterolithic facies (Johnson, 1978). Similar facies (interpreted as wave-dominated shallow marine) are described by de Raaf et al (1977). It is recognized that the heterolithic style of bedding is not solely restricted to shallow marine environments. However, the presence of brackish marine indicators in associated facies, along with the textural maturity of the sands and considerable facies thicknesses developed, strongly bias interpretation in this case towards a shallow marine environment. The lack of detail in internal structures prevents an attempt to identify whether wave or tidal processes were the major influence. An overall context of increasing marine influence is supported by the knowledge that the Old Red Sandstone sequence on the Beara peninsula, less than 5 km to the south, is overlain by a similar sequence of facies which pass up into undoubted marine shales containing marine fauna and bioclastic limstones (Jones, 1974; Russell, 1976).

3.11 Rossmore Sandstone Formation - HETEROLITHIC FACIES

This facies consists of very thinly interbedded sandstone and mudstone, with sharp separation between the two grainsizes (PLATES 51-53). Although both this and the sand-lensed siltstone facies might both properly be termed heterolithic, the thickness of the sandstone beds in the latter are in many cases above the normal limits of usage (10 cms) for this term. It was felt more appropriate to restrict the name heterolithic to other facies described here, in which bed thickness is typically less than 5 cms, and frequently less than 1 cm. There is a complete range of heterolithic types between sand-dominant (PLATE 51) and mud-dominant (PLATE 52). Units of this facies tend to vary between the two extremes, on a scale of tens of centimetres.

The facies is developed only in the uppermost part of the Rossmore Sandstone Formation exposed to the east of Sneem, and even within this occurrences are rare and usually do not exceed 2m in thickness. An exceptional thickness of 10m is seen exposed on the south side of Rossmore Island, which is at the top of the local succession. Evidence of bioturbation is seen in the form of small burrow traces, oriented vertically, horizontally and obliquely in relation to bedding. Burrowing is best seen in cases where the sand/mud ratio is approximately 50:50, when it is picked out by the contrast in grainsizes (PLATES 52 and 53).

Palynological analysis of a sample from this facies established that it contained acritarchs in addition to a rich assemblage of plant spores.

The facies is composed of a mixture of lenticular, flaser and linsen bedded heterolithics. Thinly interlaminated sandstone and mudstone is the dominant type, with sandstone laminae occasionally thickening and becoming faintly ripple-bedded (PLATE 53). 'Pin-stripe' sandstone lamination is also common (PLATE 52). Internal structure in ripple bedding is rarely distinct except on cut slabs or wave-polished outcrops. Although opposed ripple cross-lamination directions were observed in close proximity, no examples of herringbone cross-lamination have been identified. Some small-scale loading of the sandstone laminae, as well as disturbed bedding, has been observed on polished slabs (PLATE 53).

Interpretation

The alternation between sandstone and mudstone separated by sharp grainsize changes, points to fluctuating energy levels and alternation between bedload and suspension deposition. The facies is similar to that described from tidal and shallow marine environments (Reineck and Singh, 1973). Although heterolithic bedding is known to form in non-tidal environments, the presence of acritarchs in this case demonstrates a marine influence, and associated facies are consistent with a shallow marine origin. Comparing the features with the mesotidal estuarine sediments described by Clifton (1983), where the grey siltstone facies

(SECTION 3.9) corresponds to the muddy supra- or upper intertidal flats, the heterolithic facies corresponds to the higher energy in the lower intertidal flats.

3.12 Sedimentological Model

The sedimentary facies, considered individually, indicate a variety of settings ranging from alluvial fan to marginal marine. This section attempts to provide a sedimentological model which explains the pattern of facies variation, and is consistent with other evidence such as rates of sediment accumulation, sequence and relative abundance of facies, regional geology and structural setting.

Regional and Structural Constraints

The regional geology shows deposition to have taken place close to the fault-controlled northern margin of the extensive half-graben feature known as the Munster Basin. Palaeocurrent evidence shows sediment to have been transported mainly from the NNW. Conglomerates of alluvial fan facies are restricted to the northern margin of the area, and are shown (CHAPTER 6) to be laterally equivalent to sheet-flood sandstones and fine-grained playa-type sediments further to the south. The vertical sequence of sediments shows a general coarsening upwards trend, a pattern typical of infilling basins where coarser proximal facies progressively extend further into the basin as subsidence fails to keep pace with sediment input. Subsidiary small-scale coarsening-up cycles such as those described by Steel et al.(1977) have not been observed. This may suggest that subsidence controlling basin development was gradual rather than intermittent, although alternatively the location may not have been sufficiently close to the marginal fault for such cycles to be readily apparent.

Rate of sediment accumulation

Facies units show generally high rates of sediment deposition. Units of climbing-rippled siltstones and sandstones up to 50cm thick are common, representing single depositional events. Taking the redbed sediments alone, a minimum thickness of 3755m accumulated during the late Devonian; at most this represents a period of 15 million years. This gives a safe estimate of at least 0.25 mm/year. This compares fairly closely with rates of sediment accumulation quoted in Friend (1978) for a number of fluvial sequences from Norway, Greenland, Spain and Pakistan. An average of forty-five percent of the sequence is siltstone or finer, and some allowance must be made for compaction in order to make some comparison with Recent rates of sediment accumulation. Studies on buried alluvial sediments by Meade (1968), (cited in Engelhardt, 1977, p. 273), suggest a volume reduction of the order of 15%. Allowing for this, the estimated sedimentation rate is increased to 0.27 mm/year. Wolman and Leopold (1957) postulated an expected rate for floodplain accumulation of about 1.5 mm/year. Schumm and Lichty (1963) give a rate of 5.2 cm/year for the Cimarron River floodplain. Alexander and Prior (1971) looked at overbank deposition rates for a Recent example using carbon-dating techniques and found that over a 1000 year period rates ranged between 0.6 and 10 mm/year. Preservation potential in a subsiding basin is high, but even if some loss of section due to erosion or non-deposition is allowed for, the Old Red Sandstone alluvium could conceivably have accumulated as it is today by 'overbank' deposition alone. Pedogenic nodular carbonates developed in the upper part of the Old Red Sandstone succession indicate probable slowing of sedimentation towards the end of the basin's history. Modern calcretes develop in semi-arid climates, in alluvial settings where periods between flooding are long enough to allow a concretionary horizon to form. Most examples from the study area consist of sparsely scattered nodules which may have formed over inactive periods of only several hundreds of years (Allen, 1974), but at least one mature horizon is developed which may have taken several thousands of years (Ibid.) to form. The brighter purple colour of the upper part of the succession may also possibly be a reflection of slower deposition rates, allowing longer exposure of sediment for oxidation before burial.

Facies sequence and abundance

Sandstone body facies forms a relatively small proportion of the total sediment volume, and the features do not generally suggest a permanent incised channel system. Palaeocurrent patterns from both cross-bedded sandstone units and rippled finer-grained facies show the same transport direction, and where the former are partly plane-bedded there is a tendency to share the same broad sheetlike geometry.

Markov analysis was carried out on the Atlantic Coast section (Text Fig. 3) to test for sequential facies patterns (Text Figs. 21-24). Two points must be noted in interpreting the results; firstly that the technique used to measure Chi-square becomes inaccurate where a particular transition type is observed less than six times (Agterberg, cited in Miall, 1973), and secondly that a significant facies relationship can be 'swamped' when seen against a background of other relatively more abundant facies. The data analysed include only one example of either conglomerate or massive mudstone facies, so the transition matrices can in practice be treated as (4 x 4) rather than (6 x 6). This significantly reduces the degrees of freedom from 24 to 8. The Valentia Slate, St. Finan's Sandstone and Ballinskelligs Sandstone Formations all show a tendency for the sequence shown below:-

SANDSTONE BODY ---> SAND-LAMINATED SILTSTONE <--- ---> RIPPLED AND LAMINATED

A variation on this motif is the addition of bioturbated facies following after sandstone body facies, and being followed in turn by either the sand-laminated siltstone or rippled and laminated facies. All the formations have greater than 90% probability that the sequences are non-random, and in two cases the probability is better than 99.9%. Essentially the sequence shows a fining-upwards tendency, with both the coarser facies (sandstone body and rippled and laminated) tending to be followed by the finer sand-laminated siltstone facies. Repeated cycling between the latter and rippled and laminated facies supports the interpretation that both are

VALENTIA SLATE FORMATION

** List of facies frequencies **

(1) Conglomerate.................	0
(2) Sandstone body...............	10
(3) Rippled and laminated........	105
(4) Sand laminated siltstone.....	111
(5) Bioturbated..................	34
(6) Massive mudstone.............	0

** Transition count matrix **

	To (1)	(2)	(3)	(4)	(5)	(6)
From (1)	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
(2)	0	0	1	7	2	0
(3)	0	0	0	91	14	0
(4)	0	0	83	0	19	0
(5)	0	0	11	23	0	0
(6)	0	0	0	0	0	0

** Transition probability matrix **

	To (1)	(2)	(3)	(4)	(5)	(6)
From (1)	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
(2)	0.00000	0.00000	0.10000	0.70000	0.20000	0.00000
(3)	0.00000	0.00000	0.00000	0.86667	0.13333	0.00000
(4)	0.00000	0.08108	0.74775	0.00000	0.17117	0.00000
(5)	0.00000	0.00000	0.32353	0.67647	0.00000	0.00000
(6)	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

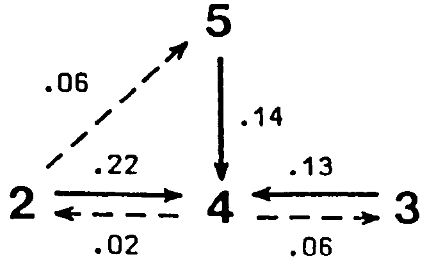
** Independent trials matrix **

	To (1)	(2)	(3)	(4)	(5)	(6)
From (1)	0.00000	0.03462	0.36538	0.46538	0.13462	0.00000
(2)	0.00000	0.00000	0.37849	0.48207	0.13944	0.00000
(3)	0.00000	0.05455	0.00000	0.73333	0.21212	0.00000
(4)	0.00000	0.06475	0.68345	0.00000	0.25180	0.00000
(5)	0.00000	0.04000	0.42222	0.53778	0.00000	0.00000
(6)	0.00000	0.03462	0.36538	0.46538	0.13462	0.00000

** Difference matrix **

	To (1)	(2)	(3)	(4)	(5)	(6)
From (1)	0.00000	-0.03462	-0.36538	-0.46538	-0.13462	0.00000
(2)	0.00000	0.00000	-0.27849	0.21793	0.06056	0.00000
(3)	0.00000	-0.05455	0.00000	0.13333	-0.07879	0.00000
(4)	0.00000	0.01633	0.06429	0.00000	-0.08063	0.00000
(5)	0.00000	-0.04000	-0.09869	0.13869	0.00000	0.00000
(6)	0.00000	-0.03462	-0.36538	-0.46538	-0.13462	0.00000

Value of chi-square = 21.99760 by the method of Billingsley (1961).



Transition pattern based on the difference matrix positive values, ignoring transitions which occur less than six times.

TEXT FIG. 21

ST. FINAN'S SANDSTONE FORMATION

** List of facies frequencies **

(1)	Conglomerate	1
(2)	Sandstone body	120
(3)	Rippled and laminated	282
(4)	Sand laminated siltstone	314
(5)	Bioturbated	107
(6)	Massive mudstone	0

** Transition count matrix **

	To (1)	(2)	(3)	(4)	(5)	(6)
From (1)	0	0	1	0	0	0
(2)	0	0	44	69	7	0
(3)	0	37	0	198	47	0
(4)	1	66	193	0	54	0
(5)	0	16	42	49	0	0
(6)	0	0	0	0	0	0

** Transition probability matrix **

	To (1)	(2)	(3)	(4)	(5)	(6)
From (1)	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000
(2)	0.00000	0.00000	0.36667	0.57500	0.05833	0.00000
(3)	0.00000	0.13121	0.00000	0.70213	0.16667	0.00000
(4)	0.00318	0.21019	0.61465	0.00000	0.17197	0.00000
(5)	0.00000	0.14953	0.39252	0.45794	0.00000	0.00000
(6)	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

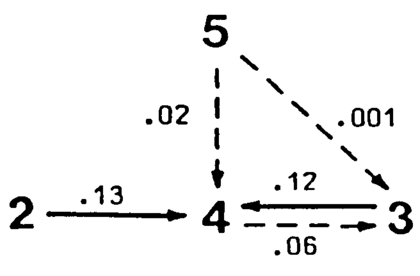
** Independent trials matrix **

	To (1)	(2)	(3)	(4)	(5)	(6)
From (1)	0.00000	0.14459	0.34022	0.38396	0.13123	0.00000
(2)	0.00142	0.00000	0.39716	0.44823	0.15319	0.00000
(3)	0.00184	0.21875	0.00000	0.58088	0.19853	0.00000
(4)	0.00197	0.23425	0.55118	0.00000	0.21260	0.00000
(5)	0.00140	0.16620	0.39106	0.44134	0.00000	0.00000
(6)	0.00121	0.14442	0.33981	0.38350	0.13107	0.00000

** Difference matrix **

	To (1)	(2)	(3)	(4)	(5)	(6)
From (1)	0.00000	-0.14459	0.65978	-0.38396	-0.13123	0.00000
(2)	-0.00142	0.00000	-0.03050	0.12677	-0.09486	0.00000
(3)	-0.00184	-0.08754	0.00000	0.12125	-0.03186	0.00000
(4)	0.00122	-0.02406	0.06347	0.00000	-0.04062	0.00000
(5)	-0.00140	-0.01667	0.00146	0.01660	0.00000	0.00000
(6)	-0.00121	-0.14442	-0.33981	-0.38350	-0.13107	0.00000

Value of chi-square = 38.85861 by the method of Billingsley (1961).



Transition pattern based on the difference matrix positive values, ignoring transitions which occur less than six times.

TEXT FIG. 22

BALLINSKELLIGS SANDSTONE FORMATION

** List of facies frequencies **

(1) Conglomerate................. 0
(2) Sandstone body............... 67
(3) Rippled and laminated........106
(4) Sand laminated siltstone.....113
(5) Bioturbated.................. 54
(6) Massive mudstone............. 0

** Transition count matrix **

	To (1)	(2)	(3)	(4)	(5)	(6)
From (1)	0	0	0	0	0	0
(2)	0	0	30	33	4	0
(3)	0	26	0	57	23	0
(4)	0	34	52	0	27	0
(5)	0	7	27	20	0	0
(6)	0	0	0	0	0	0

** Transition probability matrix **

	To (1)	(2)	(3)	(4)	(5)	(6)
From (1)	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
(2)	0.00000	0.00000	0.44776	0.49254	0.05970	0.00000
(3)	0.00000	0.24528	0.00000	0.53774	0.21698	0.00000
(4)	0.00000	0.30088	0.46018	0.00000	0.23894	0.00000
(5)	0.00000	0.12963	0.50000	0.37037	0.00000	0.00000
(6)	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

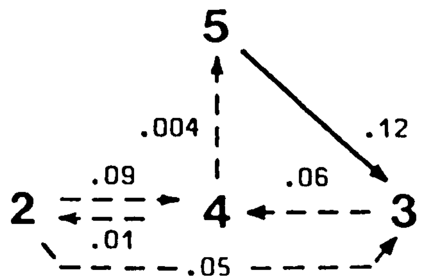
** Independent trials matrix **

	To (1)	(2)	(3)	(4)	(5)	(6)
From (1)	0.00000	0.19706	0.32059	0.32353	0.15882	0.00000
(2)	0.00000	0.00000	0.39927	0.40293	0.19780	0.00000
(3)	0.00000	0.29004	0.00000	0.47619	0.23377	0.00000
(4)	0.00000	0.29130	0.47391	0.00000	0.23478	0.00000
(5)	0.00000	0.23427	0.38112	0.38462	0.00000	0.00000
(6)	0.00000	0.19706	0.32059	0.32353	0.15882	0.00000

** Difference matrix **

	To (1)	(2)	(3)	(4)	(5)	(6)
From (1)	0.00000	-0.19706	-0.32059	-0.32353	-0.15882	0.00000
(2)	0.00000	0.00000	0.04849	0.08961	-0.13810	0.00000
(3)	0.00000	-0.04476	0.00000	0.06155	-0.01679	0.00000
(4)	0.00000	0.00958	-0.01374	0.00000	0.00416	0.00000
(5)	0.00000	-0.10464	0.11888	-0.01425	0.00000	0.00000
(6)	0.00000	-0.19706	-0.32059	-0.32353	-0.15882	0.00000

Value of chi-square = 14.53652 by the method of Billingsley (1961).



Transition pattern based on the difference matrix positive values, ignoring transitions which occur less than six times.

TEXT FIG. 23

ATLANTIC COAST SECTION

** List of facies frequencies **

(1) Conglomerate................. 1
(2) Sandstone body..............197
(3) Rippled and laminated........493
(4) Sand laminated siltstone.....538
(5) Bioturbated.................195
(6) Massive mudstone............ 0

** Transition count matrix **

	To (1)	(2)	(3)	(4)	(5)	(6)
From (1)	0	0	1	0	0	0
(2)	0	0	75	109	13	0
(3)	0	63	0	346	84	0
(4)	1	109	328	0	100	0
(5)	0	23	80	92	0	0
(6)	0	0	0	0	0	0

** Transition probability matrix **

	To (1)	(2)	(3)	(4)	(5)	(6)
From (1)	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000
(2)	0.00000	0.00000	0.38071	0.55330	0.06599	0.00000
(3)	0.00000	0.12779	0.00000	0.70183	0.17039	0.00000
(4)	0.00186	0.20260	0.60967	0.00000	0.18587	0.00000
(5)	0.00000	0.11795	0.41026	0.47179	0.00000	0.00000
(6)	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

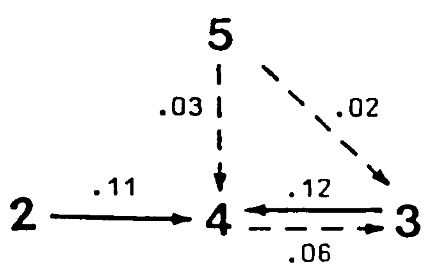
** Independent trials matrix **

	To (1)	(2)	(3)	(4)	(5)	(6)
From (1)	0.00000	0.13703	0.34013	0.38440	0.13844	0.00000
(2)	0.00081	0.00000	0.39382	0.44508	0.16029	0.00000
(3)	0.00106	0.20745	0.00000	0.58191	0.20957	0.00000
(4)	0.00114	0.22235	0.55188	0.00000	0.22463	0.00000
(5)	0.00081	0.15892	0.39446	0.44580	0.00000	0.00000
(6)	0.00070	0.13694	0.33989	0.38413	0.13834	0.00000

** Difference matrix **

	To (1)	(2)	(3)	(4)	(5)	(6)
From (1)	0.00000	-0.13703	0.65987	-0.38440	-0.13844	0.00000
(2)	-0.00081	0.00000	-0.01311	0.10822	-0.09430	0.00000
(3)	-0.00106	-0.07966	0.00000	0.11991	-0.03919	0.00000
(4)	0.00072	-0.01975	0.05778	0.00000	-0.03876	0.00000
(5)	-0.00081	-0.04098	0.01580	0.02599	0.00000	0.00000
(6)	-0.00070	-0.13694	-0.33989	-0.38413	-0.13834	0.00000

Value of chi-square = 60.37583 by the method of Billingsley (1961).



Transition pattern based on the difference matrix positive values, ignoring transitions which occur less than six times.

TEXT FIG. 24

closely associated with the intermittent flooding on an alluvial flood-plain. Beyond demonstrating that the sequence is statistically non-random, the Markov analysis adds little to the interpretations previously arrived at by individual study of the sedimentary facies.

Attempting to synthesise all of the evidence presented above and in the previous sections, the picture that emerges is one of a rapidly subsiding and infilling basin near the margin of the Old Red Sandstone supercontinent. Direct analogies with present-day environments based on the principle of uniformity have to be used with caution. Physical principles taken by themselves remain valid, for example the relation of bedforms to hydrodynamic conditions will remain constant with time. Present-day rates of sediment supply are anomalously high due to the abundance of postglacial material available for reworking, which would lead to overestimates of sedimentation rates in using Recent models to quantify non-postglacial ancient deposits. This is balanced to an unknown extent by lack of extensive vegetation cover, allowing free removal of erodible material, although again there would be a lack of humic acids to promote rapid chemical weathering of the bedrock. The sheer scale of the Old Red Sandstone continent as an unvegetated landmass is unknown today, and may have significantly affected climatic extremes with resulting unusual patterns of evaporation and precipitation, air circulation and so on. Despite these uncertainties, several areas of present or Recent sedimentation show sufficient similarities to the facies described from the study area, to propose a possible model (Text Fig. 25).

The Model

The apparent lack of a permanent incised channel system and the overwhelming predominance of sheetflood sandstones and siltstones immediately excludes the more commonly occurring fluvial models such as those outlined in Allen (1965). During the past five years, increasing recognition has been given to the depositional processes associated with extensive non-channelised sheetflows, resulting from highly episodic rainfall. Unfortunately there is still a general scarcity of published work dealing with this type of sedimentary environment. Friend (1978) cites a number of ancient fluvial sequences from Spitsbergen, Greenland and the Ebro basin which show a similar lack of channel incision, and in which channel sandstones 'thin-out' into apparently sheetflood dominated fine-grained sediments in a downstream direction. He proposed a 'terminal-fan' model to explain these features, based on Quaternary examples from the Indo-Gangetic Plain and the Biskra region of the Sahara. It is suggested that a 'terminal-fan' model may also be successfully applied to the red-bed sequence on Iveragh.

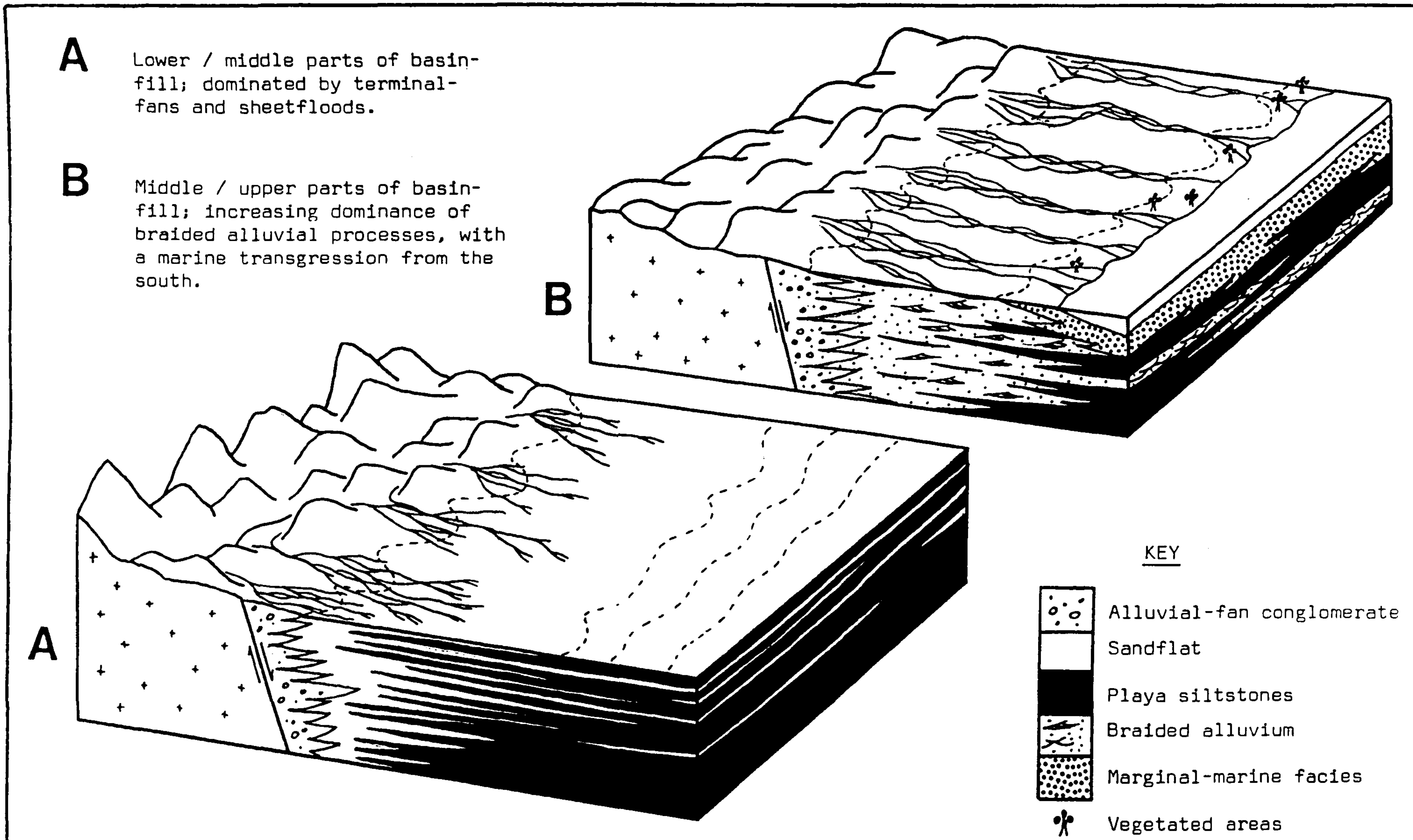
Lake Eyre in central Australia (Bonython, 1955, 1963; Williams, 1971) is a large example of this 'terminal-fan' style of sedimentation. The lake is the centre of a huge (1.5×10^6 km^2) arid-zone basin of internal drainage. Low-lying areas towards the central part of the basin consist of silt and clay dominated 'distal floodflats' (Williams, 1971, p.2) as well as the ephemeral Lake Eyre itself. Many of the rivers feeding into the basin diverge into distributaries merging with the margins of the floodflats.

Williams (1970) describes sedimentation on an arid piedmont alluvial plain 30-40km wide in the Biskra region of the northern Sahara. Coalescing alluvial fans extend out on to an extensive alluvial floodplain consisting of silts and fine sands deposited by periodic extensive flooding. Distal fan deposits are sheetlike clayey silts and fine sands, and proximal to distal fan profiles (Ibid., figs. 3 and 4) show similarities to proximal/distal trends in the area studied for this thesis.

Mukerji (1976) and Parkash et al (1983) describe terminal fans from the semi-arid Sutlej-Yamuna Plain in northern India. The fans are formed on low relief floodplain areas in response to loss of stream power, due to a combination of low gradient and down-channel water-loss by evaporation and absorption. Streams branch to form a terminal distributary system. Discharge is highly seasonal and flow is restricted to the primary channels during most of the year. During the wet season, deposition of large volumes of silt takes place by sheet-flooding. Mukerji noted that stream channels tend to be straight and stable due to the cohesive nature of the fine-grained bank material, and channel depths are shallow (0.5-1.5m). He also noted that fan shapes are irregular, tending to be strongly elongate in the direction of overall transport and starting to expand only at some distance from the fan apex. The sedimentary facies described by Parkash et al from the Markanda fan are virtually identical to those described from the Old Red Sandstones on Iveragh. Their 'Trough cross-bedded sand', 'Planar cross-bedded sand', 'Horizontal bedded sand', and 'Scour-fill sand' correspond directly to sub-units of the sandstone body facies. The

'Horizontally laminated silt', 'Laminated sand, silt and mud', and 'Flaser-bedded sand' correspond to the sand-laminated siltstone facies. The 'Ripple cross-laminated sand' corresponds to the rippled and laminated facies, and the 'Mud or silty mud' may correspond to the massive mudstone facies.

The model shown in Text Fig. 25 illustrates predominantly terminal-fan processes during the lower and middle parts of the Iveragh succession, with a change to braided-channel style deposition and marginal marine distributaries in the upper part as the basin became filled. To date, no evidence suggests that a saline playa-lake existed in the centre of the basin. Since the southern margin of the basin is not exposed, there is a possibility that it may have existed further to the south. The asymmetric geometry of the basin shows however that deposition and subsidence were greatest near the northern margin, so it is most probable that any lake would have formed there. A more likely explanation is that low carbonate content in the source sediments coupled with a high rate of sediment influx resulted in 'dilution' of any evaporite minerals which formed, and that subsequent diagenetic solution has largely removed anything which remained.


A
Lower / middle parts of basin-fill; dominated by terminal-fans and sheetfloods.
B
Middle / upper parts of basin-fill; increasing dominance of braided alluvial processes, with a marine transgression from the south.
B
A
KEY
Alluvial-fan conglomerate
Sandflat
Playa siltstones
Braided alluvium
Marginal-marine facies
Vegetated areas

TEXT FIG. 25

CHAPTER 4

PALAEONTOLOGY

Previous workers who have looked at the Iveragh succession have commented on the scarcity of fossils. Indeed, the resulting overdependence on lithostratigraphy for correlation in an area of rapid lateral and vertical facies change has inevitably led to frequent differences of opinion.

The early work by officers of the Geological Survey (Jukes et al, 1861) led to a few discoveries of 'fucoidal impressions' and crawling trails, and rare fragmentary plant remains. Capewell (1957) recorded algal pisolites and plant fragments from the uppermost part of the succession, in the Rossmore Sandstone Formation (for stratigraphic terminology see CHAPTER 6). Walsh (1968) noted the occurrence of plant fragments in the Old Red Sandstone succession at Moll's Gap quarry, at the eastern end of the Iveragh peninsula. Unfortunately none of these discoveries proved to have any stratigraphic significance.

In spite of this rather pessimistic background, detailed investigation of the area for this thesis has shown the succession to contain stratigraphically significant plant miospores and fossil fish material. These, together with occurrences of plant material, algal pisolites and trace fossils of different types, are described in the sections which follow.

4.1 Plant macrofossils

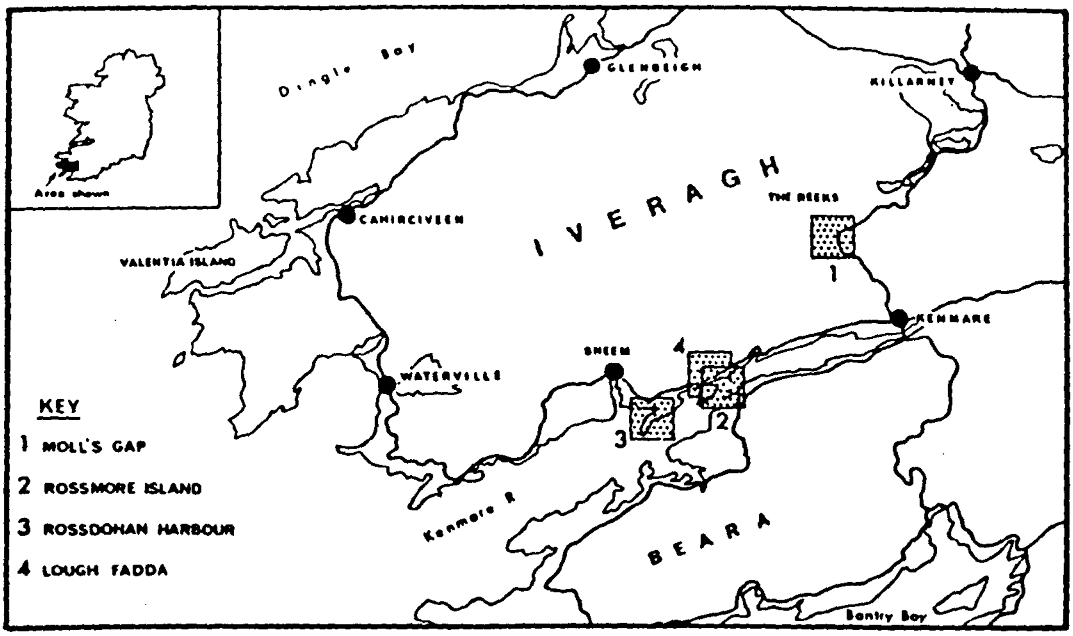
Within the Old Red Sandstone part of the succession, plant macrofossils are extremely rare. Jukes et al (1861) recorded plant stems with irregular rib patterns, from the western shore of Coomasaharn lake on the northern side of the peninsula. Smith (referenced in Walsh, 1968) collected fragmentary plant material from the Moll's Gap quarry. The material was suggested to resemble *Archaeopteris hibernica*, although this identification has never been substantiated. The Moll's Gap quarry was revisited for palynological sampling (Higgs and Russell, 1981) and found to contain locally abundant fragmented plant material, mostly consisting of small pieces of flattened plant stems with a slight longitudinal ribbed pattern. The material is too poorly preserved to allow proper identification.

Apart from the two cases noted above, the remainder of the Old Red Sandstone part of the succession has essentially failed to yield any further plant material, despite detailed examination of the continuous and extremely well exposed coastal sections.

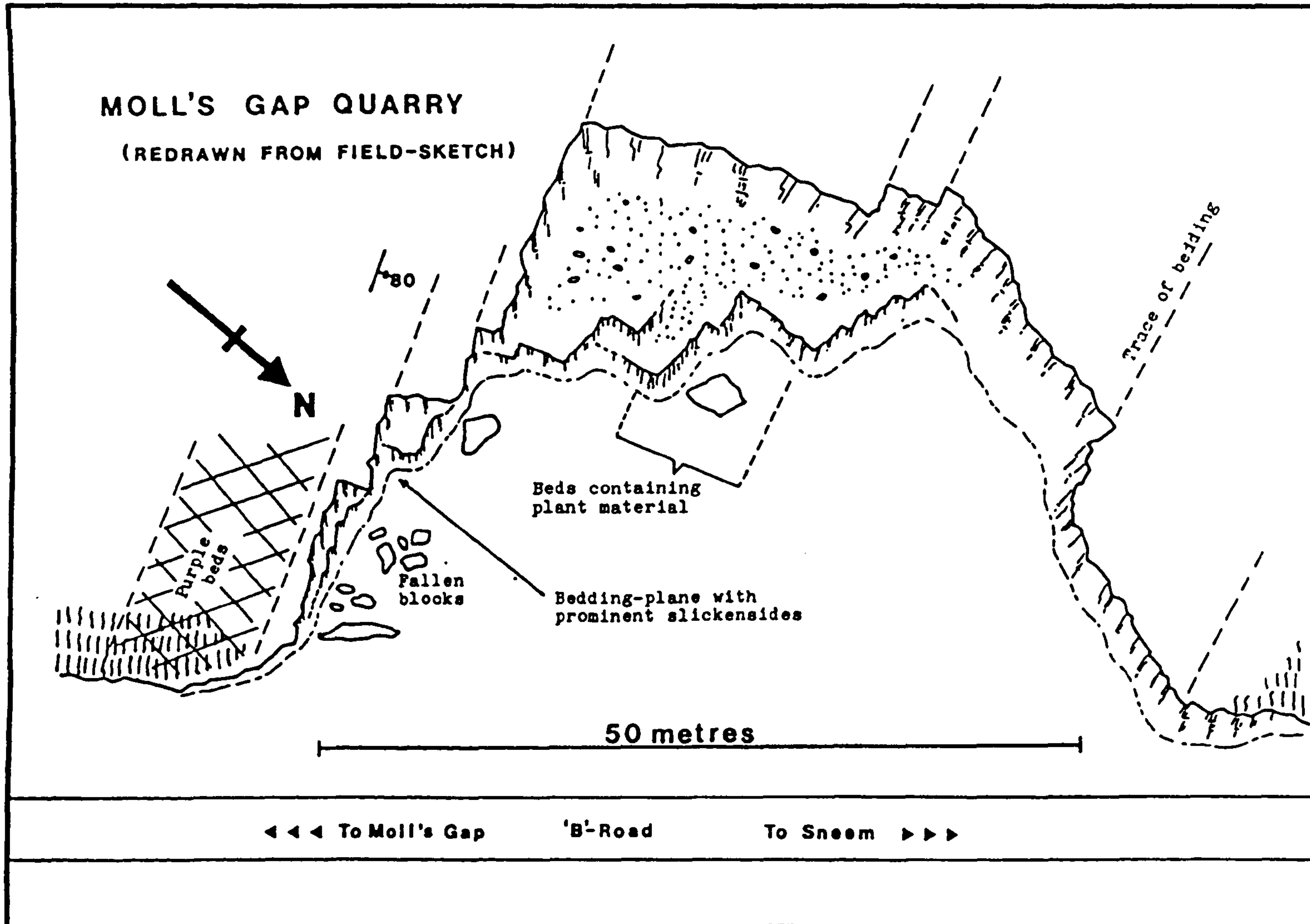
In contrast to this, the Rossmore Sandstone Formation at the top of the Iveragh succession occasionally contains fragmentary plant material, which may also occur exceptionally in 'red-beds' up to several tens of metres below the base of the formation. The Rossmore Sandstone Formation consists of dark grey siltstones and pale grey sandstones. The most abundant concentration of plant material occurs in a greenish grey siltstone overlying a conspicuous pisolitic lag on the shore of Rossdohan Harbour (V 717 637). At a separate location on the coast just east from the mouth of the Tahilla river, a branching plant stem over 30cm in length (PLATE 77) was collected from a sandstone overlying another pisolitic lag. The stem is preserved as a carbonaceous film lining the mould, and still bears the faint impression of a ribbed or slightly reticulate pattern. None of the plant material from the Rossmore Sandstone Formation has proved identifiable.

4.2 Plant miospores

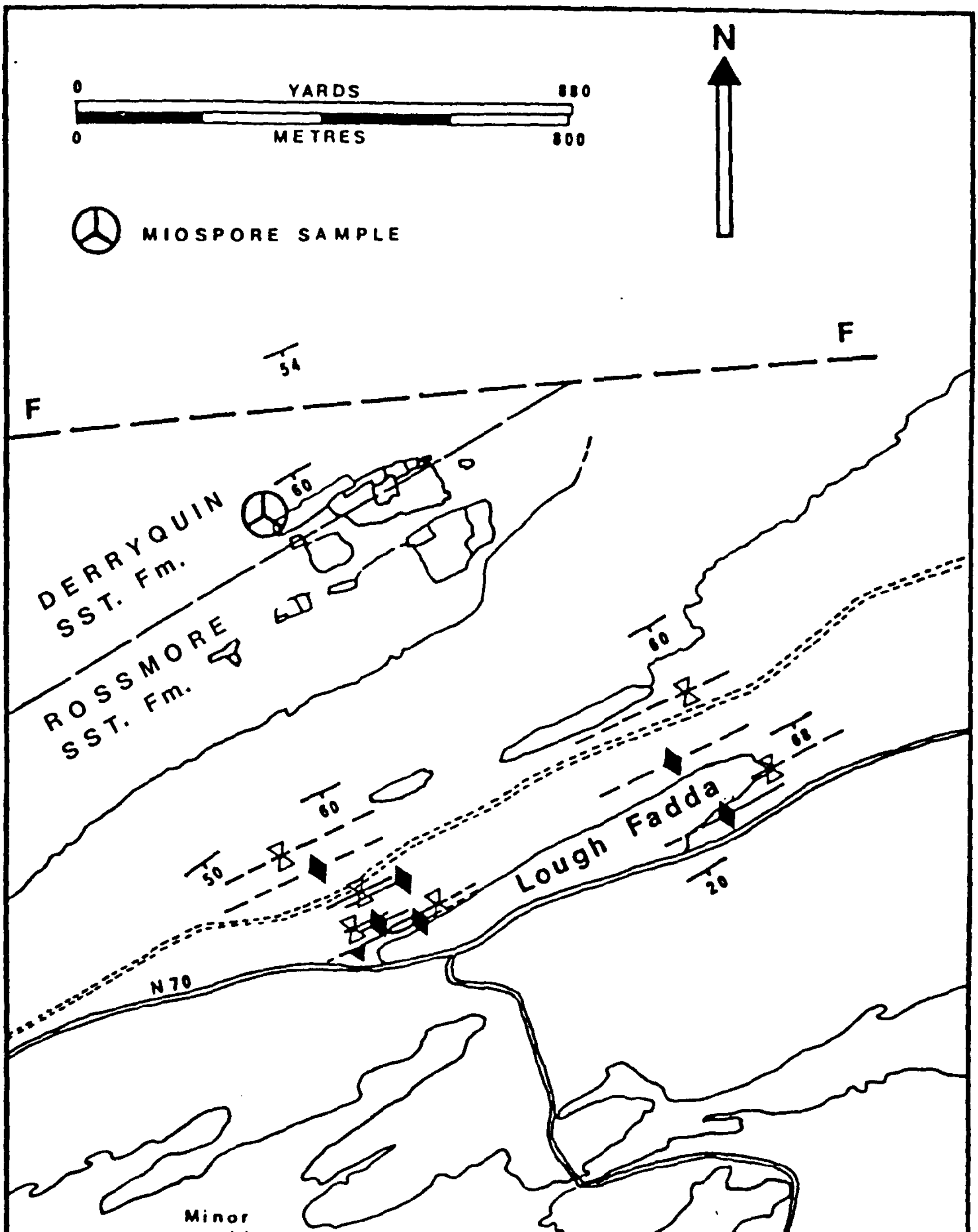
During logging of the major sections a large number of samples were collected for palynological analysis by Dr. K. Higgs of the Irish Geological Survey. The majority of these samples were collected from pale grey and green siltstones and claystones in the Old Red Sandstone part of the succession, and proved mainly barren. Only four samples yielded spore assemblages (Higgs and Russell, 1981), three from the Old Red Sandstone part of the succession and one from the overlying Rossmore Sandstone Formation. The Old Red Sandstone assemblages were collected from Moll's Gap quarry, Lough Fadda, and Rossdohan Harbour. The Rossmore Sandstone assemblage was collected from Rossmore Island. Text Figs. 26-30 show the locations of the sampling sites which yielded spores.


Dingle Bay
GLENBEIGH
KILLARNEY
Area shown
IVERAGH
THE REEKS
CAHIRCIVEEN
VALENTIA ISLAND
1
KENMARE
SNEEM
4
WATERVILLE
KEY
1 MOLL'S GAP
2 ROSSMORE ISLAND
3 ROSSDOHAN HARBOUR
4 LOUGH FADDA
2
3
Kenmare R
BEARA
Bantry Bay

TEXT FIG. 26

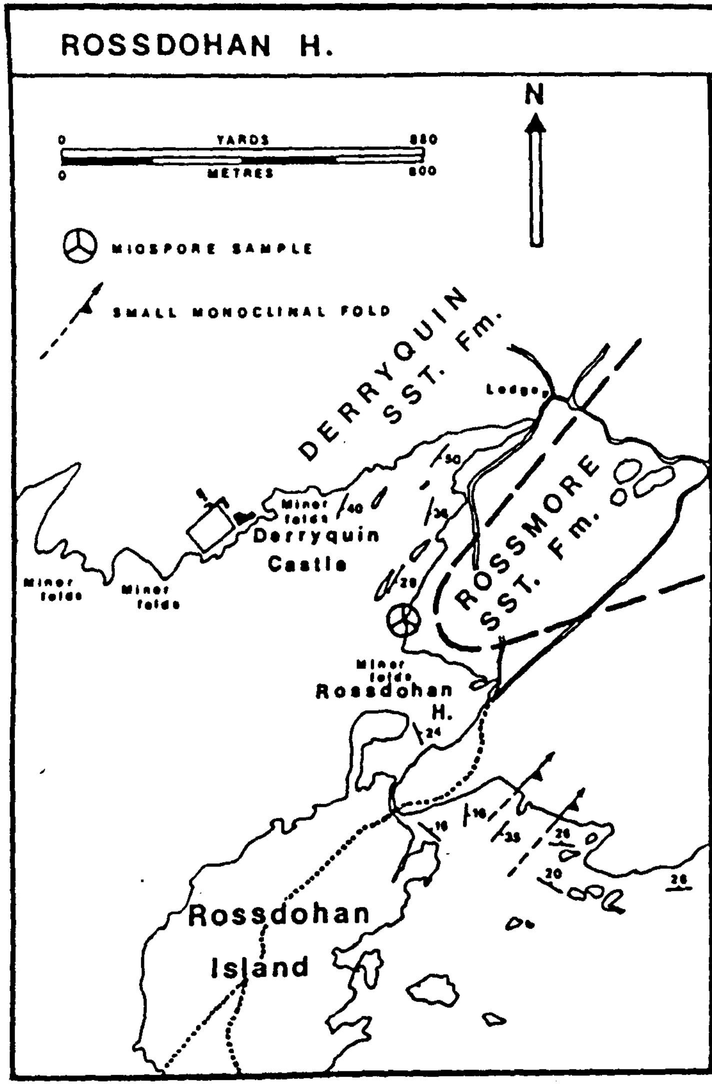

MOLL'S GAP QUARRY
(REDRAWN FROM FIELD-SKETCH)
N
80
Purple beds
Fallen blocks
Bedding-plane with prominent slickensides
Beds containing plant material
Trace of bedding
50 metres
◄◄◄ To Moll's Gap
'B'-Road
To Sneem ►►►

TEXT FIG. 27

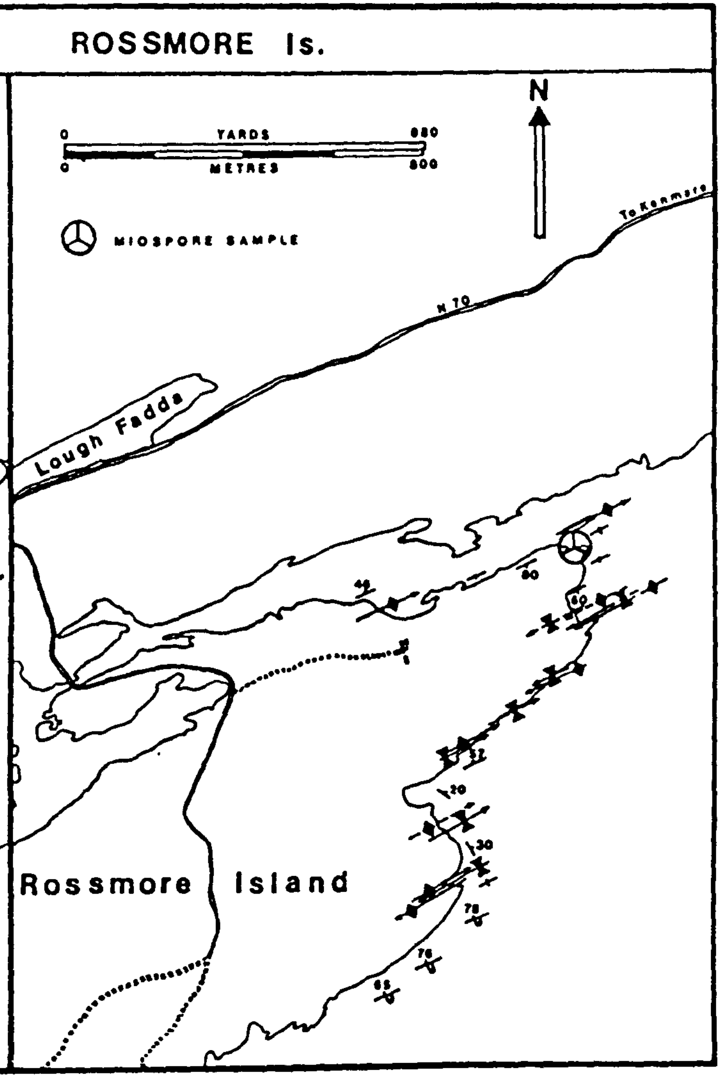


0
YARDS
880
0
METRES
800
MIOSPORE SAMPLE
N
F
54
F
DERRYQUIN
SST. Fm.
60
ROSSMORE
SST. Fm.
60
68
60
50
Lough Fadda
20
N70
Minor
folds
Minor
folds

TEXT FIG. 28



TEXT FIG. 29



TEXT FIG. 30

4.2.1 Location of the spore samples

Moll's Gap Quarry (V 860 775)

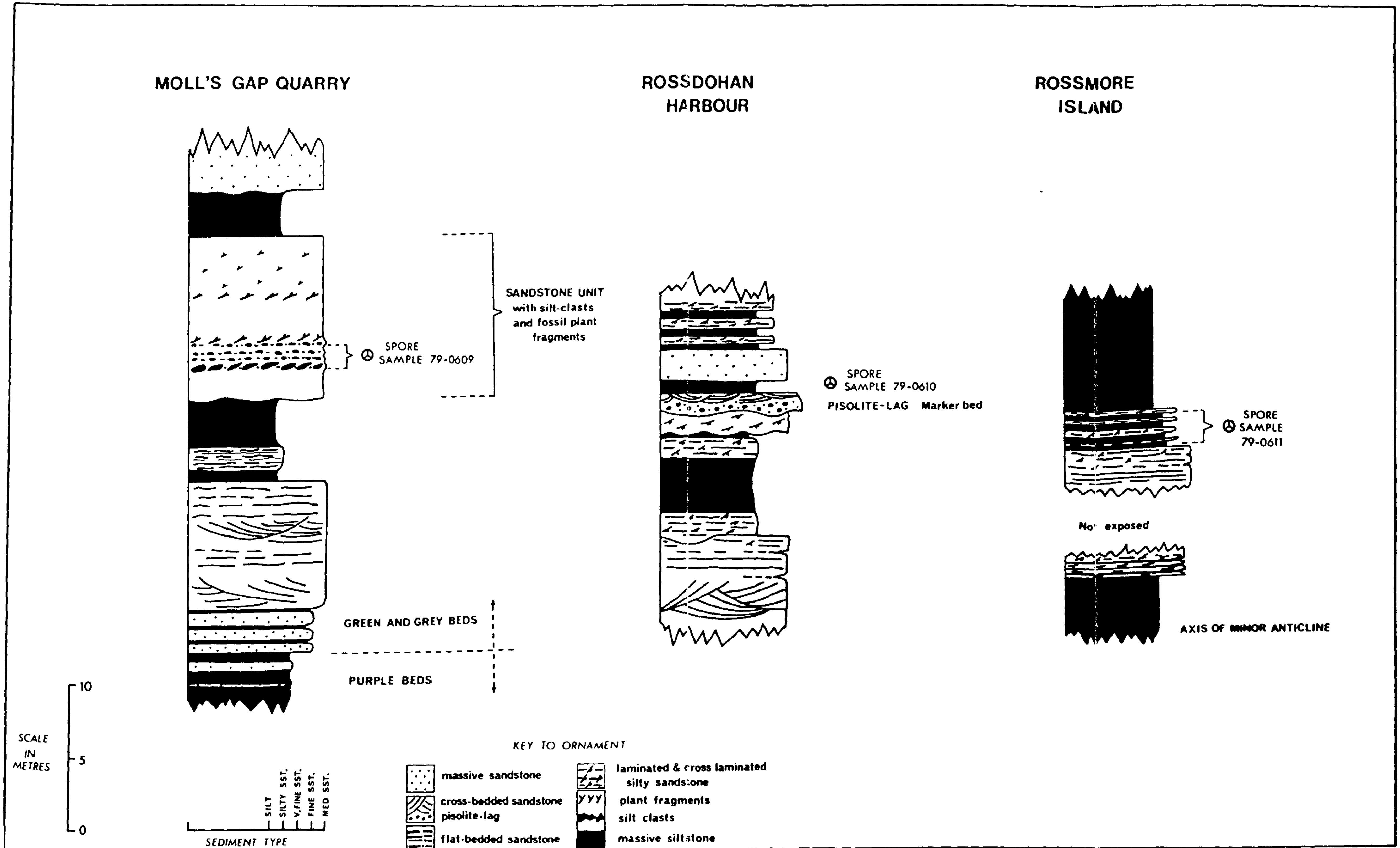
The quarry is the first large cutting on the Sneem road, several hundred metres north from the road junction at Moll's Gap. Stratigraphically it occurs in the 'Green Sandstone Formation' of Walsh (1968), traced beyond the limits of the area mapped by him. The sampled beds lie an estimated 800m downsection from where Walsh positions his boundary with the overlying 'Grey Sandstone Formation', just north of Owenreagh River. Walsh noted at least a similar thickness of green sandstones exposed along the Kenmare - Killarney road skirting the Upper Lake, which is stratigraphically below the quarry cutting, so the sample would appear to come from the middle part of the 'Green Sandstone Formation'. Walsh suggests that his 'Green Sandstone Formation' is at least partly equivalent to the 'Chloritic Sandstone Group' described by Capewell (1957) at Sneem and redefined in this thesis as the Chloritic Sandstone Formation (see CHAPTER 6).

Steeply inclined beds of greyish-green, fine to medium sandstones and subordinate siltstones are exposed in the quarry face. The sandstones are plane-bedded or large scale trough cross-bedded, usually resting on an erosive base which is often lined with angular siltstone clasts of intraformational origin. The siltstones are massive or show faint traces of parallel lamination or small scale cross-lamination. The beds dip and the rocks young in a northerly direction.

On the southern side of the quarry, a thick unit of purple beds forms a prominent marker horizon from which the sample horizon can be located (Text figs. 27 and 31). Virtually in the centre of the quarry cutting, below a wide patch of scree, a prominent rib of rock projects from the base of the quarry face. Fallen blocks on the quarry floor at this point contain abundant fragmented plant material, which is also conspicuous in the quarry face behind the blocks. Spore sample 79/0609 was collected from the intraformational siltstone clasts in the thick sandstone unit containing the plant material.

Lough Fadda (V 755 663)

Approximately 800 metres north from the western end of Lough Fadda, the ground rises from a broad stretch of poorly drained bog to a series of ridges along which the bedrock is moderately well exposed. A small cluster of fields enclosed by low stone walls is a conspicuous landmark and coincides with a sharp change from white weathering quartzitic sandstones and grey siltstones to massive purple sandstones. Spore sample 76/0612 was collected from an outcrop of grey siltstone occurring less than 20m from the north-western corner of the most northwesterly of the cluster of small fields, (Text Fig. 28). Stratigraphically the sampled beds lie approximately 44m below the top of the Derryquin Sandstone Formation.



TEXT FIG. 31 Lithostratigraphical logs of the Moll's Gap Quarry, Rossdohan Harbour, and Rossmore Island sections, showing the stratigraphical positions of the samples studied.

Rossdohan Harbour (V 717 637)

Rossdohan Harbour is the small embayment between the landward end of Rossdohan Island and the mainland a short distance to the northeast. The mainland side of the harbour is formed by a small headland, on which minor folding is locally well developed. Rocks exposed along this short stretch of coast are only several tens of metres below the base of the Rossmore Sandstone Formation, which is concealed inland in poorly exposed ground (Text Fig. 29).

A conspicuous thickly developed lag consisting of limestone pisolites and coarse sand occurs on the north side of the small headland mentioned above. The same lag is repeated several times by minor gentle folds along the coast to the northeast. Immediately overlying the lag unit at its most northwesterly occurrence is a 0.80m greenish-grey siltstone containing fragmentary plant material. Spore sample 76/0610 was collected from the finer parts of this siltstone unit (Text fig. 31).

Rossmore Island (V 768 660)

East of the bridge connecting Rossmore Island with the mainland, bedrock is intermittently exposed as far as the northeastern corner of the island. At this point the line of the coast swings south and at low tide bedrock is continually exposed along the wave-cut platform (Text fig. 30). The island consists entirely of Rossmore Sandstone Formation. The base of the formation is concealed on the mainland in a poorly exposed area, and coastal exposures on both the mainland and the island are complicated by frequent minor folding and fracturing. The sampled beds are thought to lie approximately 300m above the base of the Rossmore Sandstone Formation, although due to poor exposure and frequent folding this can only be taken as a very general estimate.

The lowest unit in the continuous section exposed on the northeast corner of Rossmore Island is a massive siltstone, which occupies the core of a small anticline forming an obvious ridge feature on the rock platform. A unit of very thinly interbedded dark siltstones and very fine sandstones occurs 13m upsection from the lowest exposed unit (Text Fig. 31). The darkest of the interbedded siltstones are almost black in colour, and the spore sample 79/0611 was collected from these beds.

4.2.2 Microfloral assemblages

The systematic description of the spore assemblages is fully dealt with in Higgs and Russell (1981) (Enclosure 12 in Appendix), and is not considered here in detail. Identification and dating of the assemblages were carried out by Dr. K. Higgs of the Irish Geological Survey. The main features of the assemblages are described below, with particular emphasis on those which are stratigraphically important. Text Fig. 32 shows a summary guide to the spore zones referred to in the following sections.

TOURNAISIAN STRATIGRAPHY AND MIOSPORE ZONATION

(from Clayton and Higgs, 1979).

STRATIGRAPHY					MIOSPORE ZONATION	
SYSTEM	SUBSYSTEM	SERIES		STAGE		
CARBONIFEROUS	DINANTIAN (pars)	VISEAN		CHADIAN	Pu Zone	
CARBONIFEROUS	DINANTIAN (pars)	TOURNAISIAN	Tn3	COURCEYAN	CM Zone	
CARBONIFEROUS	DINANTIAN (pars)	TOURNAISIAN	Tn3 / Tn2	COURCEYAN	PC Zone	
CARBONIFEROUS	DINANTIAN (pars)	TOURNAISIAN	Tn2 / Tn1	COURCEYAN	VI Subzone	NV Zone
DEVONIAN		TOURNAISIAN	Tn1	'STRUNIAN'	LN Subzone	NV Zone
DEVONIAN		TOURNAISIAN	Tn1	'STRUNIAN'	LE Subzone	PL Zone
DEVONIAN		TOURNAISIAN	Tn1	'STRUNIAN'	LL Subzone	PL Zone

TEXT FIG. 32

Moll's Gap quarry assemblage

Sample 79/0609 contained the assemblage listed below:-

Punctatisporites irrasus Hacquebard 1957

Retusotrilites sp.

Retusotrilites famenensis Naumova 1953

Anapiculatisporites apiculatus Guennel 1963

Anapiculatisporites sp.

Baculatisporites villosus sp. nov.

Converrucusisporites liratus Clayton and Graham 1974

Videospora cf. *glabrimarginata* (Owens) gen. and comb. nov.

Videospora sp.

Verrucosisporites monticulatus Guennel 1963

Convolutispora sp.

Dictotrilites craticulus Clayton and Graham 1974

D. perlotus (Naumova) Mortimer and Chaloner 1971

Diaphanospora cf. *reticulata* Guennel 1963

Grandispora inculta Allen 1965

G. cf. *melanidus* (Naumova) Taurgourdeau Lantz 1971

G. saetosa Clayton and Graham 1974

G. tomentosa Taurgourdeau Lantz 1971

G. cf. *tomentosa* Taurgourdeau Lantz *sensu* McGregor and Camfield 1976

Grandispora sp. A

Grandispora ? sp. B

? *Rhabdosporites parvulus* Richardson 1965 *sensu* Lele and Streel 1969

Gemnispora lemurata Balme 1962

G. boleta sp. nov.

G. plicata Owens 1971

Geminospora sp.

Ancyrospora simplex Guennel 1963 emend Urban 1969

Hymenozonotrilites cf. incisus Naumova 1953 sensu Taurgourdeau Lantz 1960

Samarisporites triangulatus Allen 1965

S. inusitatus Ellen 1965

The assemblage is the oldest of the four, and the spore taxa are less well described in the literature than is the case with the three younger assemblages. Comparison of spore taxa with known spore ranges and assemblages faunally dated in other areas suggest the Moll's Gap assemblage may reasonably be assigned a late Givetian - early Frasnian age.

The presence of Samarisporites triangulatus is useful in that it ranges in age from middle Givetian to Middle/Upper Frasnian (McGregor, 1980). The Moll's Gap assemblage can be compared with an assemblage from Ferques in northern France, which conodont evidence suggests may be equated with the Givetian/Frasnian boundary. At Ferques, the zone in which Samarisporites triangulatus, Geminospora lemurata and Grandispora inculta are all present lies immediately above the zone with basal Frasnian conodont fauna. Grandispora inculta has its last appearance a few metres above the basal Frasnian beds, which if accepted for correlation implies a basal Frasnian age for the Moll's Gap assemblage. This is supported by the presence of Dictyotrilites perlotus, Ancyrospora simplex and Hymenozonotrilites cf. incisus in the Moll's Gap assemblage, all of which appear restricted to Frasnian or younger sediments.

The Moll's Gap assemblage compares closely with an assemblage from the Sherkin Formation on Clear Island (Clayton and Graham, 1974) which was assigned (by reference to known spore ranges) to a late Givetian - early Frasnian age. The main differences between the two assemblages is the absence of Archaeozonotrilites variabilis (Naumova) Allen and Hystricosporites in the Moll's Gap assemblage, and the absence of ?Rhabdosporites parvulus fron the Sherkin assemblage. The differences may reflect ecological areal variation, rather than stratigraphical differences.

Lough Fadda assemblage

Sample 79/0612 contained the assemblage listed below: -

Rugospora flexuosa (Jushko) Streel in Becker et al 1974
R. versabilis (Kedo) Streel in Becker et al 1974
Grandispora gracilis (Kedo) Streel in Becker et al 1974
G. cornuta Higgs 1975
Perotrilites caperatus Higgs 1975
Auroraspora commutata (Naumova) Keegan 1977
A. poljessica Streel in Becker et al 1974
A. macra Sullivan 1968
A. solisorta Hoffmeister, Staplin and Malloy 1955
Raistrickia variabilis Dolby and Neves 1970

Crassispora catenata Higgs 1975

Retusotriletes incohatus Sullivan 1964

R. communis Naumova 1953

R. planus Hacquebard 1957

R. leptocentrum Higgs 1975

Dictotrilites fimbriatus (Winslow) Kaiser 1970

D. subalveolaris (Luber) Potonie and Kremp 1954

Knoxisporites cf. pristinus Sullivan sensu Becker et al. 1974

Lophozonotrilites bellus Kedo 1963

L. curvatus Naumova 1953

Verrucosisporites grandis Higgs 1975

Convolutispora sp. A

Ancyrospora furcala Owens 1971

Ancyrospora sp.

Hystricosporites porcatus (Winslow) Allen 1965

Hystricosporites sp.

Archaeozonotrilites incrustatus Archangelskaya 1963

Aneurospora sp.

The assemblage is assigned to the Rugospora versabilis - Grandispora uncata (VU) Zone and is Upper Fammenian (Fa 2c) in age. This is the first record of the VU Zone in Ireland. Rugospora versabilis, Verrusocisporites grandis, Retusotrilites sp. A sensu Becker et al. (1974) (as R. leptocentrum), Raistrickia variabilis and Knoxisporites cf. pristinus represent most of the diagnostic species of the VU Zone, and the two latter species indicate a position in the upper part of the VU Zone. The absence of Retispora lepidophyta and Vallatisporites pusillites which are used to define the base of the succeeding PL Zone are taken as confirmation that the Lough Fadda assemblage is pre-Fa 2d in age.

Rossdohan Harbour assemblage

Sample 79/0610 contained the assemblage listed below:-

Retispora lepidophyta (Kedo) Playford 1976
R. cassicula (Higgs) comb. nov.
Vallatisporites pusillites (Kedo) Dolby Neves 1970
Rugospora flexuosa
Auroraspora commutata
A. poljessica
A. macra
Crassispora catenata
Perotrilites caperatus
Hymenozonotriletes explanatus (Luber) Kedo 1963
Retusotriletes incohatus
R. planus
R. triangulatus (Streel) Streel 1967
R. witneyanus (Chaloner) Streel 1967
Punctatisporites irrasus Hacquebard 1957
P. planus Hacquebard 1957
Raistrickia variabilis
R. macrura (Luber) Dolby and Neves 1970
Endoculeospora gradzinskii Turnau 1975

Dictyotriletes fimbriatus

D. subalveolaris

D. trivialis Naumova in litt Kedo 1963

Grandispora cornuta

G. cf. echinata Hacquebard sensu Higgs 1975

Discernisporites crenulatus (Playford) Clayton 1971

D. micromanifestus (Hacquebard) Sabry and Neves 1970

Convolutispora opressa

C. vermiformis Hughes and Playford 1961

Emphanisporites rotatus (McGregor) McGregor 1973

E. hibernicus Clayton, Higgs and Keegan 1977

Reticulatisporites crassus Winslow 1962

Kraeuselisporites fasciatus Higgs 1975

Verruciretusispora magnifica (McGregor) Owens var. magnifica Owens 1971

Leiotriletes trivialis Naumova 1953

Corbulispora cancellata (Waltz) Bharadwaj and Venkatachala 1961

Apiculiretusispora fructicosa Higgs 1975

Asperispora acuta (Kedo) Van der Zwan (in press)

Diducites plicabilis Van Veen (In press)

Pulvinispora scolecophora Neves and Ioannides 1974

P. quasilabrata Higgs 1975

Lophozonotrilites cf. tuberosus Sullivan 1968

Pustulatisporites sp. A. sensu Higgs 1975

Microreticulatisporites sp. (syn. Dictyotrilites sp. A Keegan 1977)

Hystricosporites sp.

Ancyrospora sp.

Aneurospora sp.

The assemblage is assigned to the *lepidophyta* - *explanatus* LE Subzone of the PL Zone, in the zonation scheme of Clayton *et al.* (1978). This subzone is considered to be Uppermost Devonian (Strunian Tn1) in age.

Assemblages of the LE Subzone have been recorded in many marine and non-marine sediments of Uppermost Devonian age in southern Ireland. There is a strong similarity in the presence of taxa such as *Retispora* (*Hymenozonotrilites*) *cassicula* (Higgs, 1975) comb. nov., *Retusotrilites witneyanus* (Chaloner) Streel, *Hystricosporites* sp. and *Ancyrospora* sp., to an LE Subzone assemblage recorded by Higgs (1975) from 76 metres below the top of the 'Old Red Sandstone' at Hook Head, Co. Wexford. The Rossdohan Harbour assemblage is unusual in the respect that *Retispora lepidophyta*, which is normally a dominant element of LE Subzone assemblages, forms less than 1% of the miospores present.

Rossmore Island assemblage

Sample 79/0611 contained the assemblage listed below:-

Retispora lepidophyta

Vallatisporites pusillites

Verrucosisporites nitidus (Naumova) Playford 1964

Rugospora flexuosa

R. versabilis

Crassispora catenata

Auroraspora commutata

A. macra

A. poljessica

Endoculeospora gradzinskii

Lophozonotrilites triangulatus (Ishchenko) Hughes and Playford 1961

Raistrickia variabilis

R. macrura

Grandispora echinata Hacquebard 1957

Retusotrilites incohatus

R. famenensis

R. triangulatus

Discernisporites crenulatus

Spelaeotrilites crustatus

Corbulispora cancellata

Convolutispora oppressa

Apiculiretusispora fructicosa

Punctatispites minutus Kozanke 1950

Knoxisporites literatus (Waltz) Playford 1964

Pulvinispora scolecophora

Asperispora acuta

Diducites plicabilis

Perotrilites caperatus

Ancyrospora furcula

Hystricosporites sp.

Convolutispora sp. A sensu Keegan 1977

Acritarchs

The assemblage is assigned to the lepidophytus - nitidus LN Subzone of the NV Zone, in the zonation scheme of Clayton et al (1978).

The LN Subzone is considered to be Uppermost Devonian (Strunian Tn1) in age. It succeeds the LE Subzone, hence the Rossmore Island assemblage is slightly younger than the Rossdohan Harbour assemblage.

The low abundance of the zonal species *Verrucosisporites nitidus* (less than 1%) suggests a position low in the LN Subzone. LN Subzone assemblages are widely recorded in southern Ireland, and with the exception of the non-marine Toe Head Formation at North Dunmanus Bay (Naylor *et al*. 1977) all records are from marine sediments. The rare occurrence of acritarchs in the Rossmore Island assemblage confirms a marine influence in the sediments.

4.3 Fossil Fish

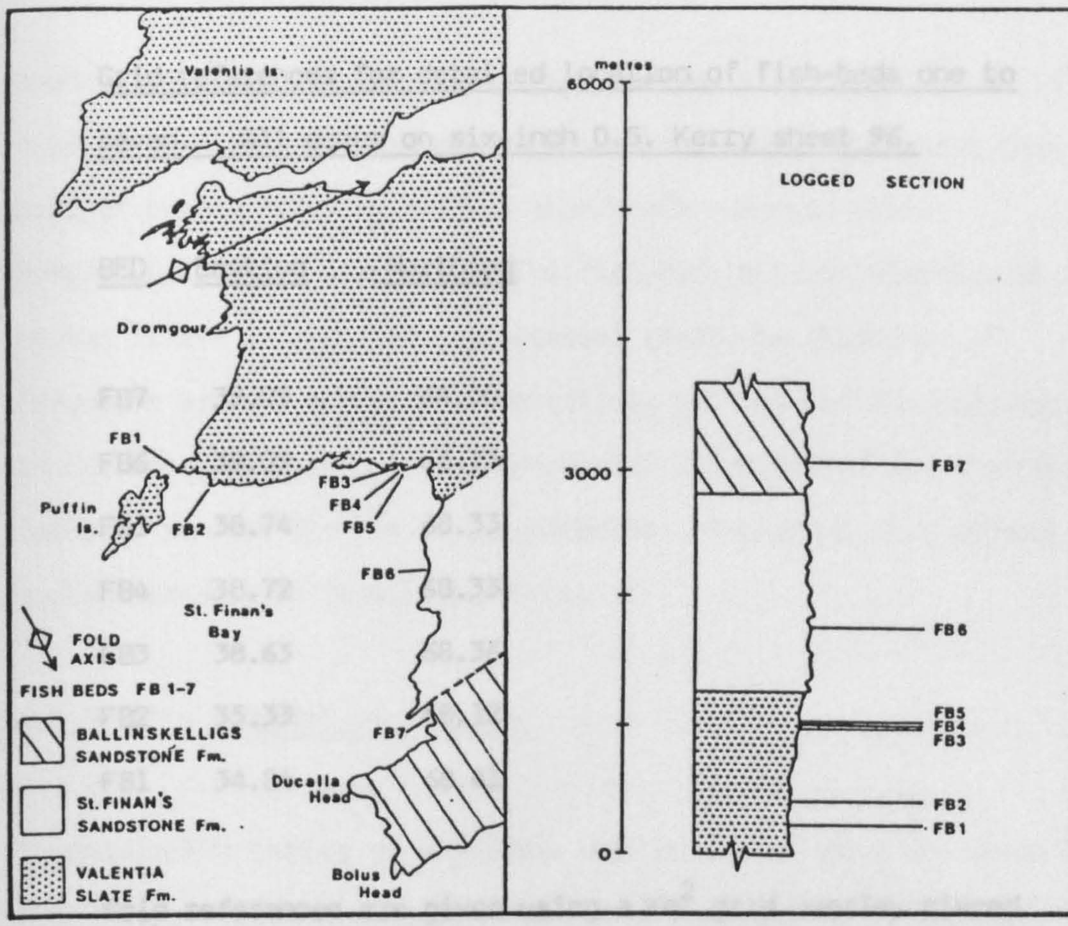
Detailed investigation has shown fossil fish material, not previously recorded, to be present in small quantities throughout the entire Iveragh succession (PLATES 55 to 76). The majority of the material is broken and so poorly preserved as to be almost unrecognizable, however, it has been recorded at all levels in the succession and from all of the sections investigated. The section exposed on the western end of the peninsula, between Dromgour and Bolus Head (Text fig. 33), is of particular interest since it contains seven distinct fish-beds which are described in detail below.

4.3.1 Preservation and general occurrence

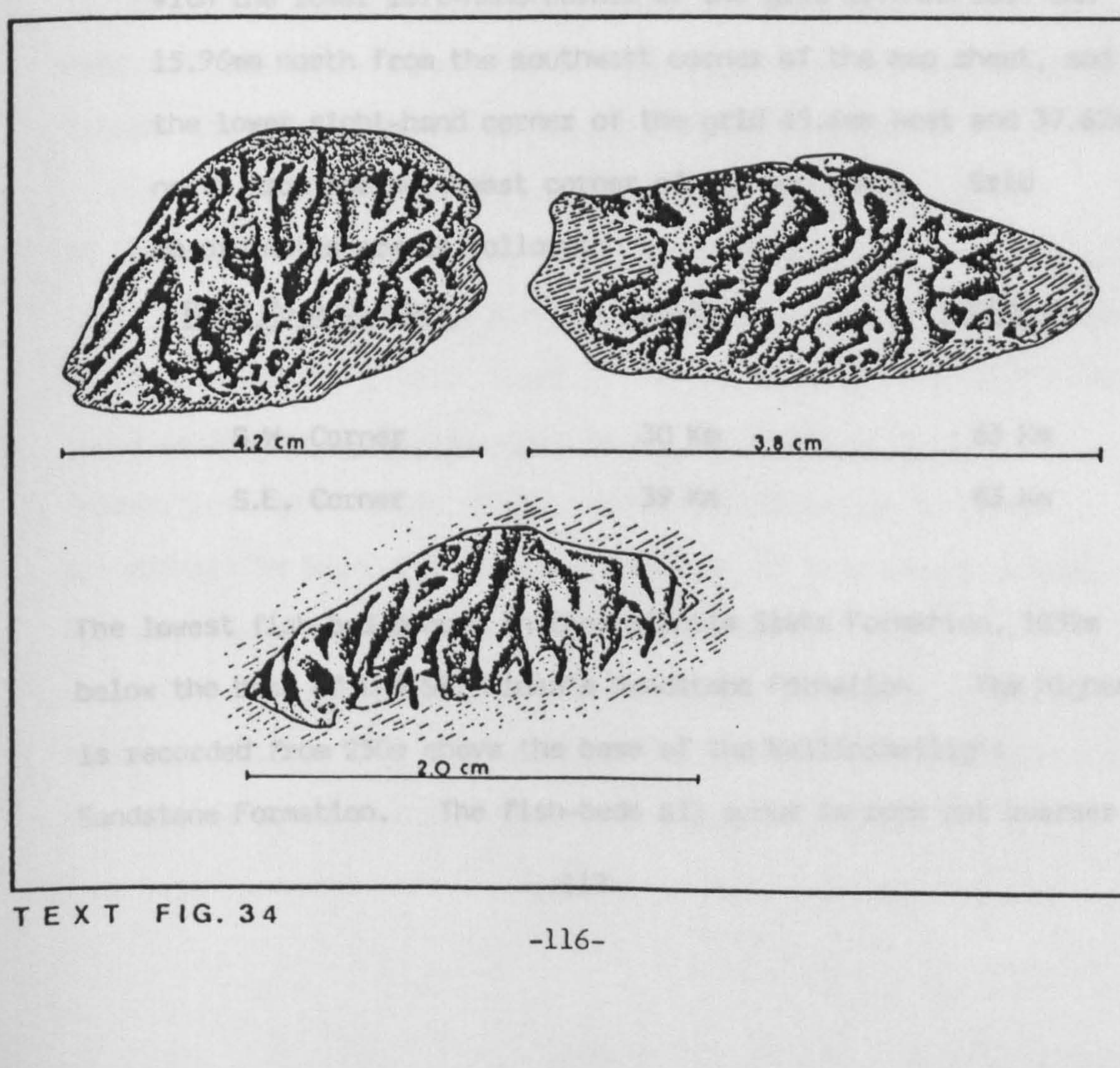
The fish fragments occur either concentrated in thin beds or as rare isolated fragments. The original material has been replaced by chlorite, in some specimens preserving the original structure in fine detail (PLATE 69). The majority of the material appears to have suffered fragmentation and abrasion. Late Palaeozoic deformation has affected the fossil material by flattening of the specimens and by rotation to parallel the regional cleavage fabric (PLATE 56).

The occurrence of isolated fragments is limited to rare single examples in siltstones and several occurrences within calcareous lags at the bases of sandstone bodies. Specimens from the latter are usually of poor quality, due to abrasion. In some cases only the cellular internal structure of the fragments distinguish them as organic material (PLATE 70). Attempts were made to extract fragments from calcareous lag material using acid digestion techniques, but proved fruitless as the carbonate content of the rock was too low.

Apart from the rare isolated fragments, seven distinct fish-beds were recorded over a thickness of 2875m of strata (Text fig. 33). Co-ordinates giving the detailed location of the fish-beds are listed below:-



TEXT FIG. 33



TEXT FIG. 34

Grid references for detailed location of fish-beds one to seven. All occur on six-inch O.S. Kerry sheet 96.

BED	Easting	Northing
FB7	39.09	64.30
FB6	39.09	66.73
FB5	38.74	68.33
FB4	38.72	68.33
FB3	38.63	68.36
FB2	35.33	68.12
FB1	34.84	68.41

Grid references are given using a Km^2 grid overlay placed with the lower left-hand corner of the grid 25.94mm east and 15.96mm north from the southwest corner of the map sheet, and the lower right-hand corner of the grid 45.6mm west and 37.62mm north from the southeast corner of the map sheet. Grid co-ordinates are as follows:

Grid Co-ordinates	Easting	Northing
S.W. Corner	30 Km	63 Km
S.E. Corner	39 Km	63 Km

The lowest fish-bed occurs in the Valentia Slate Formation, 1032m below the base of the St. Finan's Sandstone Formation. The highest is recorded from 250m above the base of the Ballinskellig's Sandstone Formation. The fish-beds all occur in rock not coarser than siltstone. An individual fish-bed may range from 2cm to 1m in thickness, with fragments either scattered evenly throughout the bed, or concentrated in several thin bands composed almost completely of fish material. The fish-beds extend laterally as far as the limits of exposure; in several cases the abundance of fragments becomes very low along strike, but none of the beds appear to die out completely. Fish-bed number 1 was traced along strike for over 17m and for 60m in the direction of bedding dip, without marked decrease in fossil abundance.

4.3.2 Fish material assemblages

A considerable number of specimens were collected from the seven fish-beds. All the material figured in Russell (1978) (ENCLOSURE 13) is lodged in the British Museum (Nat. Hist.): specimen numbers P59677-P59690. The remainder is lodged with the Geological Museum, Trinity College, Dublin: collection number TCD 19618.

At least three subclasses (classification of Moy-Thomas and Miles, 1971) have been recognized and it has been possible to identify some of the material to generic level. The material shown in PLATES 61 to 67 is identified as belonging to the genus Bothriolepis (classification of Miles, 1968). The identification is based principally on the outlines and arrangement of bony armour plates; the premedian and lateral plates shown in PLATE 61 are characteristic shapes occurring as head-shield elements in the Bothriolepididae. The comma-shaped semicircular pit-line groove in the lateral plate of PLATE 62 is also diagnostic of the

Bothriolepididae. PLATE 67 shows a plate from a Bothriolepid pectoral appendage, which attached to the body of the fish by means of the articular surface shown in PLATES 63 to 66. The three plate fragments shown in Text Fig. 31 are indeterminate, but may possible belong to Bothriolepis. Measurements of the premedian plate indicates that the species of Bothriolepis was a fairly large one, perhaps similar to B. giganteus Traquair, or B. maxima Gross. Much material remains to be collected, and it is felt preferable at this stage to designate the identified material simply as Bothriolepis sp.

PLATE 69 shows material identified as a scale fragment belonging to the genus Sauripterus. PLATE 71 shows an incomplete specimen also attributed to Sauripterus.

The specimen in PLATE 68 is identified as a fin-spine belonging to a member of the class Acanthodii. The Acanthodians characteristically possessed large spines forming the leading edges of dorsal, anal, and paired fins. Smaller spines occur as a primitive condition, distributed in pairs between the pectoral and anal fins. The specimen shown is one of the larger fin-spines, having a slender outline typical of the later more evolved forms. Earlier forms tended to have broad, blade-shaped spines.

4.3.3 Age and stratigraphic significance

Bothriolepis has been positively identified from fish-bed number 1, occurring approximately 240m above the lowest strata exposed in the Iveragh succession. Its presence is stratigraphically significant in determining a maximum age for the lower part of the Valentia Slate Formation. Bothriolepis has been described from Late Devonian continental deposits in every continent of the world, with the exception of South America and Africa (Miles, 1968). Specimens have been recorded from Eifelian-Givetian equivalents in China (Westoll, 1979), but the oldest European record is from the Baltic province, where Gross (1934) commented on its occurrence in the Middle Devonian of that region. He recognized two species, Bothriolepis prima and B. obrutschewi, from the Podsnegor (subsequently the Sudsnetogor) of Klauenstein (Gross, 1942). He stated that this level was equivalent to the Asterolepis radiata Zone, which he believed to be uppermost Givetian in age (D.m. 5/a4 of the Baltic region). Tarlo (1964) however states (following work by Obruchev and others) that the Asterolepis radiata Zone occurs in beds of known basal Frasnian age, and that detailed work indicates that the Middle/Upper Devonian boundary lies between the Tarta and Gauja horizons. Depending on which interpretation is used, presence of Bothriolepis would imply a maximum age of either uppermost Givetian or basal Frasnian. In any case, the maximum age is very close to the Middle/Upper Devonian boundary.

Sauripterus has been positively identified from fish-bed number 6. The oldest reliable record of Sauripterus, from the Catskill Formation in Pennsylvania, is of Fammenian age (Harland et al, 1967). Identifications from the Frasnian Alves Beds of Morayshire, Scotland (Traquair, 1895, 1897) are considered doubtful (Miles, 1968). Presence of Sauripterus in fish-bed number 6 suggests an Upper Devonian, probably Famennian, age for the lower part of the St. Finan's Sandstone Formation.

The Acanthodian material is recorded from fish-bed number 1, but lacks stratigraphical significance as this taxon has a long time-range from late Silurian to early Permian.

Dr. P.L. Forey and Dr. R.S. Miles of the British Museum (Natural History) are gratefully acknowledge for their assistance in confirming the identification of Bothriolepid and Acanthodian material, and for identifying the Sauripterid material.

4.4 Trace fossils

The few observations by Jukes et al. (1861) of 'fucoidal impressions' and crawling trails suggests a generally low abundance of trace fossils in the Iveragh succession. This impression is misleading, since virtually all of the fine-grained facies contain abundant burrow traces. In some cases burrowing is so intense that the primary sedimentary texture is replaced by a mottled texture to form the bioturbated facies (see CHAPTER 3). Burrow traces in these cases are dominantly simple small sub-vertical tubes with a cross-section 2mm or less in diameter (PLATE 78). Associated with these and occurring in the same fine-grained sedimentary facies, although much rarer in abundance, are slightly more complex larger burrow traces with a cross-section 3-5mm in diameter (PLATE 79). A third and much larger burrow trace is occasionally noted, mainly in very fine sandstones of the rippled and laminated facies, with a cross-section approximately 2cm in diameter, and lengths in excess of 60cm (PLATE 83).

Crawling trails of the type noted by Jukes <u>et al</u>. (Ibid) have not been observed. G.H. Kinahan described these from slate beds on Valentia Island, as.....

> 'a double row of small indentations, each about a quarter of an inch in length, pointed at one end and slightly curved, occurring at regular distances of about an eighth of an inch apart, forming a continuous series and nearly a straight line, which can be traced for more than sixteen inches on the slab.....'

Charles Galvan, another officer of the Geological Survey, noted 'tracks, probably crustacean' from rocks on the shore at Fort Point, on the north coast of Valentia Island. The present study did however reveal some narrow (3-5mm) continuous bilobed crawling trails, exposed on a bedding plane in the St. Finan's Sandstone Formation (PLATE 81).

4.4.1 Burrow traces

Type 1

The smallest and most abundant of the burrow types are simple cylindrical tubes, 1-2mm in diameter and typically exposing lengths less than 3-4cm, although several examples up to 10cm long were observed. All orientations occur, but vertical and near vertical orientations are most frequent. The burrows appear to be unbranching, although due to the short lengths exposed and frequent truncations in abundantly burrowed patches, branching cannot be positively excluded. Some lengths of burrows are sharply curved, although the majority are straight to very gently curved. No internal structure is observed in the burrow fill, which is homogenous sediment similar in grainsize, texture and composition to the surrounding rock. Burrows are generally picked out by differential weathering or a slightly darker purple colour, which may be related to slight differences in cementation and oxidation due to their organic origin. The burrows are to be found only in rocks of either the bioturbated or the sand- laminated siltstone facies, in which grainsize rarely exceeds siltstone or very fine sandstone.

Type II

A second burrow type is poorly known since only a few examples of it have been recorded. It is seen as a vertical or sub-vertical burrow 3-5mm in diameter and up to 10cm in length. One example showed a faint pattern of sinuous and interwoven fine ridges running along the outer surface, parallel to the burrow axis. A less well-preserved specimen, not showing the ridge pattern, branched at several points with slightly smaller sub-horizontal branches coming off at a high angle to the main burrow axis. All examples of this burrow type have been observed in the same fine-grained facies as the more abundant Type I burrows.

Type III

A third burrow type, known from only one occurrence, consists of numerous straight or slightly curving traces 1-2mm wide and at least 10cm long, exposed on the mud-draped surface of a very fine sandstone bed (PLATE 80). As can be seen from the photograph, the burrows clearly radiate from a slightly raised circular mound (approximately 5mm in diameter) which would appear to be the surface expression of a vertical burrow trace. The horizontal traces are burrows rather than crawling trails, since they are preserved as positive ridges on the upper surface of the bedding plane. It is possible that the horizontal burrows were made just below the sediment surface, and therefore the central vertical shaft would have had its surface termination at or just above the bedding plane shown in the photograph.

Type IV

The fourth type of burrow trace consists of fairly large cylindrical burrows, up to 2cm in diameter and up to at least 60cm in length (PLATES 83-85). The burrows are straight to slightly curved, with a slightly flattened (compressed?) cross-section. All the examples observed were inclined at an angle of at least forty-five degrees to the bedding. Upper and lower terminations of the burrows were not observed in any of the examples recorded. The burrows appear to have straight parallel sides, and are infilled with texturally mottled sediment similar in grainsize and composition to the surrounding rocks. In one example, a very weak suggestion of spreite with an upwards concave meniscus is present. No branching of the burrows was observed. The burrows are recorded mainly from the St. Finan's Sandstone Formation on the shores of St. Finan's

Bay, either in rippled and laminated facies or very coarse grained examples of the sand-laminated siltstone facies. The burrows tend to be etched into relief where they cut across slightly finer beds in the enclosing rocks (PLATE 83), or remain as a projection above the bedding plane as weathering removes the softer beds (PLATE 85).

Type V

Occurring in association with the Type IV burrows, a fifth 'burrow' type has been recorded in a very few cases (PLATE 86). The 'burrow' consists of an irregular patch with a more or less rounded outline when viewed in vertical section. The patches are approximately 12cm in diameter, infilled with a texturally mottled sediment similar to that seen in the large Type IV burrows. Although the type IV burrows occur in the same facies and at the same locations as these irregular patches of mottled sediments, no physical connection between them has been established. All examples of the mottled patches show the same irregular rounded outline, and since no elongate burrows of this size and scale have been observed it seems unlikely that the patches are cross-sections of large horizontal burrows. Instead it appears likely that they are approximately spherical chambers (now backfilled), and the similarity of textured infill in the nearest comparably sized burrows (Type IV) suggests the latter may be entry/exit routes for these chambers.

4.4.2 Crawling trails

Crawling trails were observed during the present study at only one location. These are exposed on the underside of a bedding plane, in sand-laminated siltstone facies of the St. Finan's Sandstone Formation, on the shores of Ballinskelligs Bay. Sampling and photography of the specimens in situ proved difficult so a latex peel was taken and used to make a resin cast (PLATES 81 and 82). The traces consist of a number of gently curved trails which are seen as positive relief on the underside of a very fine sandstone bed. Each trail is 2-3mm wide, with a distinct median groove. Trail lengths vary from short isolated 3-4mm traces to continuous trails up to 2-3cm long. A continuous trail in the centre of PLATE 81 becomes discontinuous towards the lower-right. The trails reflect an originally negative feature on the surface of the siltstone bed underlying the sandstone. These trails would originally have had the form of two parallel furrows, separated by a slight median ridge. The similarity between the continuous and the shorter isolated trails, together with the example of one passing laterally into the other, show that both were produced by the same organism.

4.4.3 Identification and discussion

The small burrows of Type I are unfortunately not exposed in sufficient detail to investigate features such as depth below the palaeosurface, or the type of lower termination. The simple unlined and unbranching cylindrical burrow style could belong to a number of ichnogenera. Vertical and oblique burrows of this type have been ascribed to Skolithos, Cylindricum and Sabellarifex, while shallow horizontal burrows of this type are ascribed to Planolites. The distinctions are based simply on morphology and geometry, and in no way imply that different organisms must be responsible for each type. Due to the lack of detail noted above, it is not justified to assign the traces to a particular ichnogenus.

The Type I burrows are significant in showing the ubiquitous presence of small invertebrate organisms in the sand-laminated siltstone facies, which represented extensive floodplain areas subjected to periodic flooding and drying out. Stanley and Fagerstrom (1974) suggested in a population of burrows studied by them that the vertical burrows formed semi-permanent shelters, or were access passages to the surface or different levels within the sediment. They noted that meniscate structures are difficult to detect when burrow diameter falls below 1-2mm, but also pointed out that these may be produced by passing sediment around the body rather than by ingestion/excretion and are in any case not necessarily proof of feeding activity. The type of burrows has no particular environmental significance, similar burrows are known from shallow marine and freshwater environments (Seilacher, 1963) and have also been described from Holocene and Recent subaerial environments (Ratcliff and Fagerstrom, 1980).

The slightly larger Type II burrows have not been identified in comparison with any described ichnogenus. The sub-vertical larger shaft appears to have been a main passage, with smaller horizontal branches possibly representing feeding burrows. The burrow was unlined, and faint longitudinal striations may have formed by repeated brushing with pointed appendages belonging to the inhabiting organism.

Type III burrows are also not assigned to a particular ichnogenus. The presence of so many burrows linked to a central shaft at a single precise level might conceivably occur at depth but is much more likely to have been controlled by burrowing at a very shallow level below the exposed sediment surface. Such behaviour is known for the mole cricket *Gryllotalpa* (Ratcliff and Fagerstrom, 1980) although in its case the pattern produced is irregular and branching in plan. The purpose of the horizontal burrows in this case is almost certainly to obtain food, while the vertical shaft formed a semi-permanent shelter for the organism.

Type IV burrows are tentatively identified as *Beaconites sp.* on the basis of their size, shape, and suggestion of rare internal *spreite*. Similar burrow traces have been described from upper Palaeozoic sediments in Antarctica (Gevers *et al*, 1971), South Wales (Allen and Williams, 1981), Fife in Scotland (Forsyth and Chisholm, 1977), Devon (Pollard, 1976) and Co. Mayo, Ireland (Graham and Pollard, 1982). In the discussion by Graham and Pollard (op. cit.) reference is made to separation of two ichnospecies, *B. antarcticus* and *B. baratti*. Such refinement is not justified in this case, where internal *spreite* are barely visible and burrow terminations are not seen. The organism responsible for these burrows is yet unknown, suggestions range from lungfish to worms or arthropods. The Type V bioturbated 'patches' associated with *Beaconites* burrows in some instances are not known from any published descriptions and it is suggested may represent some form of resting chamber. No physical connection to *Beaconites* has been demonstrated but it is interesting to speculate that the latter could form an exit passage to the chamber.

The crawling trails observed compare closely with the description of the ichnogenus Isopodichnus (Hantzschel, 1975), to which they are assigned. The parallel grooves are thought to have been excavated by the pushing action of paired appendages. Lateral transition from a continuous trail to a series of short lengths suggests the organism responsible was able to maintain only intermittent contact with the sediment surface, probably by swimming with only occasional periods of resting or crawling.

4.5 Algal pisolites

The occurrence of these was first noted by Capewell (1957), who commented that they represented algal deposits in delta-surface lagoons.

PLATE 54 shows a polished slab consisting largely of these pisolites. They vary in size, up to 1.5cm in diameter. The outline is more or less rounded, and in some cases a poorly defined concentric banding is visible. Internal calcite filled shrinkage cracks are common. The pisolites occur in lenticular lags in the lower parts of some units of grey quartzitic sandstone facies, along with pebbles and plant fragments in a matrix of medium sand. Many of the pisolites have angular facets indicating breakage, and some lags are coarsely trough cross-bedded.

Minoura and Nakamori (1982) describe very similar cross-bedded deposits of algal balls from Pleistocene deposits in southwestern Japan, although in their case the modal diameter of the balls

(3.5cm) is slightly larger. They interpreted the balls as having formed by algal growth while rolling around in shallow marine reef channels. It has however been shown that continual agitation in a high energy environment is not necessary for pisolite formation (Davies et al., 1978) (Risacher and Eugster, 1979). It therefore remains open whether the pisolites described here originated in a quiet lagoonal environment and were subsequently reworked into their present setting, or whether they were actually forming in a situation similar to that evoked by Monoura and Nakamori.

4.6 Palaeoecology

From the evidence presented above it is apparent that the environment possessed a moderate ecological diversity. The scarcity of plant fossils in the Old Red Sandstone part of the succession could simply be a reflection of non-preservation due to oxidation, but a simpler explanation is that land plants had not yet adapted sufficiently to withstand more extreme terrestrial conditions, particularly arid situations. Rare plant fragments may reflect sparse colonisation of areas near more permanent fluvial channels. The coastal/estuarine setting of the Rossmore Sandstone Formation was more favourable and this is reflected in the greater abundance of preserved plant fossils recorded, and diversity of plant miospores. The unvegetated floodplains were able to support a reasonably diverse fauna witnessed by the presence of at least three different genera of fish, and up to six morphologically distinct types of trace fossils.

The organisms responsible for the trace fossils are unfortunately not known from body fossils. Far from being a rare or occasional feature, particularly in the case of the Type I burrows, the infauna was an abundant and constant feature of the sedimentary environment. The favoured environment is interpreted to have been a low relief extensive area of fairly rapid sediment accumulation, which would have been subaerially exposed but subject to periodic flooding and ponding of flood waters. In the case of Beaconites burrows, the size of organism responsible suggests an aquatic organism such as a fish, amphibian or eurypterid-type arthropod. The Isopodichnus crawling trails as already noted change locally suggesting a part swimming mode of travel. These latter two types of trace fossil are therefore considered to have probably formed in semi-permanently ponded areas of the floodplain. The work of Ratcliffe and Fagerstrom (1980) has demonstrated that the remaining smaller burrows could have been formed entirely by insects during subaerial exposure. The oldest spiders, millipedes and insects appear in the Devonian so this is a possibility which deserves consideration.

The fish fossils recorded show clear signs of transport, sorting and abrasion and are obviously not in their true life environment. The abundance of material however, particularly in Fish-bed number 1, demonstrates that the less ephemeral bodies of standing water on the floodplain were well populated in terms of both numbers and variety of fish. Bothriolepis is particularly interesting since it is known from Devonian rocks in all except two of the continents, and must have been capable of marine migration to achieve uniform distribution over so wide an area (Dineley and Loeffler, 1979). Its presence may suggest that the sedimentary basin was one of external rather than internal drainage; at least there is no obvious evolutionary divergence from the forms recorded elsewhere.

CHAPTER 5

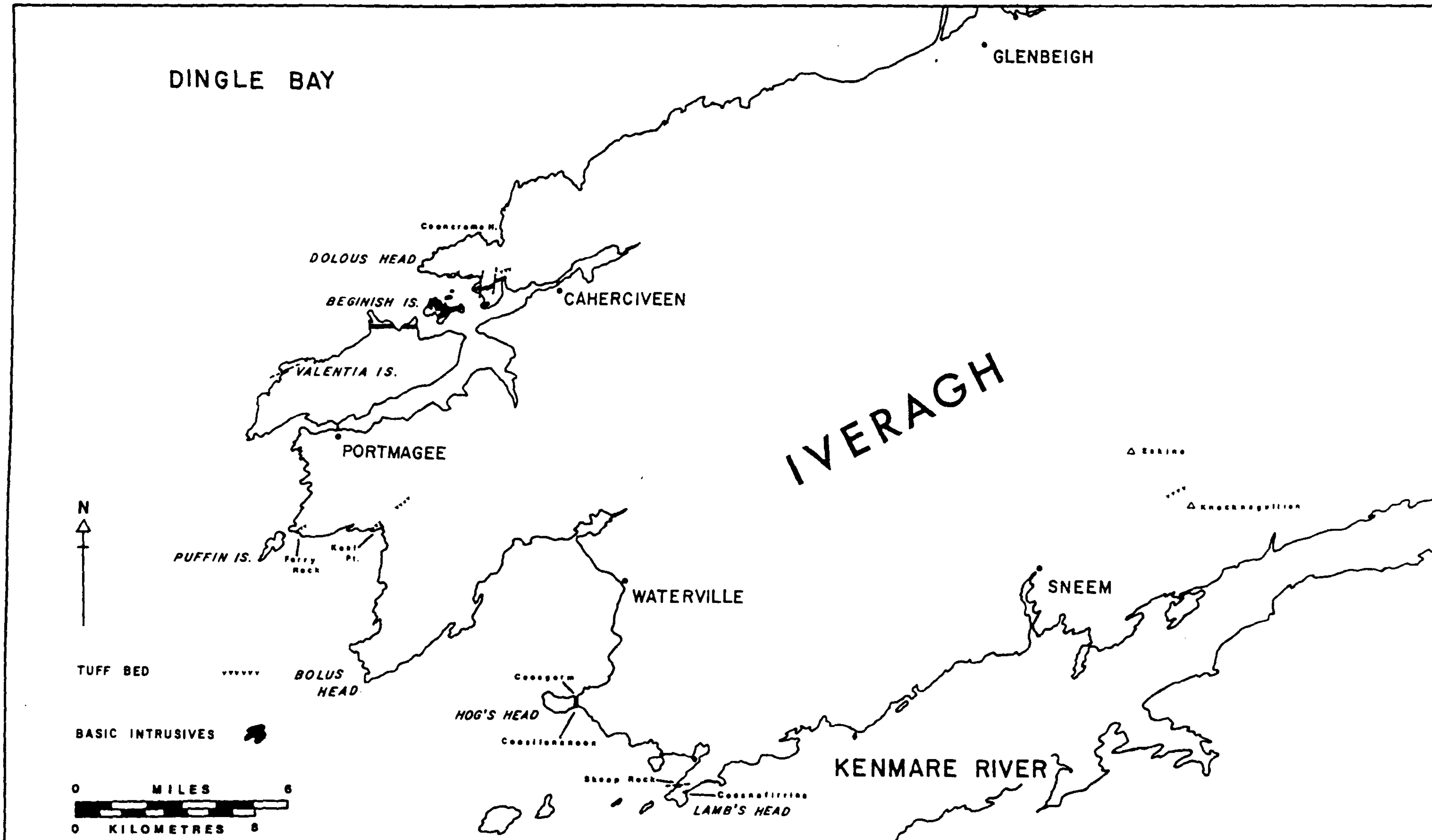
IGNEOUS ACTIVITY

Both intrusive and extrusive igneous rocks are present in the area. Previous accounts of the geology only noted igneous rocks in the Valentia Harbour area and along the western end of the peninsula (Jukes et al., 1861; Capewell, 1975). Detailed work for this thesis has identified new outcrop not previously described and in some cases has led to re-evaluation of the interpretations made by previous workers.

The igneous rocks consist of basic dyke and sill intrusions as well as agglomeratic and tuffaceous material interbedded with the sedimentary rocks. The following sections detail the lithological characteristics, field relations and geographical distribution of these rock types in the sequence given below. The locations of the igneous outcrops are shown in Text Fig. 35.

1. Intrusive rocks
   - (a) The Valentia Harbour sill
   - (b) Dyke intrusion

2. Extrusive rocks
   - (a) Tuff beds
   - (b) Agglomerate


DINGLE BAY
GLENBEIGH
DOLOUS HEAD
BEGINISH IS.
CAHERCIVEEN
VALENTIA IS.
PORTMAGEE
IVERAGH
N
PUFFIN IS.
Ferry Rock
WATERVILLE
SNEEM
TUFF BED
BOLUS HEAD
HOG'S HEAD
BASIC INTRUSIVES
Sheep Rock
LAMB'S HEAD
KENMARE RIVER
0 MILES 6
0 KILOMETRES 8

TEXT FIG. 35

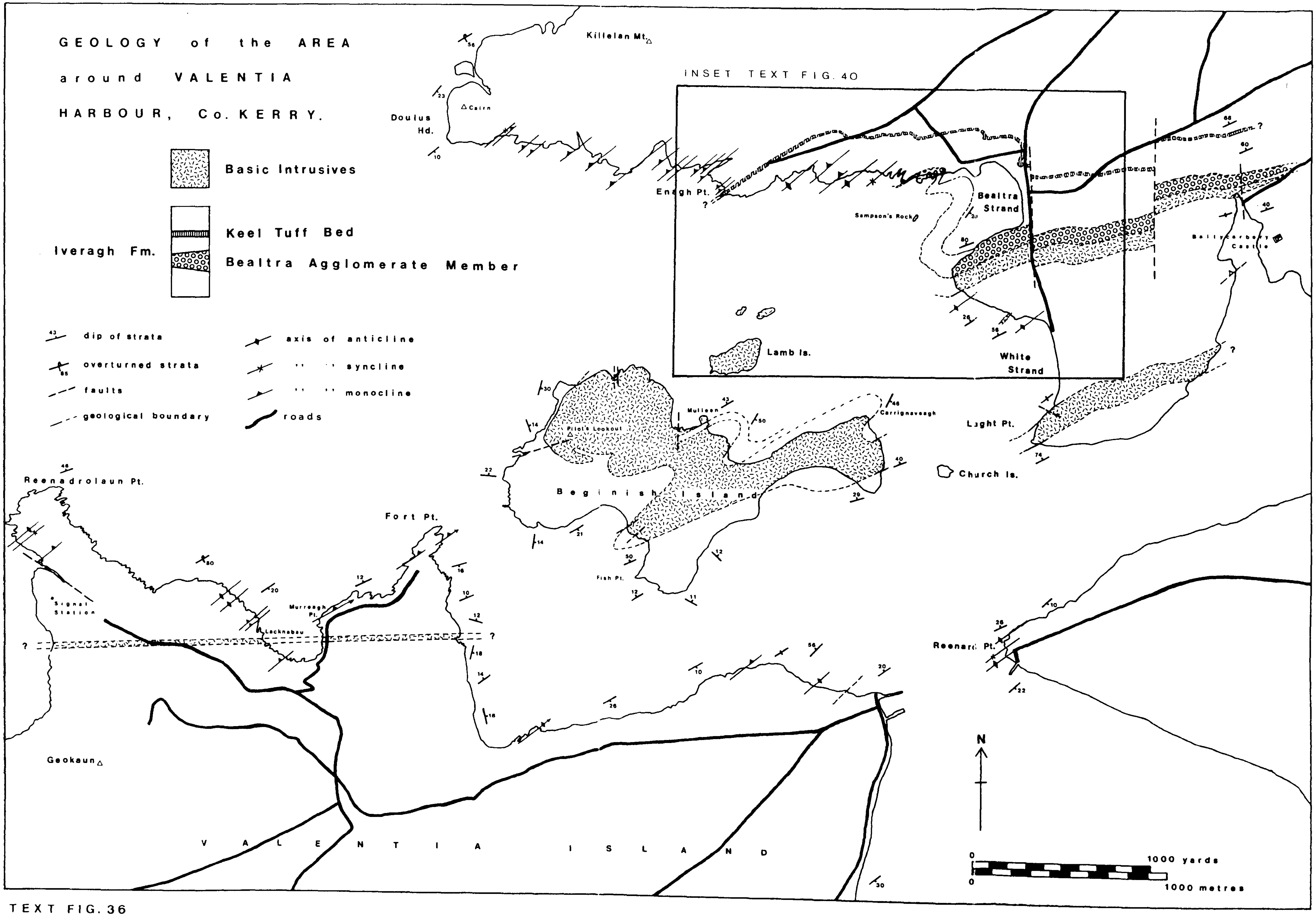
5.1 Intrusive rocks: (a) The Valentia Harbour sill

The most striking example of igneous activity is a complex sill intrusion which outcrops in the Valentia Harbour area (Text Fig. 36). The islands in the middle of the Harbour are composed largely of gabbro (PLATE 84), which also extends on to the mainland on the eastern side of the Harbour. The main part of the sill is exposed on Beginish Island, in the centre of the Harbour.

The contacts between the sill and the surrounding sedimentary rocks are exposed at a number of locations on Beginish Island and the mainland. On Beginish the base of the sill is exposed at two points near Fish Point and Pilot's Lookout on the western coast (Text Fig. 36), and again opposite Church Island on the eastern coast.

At the location 300m north of Fish Point (V 415 780) the base of the sill is faulted against the sedimentary rocks along a fracture lying at a low angle to the original intrusive contact. The fault appears to have only minor displacement since the gabbro has a chilled margin and the sediments are baked to a depth of over 4m away from the contact. The baked sediments show traces of burrows and small-scale cross-lamination.

The exposure west of Pilots Lookout (V 409 786) is more extensive. The base of the sill can be traced along a cliff section for almost 300m. The contact is generally parallel to bedding in the sediments, but towards the southwestern end of the exposure the sill gently 'steps-down' by cutting across bedding in several places.


GEOLOGY of the AREA
around VALENTIA
HARBOUR, Co. KERRY.
Basic Intrusives
Iveragh Fm.
Keel Tuff Bed
Bealtra Agglomerate Member
dip of strata
overturned strata
faults
geological boundary
axis of anticline
" " syncline
" " monocline
roads
INSET TEXT FIG. 40
Killelan Mt.
Cairn
Doulus Hd.
Enagh Pt.
Bealtra Strand
Sampson's Rock
Lamb Is.
White Strand
Ballycarbery Castle
Light Pt.
Church Is.
Mulleen
Carrignaveagh
Pilot's Lookout
Beginish Island
Fish Pt.
Reenadrolaun Pt.
Fort Pt.
Signal Station
Murreagh Pt.
Locknabau
Reenard Pt.
Geokaun
VALENTIA ISLAND
N
1000 yards
1000 metres

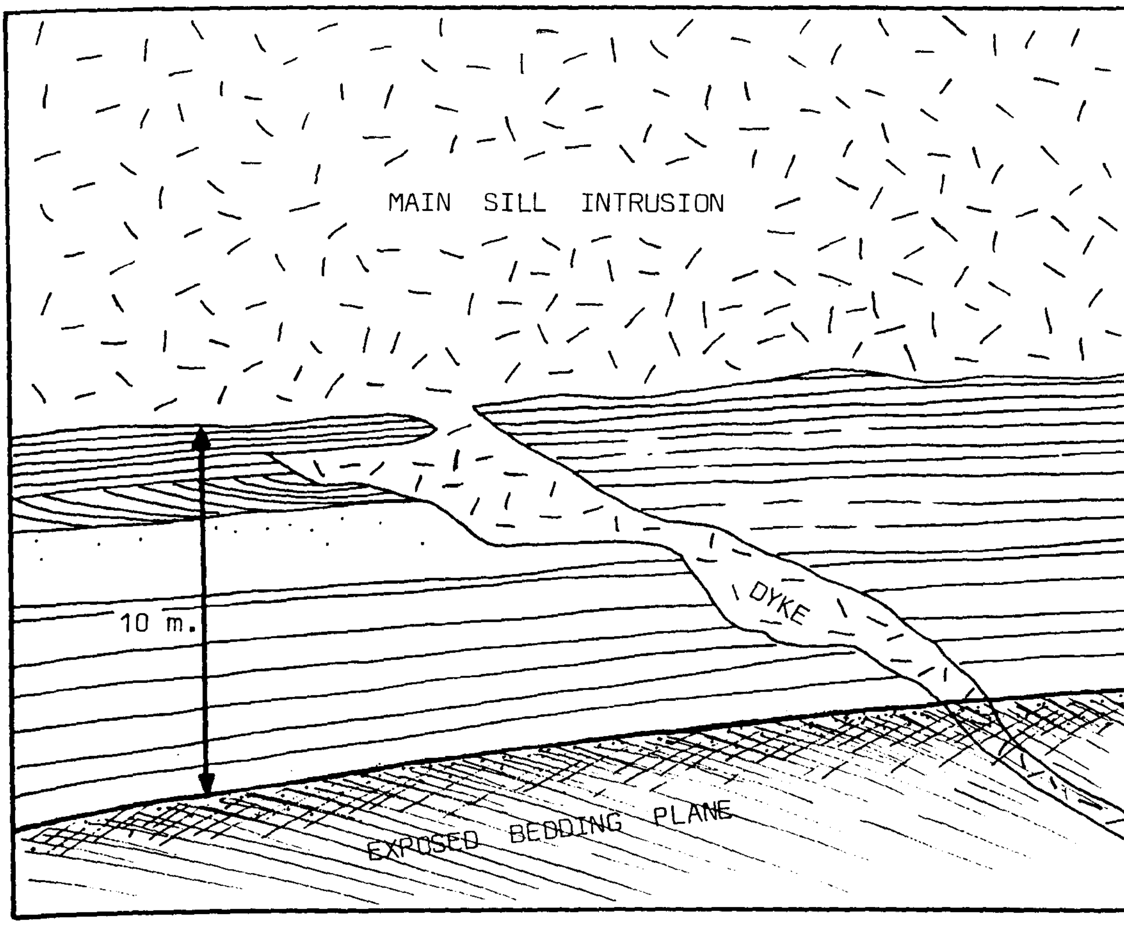
TEXT FIG. 36

At one point a thin dyke, 10-20cm wide, penetrates downwards at a shallow angle to the base of the sill, into the underlying sediments (Text. Fig. 37). Near the same point, the sediments underlying the sill are locally interleaved with bedding-parallel fine-grained intrusions to a distance of several tens of metres below the main contact. Approximately 80m inland from here, on the southeastern side of a small valley feature, the gabbro above the contact contains elongate blocks of baked sediments in which bedding strikes into the main mass of the gabbro. Bedding in some of the blocks appears slightly buckled. The exposure is limited but generally suggests that it is part of an interstratified gabbro/sediment contact which was locally becoming disrupted and rafted into the main mass of the gabbro.

On the eastern coast of Beginish, the base of the sill is exposed at only one point, approximately 300m due west from Church Island (V 430 785). Here, it rests on baked sedimentary rocks with the gabbro locally intruding downwards to form thin sills and dykes.

The upper contacts of the sill are less clearly defined. On the western end of Beginish although a clear upper contact is not exposed, three localities along the northwestern coast have beds or large blocks of baked sediments contained in the upper part of the gabbro, so the actual contact is presumed to lie not far above this.

A large block of baked sedimentary rock in the gabbro is exposed in a small cove (V 414 790) some 600m northwest of the small promontory known as Mulleen. The baked sediments young and bedding dips at



TEXT FIG. 37

about 35 degrees to the northeast. Contacts with the gabbro are sheared and faulted, except on the northern end where the sediments are clearly truncated by the gabbro without any evidence of shearing, although some fracturing occurs locally in the surrounding gabbro.

At Mulleen itself, beds of baked sedimentary rock are interleaved with the gabbro, dipping consistently northwest. Apart from interleaving with the gabbro, the sediments show little disruption. The sediments are overlain by at least 30m thickness of gabbro before the exposure is terminated by the coast.

Approximately 200m southeast from Mulleen, the gabbro is overlain by a small exposure of baked sedimentary rocks with bedding dipping to the southeast. The contact is parallel to bedding, and partly faulted in places.

On the eastern end of Beginish, the gabbro is overlain by sedimentary rocks on the coast south of Carrignaveagh (V 426 788). The gabbro is folded in a broad gentle syncline plunging shallowly northeastwards, the core of which is occupied by sedimentary rocks. On the northern limb, the sediments young and bedding dips to the southeast, with baking of the sediments adjacent to the contact. On the southern limb, the sediments again overlie the gabbro with a baked contact, but here the sediments overlying the contact are interleaved with chilled gabbro which in places contains rounded fragments of baked sedimentary rock.

Mapping of coastal and inland exposure on Beginish Island shows that the gabbro is in the form of a large sill-type body, with baking of the sediments and chilling of the gabbro adjacent to the contact margins. The base and top of the sill run broadly parallel to bedding in the sedimentary rocks, and both sill and sediments are folded by NE-SW trending Variscan folding. The gabbro is generally massive and homogenous, but some features are worth recording. Polygonal jointing (PLATE 87) is well-developed in good exposure on the northwestern end of the island, giving the cliffs a spectacular columnar appearance when viewed from the sea. On the northern side of the island, just east of the sandy neck separating the main masses of gabbro on the eastern and western ends of the island, gabbro exposed along the top of the beach contains a number of thin (2-3cm) bands of different colour to the main gabbro body. The bands dip slightly west of north at an angle of 60°, and are spaced at approximately 35cm intervals or less. The centre of each band is lighter coloured than the main mass of the gabbro, flanked above and below by darker than normal margins. The most likely explanation for this is later injection of an igneous melt with a slightly different composition, possibly from a chamber at depth in which magmatic differentiation was taking place. The injections could be controlled by a set of planes of weakness, and the darker margins would be finer-grained due to chilling. Unfortunately the flat nature of the outcrop and extreme hardness of the rock prevented collection of samples for thin-section study. Layering due to crystal settling is unlikely since one would then expect banding to be developed much more widely, and in any case the sill was probably too small to support such a process. A further feature of interest lies just 30m inland from the same locality, in a southeasterly direction. Here, the gabbro contains a number of cognate xenoliths up to 10cms in diameter. The xenoliths are irregularly shaped with well-rounded outlines, and are conspicuously very much coarser-grained than the gabbro in which they occur.

On the mainland, the gabbro is again seen in outcrop as two sills separated by a considerable thickness of sedimentary rocks. Due to folding and exposure gaps, the thickness of sedimentary rocks separating the two sills can only be estimated as several hundred metres. The two are probably a part of the main sill seen on Beginish, which has extended laterally at two different levels. The lower of the two is well exposed at Laght Point (V 434 787), where just over 100m thickness of massive gabbro dips vertically or very steeply NNW. The sedimentary rocks above and below the sill young northwards, and upper and lower contacts of the sill are marked by chilling in the gabbro and baking of the sediments. Some blocks of baked sedimentary rock are included in the gabbro just below the upper contact, on the northern side of the outcrop. Both upper and lower contacts are generally conformable with bedding in the sedimentary rocks, although several small shear-faults displace the contact locally on the northern side of the outcrop. The sill can be traced inland for approximately 300m before it disappears below drift cover. The ground beyond this is entirely drift covered and the sill cannot be traced any further east. The second sill is exposed further to the north, between White Strand (V 435 790) and Bealtra Strand (V 433 800). It appears to be of comparable thickness to the one exposed on Laght Point, but the contacts are not so well defined and minor folding may cause greater apparent thickness in the massive gabbro and remain undetected. The southern (lower) contact is complicated by folding and shearing in the underlying sedimentary rocks adjacent to the contact, and the actual contact is concealed by a small gap in exposure. The highest sedimentary rocks below the contact are baked, with bedding dipping steeply and the rocks younging northwards. The lower part of the sill consists of massive gabbro containing wisps and veinlets of dark basaltic glass, and is marked by fractures along which extensive formation of epidote crystals has occurred. Above this the character of the gabbro changes fairly rapidly, becoming much finer grained with increased frequency of fracturing and veining, the fractures often containing clusters of epidote crystals. A further change occurs still higher in the sill, where frequent blocks and thin beds of baked sedimentary rocks (PLATES 101 and 102) are included in the igneous rock. The beds are slightly disrupted, but all dip steeply north and strike in generally the same SW-NE direction, indicating the probable attitude of the gabbro in the sill. The upper contact of the gabbro occurs as a gradual reduction in the amount of interleaved chilled igneous rock, and an increase in the amount of bedded sedimentary rocks. The interstratified gabbro and sediments are gradationally overlain by an unusual thick body of massive agglomerate, the Bealtra Agglomerate Member, which is described separately below. The sill can be traced inland by rare isolated outcrops as far east as the inlet at Ballycarbery Castle (V446 798). Some minor folding and wrench faulting is required to explain the outcrop pattern, and the sill is reduced in thickness by the time it reaches Ballycarbery Castle, probably wedging out under drift cover further to the east.

The same (upper) sill is repeated by folding on the coast northwest of Bealtra Strand, directly due north of Sampson's Rock (V 430 800). Only the top and upper part of the sill are exposed, in the core of a minor anticline plunging gently to the northeast. The gabbro contains several thin beds of highly baked sedimentary rocks, and the upper contact is conformably overlain by bedded sedimentary rocks with thin ash beds and a thin massive agglomerate.

5.2 Intrusive rocks; (b) Dyke intrusions

A number of basic igneous dyke intrusions have been observed. These are located in two main areas, the shores around Valentia Harbour and Valentia Island and the coastal section from Hog's Head to Lamb's Head (Text. Fig. 35).

The main dyke in the Valentia Harbour area cuts across the northeastern end of Valentia Island (Text. Fig. 36), from the eastern coast of Fort Point (V 403 782) westwards as far as the cliffs south of Reenadrolaun Point (V 383 785). The dyke is exposed where it cuts the coast at four localities. The most easterly of these is on the eastern side of Fort Point, approximately 600m south of the lighthouse. Here the sedimentary rocks locally dip less than twenty degrees, undulating in gentle folds which plunge shallowly either NE or SW. A basic dyke approximately 18m in width cuts across bedding, dipping due south at approximately forty degrees. The northern margin of the dyke is chilled and the sediments adjacent to the contact are baked. The southern margin in more complex, consisting of a fractured zone containing brecciated and quartz-veined gabbro and fine-grained sediments. Several metres to the north of the main dyke, the sediments are cut by a thin (0.5m) dyke (PLATE 93) which almost certainly represents an offshoot from the larger dyke.

The main dyke is again seen on the western side of Fort Point, just south of Murreagh Point (V 398 778). The dyke is exposed at three-quarters to low tide, and has a width of at least 28m. The northern margin is concealed, but the southern margin is approximately delimited by an abundance of large loose blocks of sedimentary rock penetrated by small veins of chilled igneous material.

The dyke is continued westwards across a small embayment to become exposed at Lacknabu (V 394 777), where the margins are obscured by fracturing and drift cover, and the southern margin is complicated by small dykes and sills occurring in the adjacent gently north-dipping sedimentary rocks.

The most westerly exposure of this dyke occurs on sheer cliffs, approximately 300m due south from the Signal Station above Reenadrolaun Point. A zone of greenish rock approximately 10m thick is seen in the cliff face, dipping south at an angle of about forty-five degrees and obviously cutting across the horizontally bedded sedimentary rocks. The green rock is weathered and cleaved, and as far as can be seen is in sheared contact with the sedimentary rocks. The dyke here appears to coincide with a thrust or fracture plane striking approximately E-W and dipping forty-five degrees to the south. The dyke does not appear to be affected by the folding seen in the sedimentary rocks containing it, but the regional Hercynian cleavage is seen to extend into the chilled fine-grained margins of the dyke.

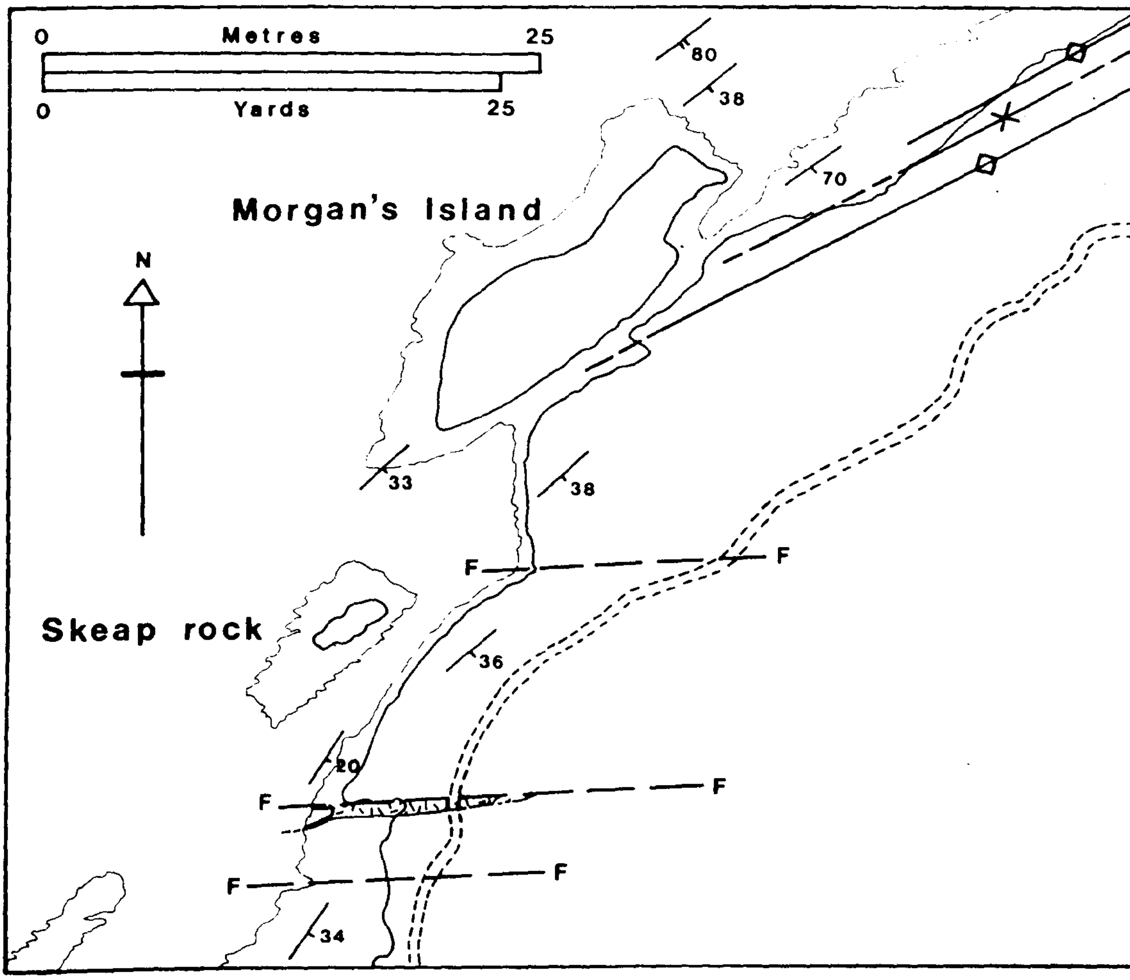
A second dyke is seen on the north coast of Valentia Island, towards the western end. A zone of dark green cleaved rock is seen dipping steeply to the south in the roof of a sea-cave at Coosnalarabaunia (V 344 755), cutting across bedding in the sedimentary rocks which locally dip gently to the north. Access to the exposure is extremely dangerous, but samples were obtained which in thin-section confirm the basic igneous nature of the green rock. The field occurrence is similar to the most westerly exposure of the other major dyke, in that the dyke appears to coincide with a fracture zone. It is not suggested that this is a continuation of the first dyke, since this exposure lies further to the south and appears to trend SW-NE rather than E-W.

A minor dyke is poorly exposed on the western (Atlantic) coast section, on Keel Strand (V 390 684) at the northwestern end of the beach. Chilled and cleaved fine-grained igneous rock is seen to coincide with a NW-SE trending fault.

The remaining dykes are all exposed on the coastal section from Hog's Head to Lamb's Head, on the southwestern corner of the Iveragh peninsula. On Hog's Head, a vertical dyke, trending N-S, cuts gently folded strata. The dyke is exposed on the northern coast at Coosgorm (V 480 610), where it projects from the back of the cove.

The contact margins are weathered out and show fracturing although there is no evidence to prove actual displacement. The eastern dyke margin contains amygdales up to 0.5cm in diameter infilled by light-coloured zeolite minerals. The same dyke is exposed on the southern coast, in the back of a cove at Coosilenanoon (V 480 606). It is approximately the same width and orientation as at Coosgorm, and is inaccessible except by boat. The rocks in a zone adjacent to the dyke margins are fractured and jointed, although again there is no means of proving displacement.

On Lamb's Head, two vertical E-W trending dykes are seen cutting the sedimentary rocks. One is situated on the north coast to the south of Skeap Rock (V 525 570). The other is on the south coast to the north of Coosnafirrina (V 530 565). Both show well-developed regional cleavage in the chilled margins (PLATES 94 to 96). The dyke intrusion on the north coast has a maximum width of two metres. It coincides with a fault plane and sandstone bodies do not match across it, indicating a displacement of at least 5m. The dyke can be traced inland through broken exposure, and although the margins of the dyke are not exposed away from the coast, the outcrop becomes narrower inland. 120m inland from the coast, the dyke is no longer seen, although the continuation of the fault is marked by a conspicuous quartz-breccia zone. The seaward end of the dyke displays an irregular contact with the sedimentary rocks (Text. Fig.38). The dyke on the south coast of Lamb's Head is not associated with any faulting, but localised fractures around the


0
Metres
25
0
Yards
25
80
38
70
Morgan's Island
N
33
38
F
F
Skeap rock
36
20
F
F
F
F
34

TEXT FIG. 38

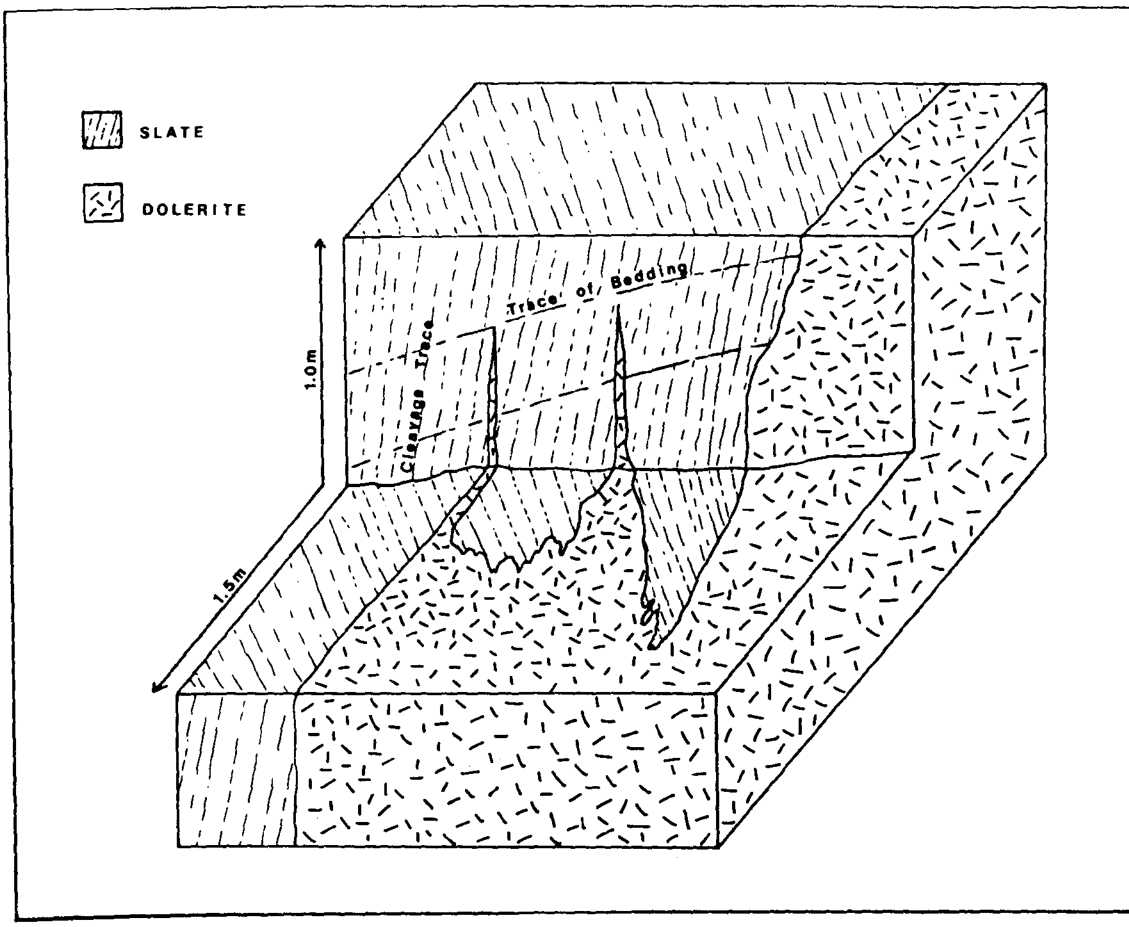
northern margin are veined with quartz, barite and malachite mineralisation. The southern margin of the dyke consists of a normal baked sediment/chilled igneous contact, but the dyke appears to wedge slightly upwards by means of a feather edge (Text. Fig.39).

5.3 Extrusive rocks; (a) Tuff Beds

Pyroclastic material is interbedded with the sedimentary rocks at several locations, at different levels within the succession. At least two, or possibly three, tuff beds are recorded.

The lowest tuff is exposed in a cliff section near Ferry Rock (V 350 682), southeast of Puffin Island. It occurs in the Valentia Slate Formation close to the base of the Atlantic Coast Section, which is the oldest part of the Old Red Sandstone succession exposed on Iveragh. The tuff is a white weathering bed partly exposed just below drift cover on the edge of the cliff approximately 50m southwest from Ferry Rock. The bed is at least 30cm thick, and is locally faulted and crushed to a fine breccia along a shear-plane running oblique to the bedding. In hand-specimen this tuff-bed is identical to a second tuff occurring higher in the succession on the same coastal section (the Keel Tuff Bed), although in thin-section a distinctive shard-texture present in the higher tuff is not preserved.

The Keel Tuff Bed is a 6.3m thick tuff occurring near the top of the Valentia Slate Formation on the Atlantic Coast section. It forms part of a resistant rib of rock jutting from the coast (PLATE 89)



TEXT FIG.39

approximately 100m to the northwest of Keel Point (V 386 682). The base of the tuff is distinctly marked by an abrupt change in colour, grainsize and composition from the underlying sediments, although there is no evidence to suggest that it is erosive. Fine-grained lithic clasts up to 1cm in diameter occur in the bottom 50cm of the bed (PLATE 90). The remaining upper part of the tuff-bed is more or less uniform in appearance, a creamy to pale grey-green rock with a uniform flinty character. Crystals of feldspar, quartz and haematite large enough to be identified with the naked eye are conspicuous on weathered surfaces. In several places an exception to the overall uniform character may be seen near the top of the bed where the tuff is faintly banded on a scale of 1cm or less. The bands are alternately darker and lighter and on close examination are picked out by concentration of the large crystals in narrow bands. The top of the tuff-bed passes gradationally up into the overlying sediments over an interval of approximately 30cm due to increasing dilution of the pyroclastic material by sediments. In thin-section under plane-polarised light, the tuff is seen to consist largely of altered glassy shards (PLATES 91 and 92), some of which have a well defined tricuspate shape. The tuff is concealed below drift cover away from the coast, but is again briefly exposed 1.6km inland along strike.

The Keel Tuff Bed is also exposed on the northern limb of the Portmagee anticline, where repetition by folding causes it to outcrop at two localities. The first of these is an inland exposure NNE of Ballycarbery Castle, approximately 150m south of the road between Cahiraveen and the White Strand. A 10m thick dull purple bed exposed on the face of a small scarp contains quartz and feldspar crystals large enough to be identified with the naked eye. The same tuff is exposed further west on the coast at Enagh Point (V 419 801) where it is 9.5m thick and greyish purple in colour. The Ballycarbery outcrop is seen in an area of poor inland exposure, but at Enagh Point the outcrop is seen in a continuous and well-exposed coastal section where it occurs just below a distinct coarsening in the succession marked by the incoming of significant amounts of sandstone body facies. Although there are some thickness and colour differences, the Keel Tuff Bed is compositionally similar in its three outcrops, and a well-developed shard texture is observed in thin-sections from all three localities.

The Keel Tuff Bed is correlated across the Portmagee Anticline axis on the following grounds:

a) It has a similar appearance in both hand specimen and thin-section, in outcrops north and south of the fold axis.

b) Lithostratigraphical and thickness matching across the fold axis suggest it occurs at a similar stratigraphical level on either limb of the fold.

c) Only one tuff bed of such magnitude (6-10m thick) is known on either limb of the fold.

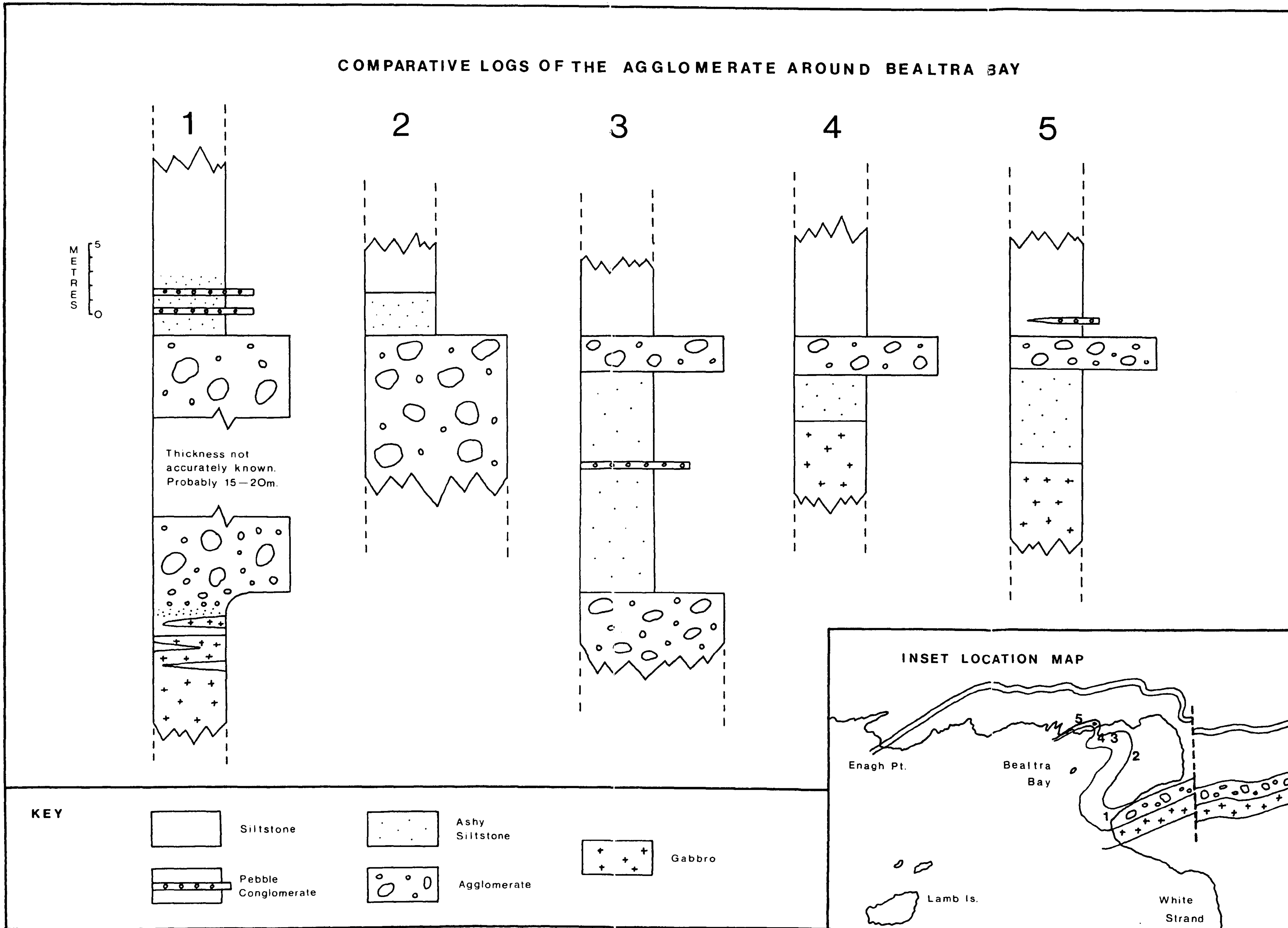
The only evidence of pyroclastic activity seen in the southeastern part of the study area is a thin (3-4cm) tuff-bed exposed on the northern flank of Knocknagullion (V 760 700). It occurs a short distance above the incoming of significant amounts of sandstone body facies. Quartz and feldspar crystals are large enough to be identified with the naked eye in hand specimen, and a possible poorly defined shard-texture is seen in thin-section.

Several very fine grained creamy-weathering beds of doubtful origin from various parts of the study area were sampled and investigated in thin-section and also by X-ray diffraction, but showed no significant differences from reference fine-grained sedimentary rock samples, and a pyroclastic origin could be neither proved nor disproved.

5.4 Extrusive rocks; (b) Agglomerate

The highest level intruded by the sill on the eastern side of Valentia Harbour is overlain by thinly-bedded ashy pyroclastic material and a massive agglomerate of varying thickness (Text Fig. 40).

Where the sill is exposed southwest of Bealtra Strand, the top passes gradationally up into sedimentary rocks by progressive reduction in the amount of igneous intrusives interleaved with the sediments. The sedimentary beds higher up in this interstratified sequence contain a high proportion of fine ashy looking fragments, in many cases making up virtually the entire bed. Well-defined


COMPARATIVE LOGS OF THE AGGLOMERATE AROUND BEALTRA BAY
1
2
3
4
5
METRES
5
0
Thickness not accurately known. Probably 15—20m.
INSET LOCATION MAP
Enagh Pt.
Bealtra Bay
Lamb Is.
White Strand
KEY
Siltstone
Ashy Siltstone
Gabbro
Pebble Conglomerate
Agglomerate

TEXT FIG. 40

bedding is rapidly lost with upwards increase in the maximum clast size and merging of the ash beds to produce an extremely poorly-sorted massive agglomerate with a fine green matrix. The agglomerate is thickly developed. Due to its massive nature the attitude of bedding is impossible to determine for a considerable part of the section until several thin lenses of concentrated coarse clasts are seen dipping steeply north. The intervening material has a hint of shallow dips, and the ash-beds at the base clearly show minor folding, so the true thickness of the agglomerate is almost certainly less than an apparent thickness of almost 100m.

A puzzling feature of the agglomerate at this locality is the 'baked' appearance of many of the clasts, similar to the baked sedimentary rocks included in the upper part of the sill. In thin-section, the baked clasts show replacement by epidote and occasional thin epidote veining. The clasts in some parts are elongate and show some alignment, giving the appearance of thin beds which have become disrupted. The matrix here is fine-grained and cleaved, with an altered appearance. The agglomerate in its upper part is traced vertically and laterally into unaltered agglomerate with unbaked clasts of both igneous and sedimentary origin, which is overlain by bedded sedimentary rocks containing occasional thin ashy or fine conglomerate beds. Outcrop of the agglomerate can be traced inland to the east, along a line just north of the sill outcrop. Exposure is poor but outcrops contain clasts which are unbaked, and outcrop patterns suggest that the agglomerate is gradually thinning in an easterly direction. At one point towards the eastern limits of exposure near Ballycarbery Castle, agglomerate outcrops again contain baked clasts within an altered looking matrix (PLATE 100). The agglomerate may be traced to a point due north of the Castle, but disappears below drift cover to the east of this, where it probably wedges out completely.

To the north of Bealtra Strand, the agglomerate is repeated by folding. The upper part of the agglomerate is exposed in the core of a small anticline on the coast due NE of Sampson's Rock. The underlying gabbro is not brought to the surface, but a minimum thickness of the agglomerate is exposed. Here it consists of unbaked sedimentary and igneous clasts in a greenish fine-grained matrix.

A short distance further north, the agglomerate is again exposed along with the underlying gabbro, in the core of a minor anticline. The agglomerate is exposed flanking the sill on either side, with a greatly reduced thickness compared with the exposures further to the south. The clasts are again of mixed sedimentary and igneous origin and show no signs of baking (PLATE 99). The agglomerate on the southern flank of the sill contains large massive blocks of olivine basalt up to 1m in diameter (PLATE 97), while on the northern flank smaller clasts of similar composition are vesicular (PLATE 98). Apart from one block which proved to be a tuff with good shard texture similar to that seen in the Keel Tuff Bed, all the igneous clasts sampled from the agglomerate were of basaltic composition. At this location the agglomerate thins from 3m thickness on the southern flank of the gabbro to 2.25m on the northern flank. It is possible to trace the agglomerate a short distance westwards on the northern flank of the gabbro where it continues to thin perceptibly before disappearing into the sea.

5.5. Summary and interpretation

The presence of several tuff-beds and an agglomerate shows that some pyroclastic igneous activity was contemporaneous with deposition of the sediments. From palaeontological evidence (Russell, 1978; Higgs and Russell, 1981) the red-bed succession exposed on Iveragh was deposited, and hence the pyroclastic activity also took place, during upper Devonian times. At least two eruptive events occurred, represented by the 30cm and 6.3m tuff-beds near the base and top of the Valentia Slate Formation. Correlations based on the incoming of significant amounts of the sandstone body facies would suggest that the 3-4cm Knocknagallion tuff represents a third eruptive event slightly later than the other two. Given the gradational nature of facies change across the area, it is equally possible that this tuff is a correlative of the Keel Tuff Bed which for some reason is dramatically thinned in this southeastern part of the area. Further detailed work is required to resolve this (see CHAPTER 8). The thickest of the tuff beds (the Keel Tuff Bed) ranges from 6.3 to 10m in thickness, much of which consists of glassy shards and quartz and feldspar phenocrysts with little dilution by normal detrital sediments. A large volume of pyroclastic material must have been erupted, and the high proportion of glassy shards suggests a highly explosive eruption, typical of an acid magma composition. Quartz phenocrysts in the tuff further support an acid magma origin. The Keel Tuff Bed may be traced over a distance of at least 15Km with a minimum thickness of 6.3m. It has not yet been conclusively identified in parts of the study area lying to the south and east, where the areas in which it might occur tend to be inland with intermittent exposure. The other two tuffs (i.e. the Knocknagullion tuff and the tuff at the base of the Valentia Slate Formation) appear similar to the Keel Tuff Bed in hand-specimen, and are probably of similar origin although the shard texture is either absent or poorly developed.

The thickness and predominance of shards in the Keel Tuff Bed suggests the possibility that it might be of ash-flow rather than ash-fall origin. The major difference between the two is that an ash-fall tuff is deposited by gravity settling of erupted material through the air column, while ash-flow tuffs flow downslope along the ground as a hot dense cloud of gas-borne particles. Beavon et al. (1961) and Rast (1962) discussed a number of diagnostic characteristics of ignimbrites (ash-flow tuffs). The main textural criterion noted by Rast which would not be expected in an ash-fall tuff is the presence of flattening and welding in the lower-central parts of ash-flow tuffs. Thin-sections from the Keel Tuff Bed show shards in a variety of orientations without any evidence of flattening, and in several cases partial bubble outlines retain their original shape. True welding (i.e. actual coalescing) of shards is not seen. Flattened pumice fragments (fiamme) which are often present in ash-flow tuffs are also absent in both thin-section and hand-specimen. A further point is the presence of fine compositional laminations in the upper part of the tuff exposed near Keel Point, which appears to be incompatible with deposition by an internally turbulent ash-flow. From the balance of evidence an ash-fall origin therefore appears most likely, although without a detailed study beyond the scope of this thesis the alternative possibility cannot be excluded.

The massive agglomerate and associated thinly-bedded ashy material are only exposed on the northeastern shore of Valentia Harbour. Due to minor folding and poor exposure a direct measurement is not possible, but an estimated 60-80m of sediments separate the agglomerate from the overlying Keel Tuff Bed. The event responsible for the agglomerate therefore occurred a considerable time before the eruption which deposited the Keel Tuff Bed. Outcrop patterns and thickness variations show the agglomerate to thin towards the west, north and east, indicating a source to the south. The large size and poor sorting of blocks in the agglomerate imply close proximity to the source. The largest blocks contained in the agglomerate are basalt, some of which is conspicuously vesicular, indicating very shallow-level intrusion or more probably an extrusive flow origin. The presence of blocks of tuff among the other clasts is proof of pyroclastic events similar to the Keel Tuff Bed but considerably earlier in time, possibly the one represented by the 30cm tuff near the base of the Valentia Slate Formation. The unusual nature of the agglomerate in the Bealtra/White Strand area with its baked clasts and altered matrix suggests some process which is

1) Localised.

2) High temperature (to produce baking of the clasts).

3) Highly reactive (to produce alteration of the matrix).

The most likely explanation is some form of gas brecciation due to localised venting of volatiles from the underlying basic sill. The regional cleavage fabric is well-developed in the agglomerate, but is not disrupted, indicating that if gas-brecciation occurred it must pre-date the regional cleavage development.

The timing of basic igneous intrusions in the area can be established within certain limits. The Valentia Harbour Sill is folded along with the sediments containing it and a cleavage fabric may be weakly developed in the chilled margins. The sill must therefore have been intruded before the regional folding and cleavage development, but after deposition of sufficient overlying sediments to prevent or restrict eruption at the surface. Francis (1968) described examples of basic sills from the British Carboniferous in Scotland and England, which formed at shallow depths and gave rise to numbers of shallow-rooted surface events. The locally altered areas in the agglomerate may reflect pathways by which volatiles, at least, escaped to the surface. Francis linked the shallow sill intrusions to eruptions which deposited basic tuffs higher in the same sequences. As already noted, however, in the area described here the tuffs appear to have originated from an acid magma composition, and in any case at least one occurs in rocks which are older than the sill intrusion.

Intrusion of basic dykes occurred in both northern and southern parts of the area. There are two phases of dyke intrusion. The first phase is represented by the majority of dykes seen in the area, intruded along a mainly E-W trend. In all cases where these develop good chilled margins, the regional cleavage fabric is seen continuing into the dykes from the local country rock. At the majority of the locations where these dykes are exposed, they are associated with fault planes having the same orientation. It was not possible to determine whether faulting had occurred due to the competence contrast between the sedimentary rocks and a pre-existing dyke, or if dyke intrusions had preferentially occurred along the line of weakness formed by a pre-existing fault. In the majority of cases a forceful mechanism of emplacement seems acceptable, but the unusual termination at the seaward end of the dyke on the northern coast of Lamb's Head (Text-Fig.38) suggests passive stoping as a possible alternative. Coe (1969) noted similar features in dykes on the Beara Peninsula to the south, and he described a partially preserved fold structure at the end of a dyke which precludes a dilational mode of emplacement and requires some form of stoping. The first phase of dyke intrusion on Iveragh must have occurred between deposition of the sediments containing them, and development of the regional cleavage fabric. This timing is similar to the Valentia Harbour Sill and there is a strong probability that these dykes and the sill are related.

The second phase of dyke intrusion is along a N-S trend and occurred much later. The only example of this occurs on Hog's Head. The margins of the dyke are chilled but not cleaved, and although it lies almost normal to the trend of regional fold axes there is no evidence of thickening or buckling. Morris (1974) described the magnetic properties of samples collected from this dyke (Iveragh Peninsula), and dykes on Garinish (Beara Peninsula) and Wine Strand (Dingle Peninsula). He related them to a N-S linear magnetic anomaly over 70km in length. Each of the samples showed a high intensity of magnetism, steep inclination, and reversed polarity characteristic of Tertiary dykes. In addition, the magnetic orientation for this dyke is close to that obtained from Tertiary dykes in Britain. It seems reasonable to conclude, especially since fresh zeolite minerals are preserved in amygdales, that this dyke is indeed Tertiary in age.

CHAPTER 6

STRATIGRAPHY

The succession of rocks exposed on the Iveragh peninsula contains over 6000m of red-bed sediments (Naylor and Jones 1967), conformably overlain by an estimated 540m of marine transitional sediments (this thesis).

The thick red-bed sequence consists of a rather monotonous succession of sandstones and siltstones, in which bulk vertical changes are not strongly marked and tend to occur gradually over thicknesses of hundreds of metres. Lateral facies changes between sections less than 15Km apart may be as pronounced as vertical changes within a single section. Apart from rare exceptions described for the first time in this thesis (see CHAPTERS 4 and 5), the red-bed succession is generally lacking in stratigraphically significant fossils or distinctive marker beds. Problems have arisen from previous attempts at correlation based solely on lithological and structural criteria, and local stratigraphies are difficult to apply in a regional context.

In the sections which follow, the historical development of the stratigraphy of the area is reviewed and summarised. Results of the present work are presented and discussed in relation to previous work, and a modified stratigraphy is proposed. An attempt is made to place the stratigraphy of Iveragh in a regional context, based on new evidence from the thesis area and recent research in adjoining areas. Text Fig. 4 provides a useful summary guide to the stratigraphic terminology used by previous workers, and shows how their local stratigraphic units are related to the revised scheme employed in this thesis.

6.1 Historical development of the regional geology - the Dingle Beds controversy

Interpretation of the geology of Iveragh has always been strongly influenced by the geology of adjacent areas, particularly that of the Dingle peninsula lying immediately to the north. These areas are therefore included in the following review.

The age and stratigraphical relationships of Iveragh and adjacent areas of Co. Cork and Co. Kerry have long been a source of dispute. It is unfortunately beyond the scope of this work to do more than summarise the protracted and at times heated debate which developed, although the subject is worthy of a book in itself and provides a classic example of the principles and pitfalls involved in geological decision-making.

The first records of the geology of the area appeared in the years between 1835 and 1838. In those years the first edition of Richard Griffith's geological map of Ireland was published (Griffith, 1838), and two papers appeared dealing with the geology of Cork and Kerry

(Weaver, 1835; Hamilton, 1838). All of these referred the rocks of the area to the 'Transition Series' or to the Silurian system and therefore regarded them as older than the true 'Old Red Sandstone'.

The first hint of the ensuing debate came in a later paper by Hamilton, in which he suggested that the rocks of the Killarney and Dingle mountains might be Devonian rather than Silurian in age (Hamilton, 1845). Griffith (1845) replied firmly that in his view they should be included in the Silurian series, although he commented that

> "this is precisely the place where a difference of opinion is likely to occur, because no fossils have hitherto been discovered in the series to assist us in determining the name by which it should be called".

He did allow that the very highest of the red-beds must be called "Old Red Sandstones" since they were clearly conformably overlain by Carboniferous Limestone. Griffith's logic was that on the Dingle peninsula the highest red-beds were relatively thinly developed and separated from underlying red and green beds by a distinct angular unconformity; therefore a similar thin development of "Old Red Sandstone" could be expected elsewhere, and the underlying sediments must belong to the Silurian series. Some ten years later the second edition of Griffith's geological map of Ireland appeared, showing the majority of the mountainous parts of Cork and Kerry as Silurian (Griffith, 1855).

G.V. Du Noyer (1857) described the rocks of the Killarney district and stated that the purple and green slates and grits (which Griffith believed to be Silurian) were of lower 'Old Red Sandstone' age. Griffith (1858) replied with a paper demonstrating that on the Dingle peninsula, fossiliferous Silurian rocks passed conformably up into the purple and green slates and grits, which were therefore by inference Silurian.

The situation had by this stage developed into a pattern in which the thick development of purple and green beds in the lower part of the red-bed succession was alternatively included in the Silurian or in the 'Old Red Sandstone'. On the Dingle peninsula rocks of this type were seen to rest conformably on top of rocks of known Silurian age, while they were very obviously separated from overlying red-beds by a pronounced angular unconformity. The red-beds above the unconformity passed conformably up into Carboniferous Limestone and therefore belonged to the true 'Old Red Sandstone'. On Iveragh and other peninsulas to the south, similar purple and green beds again formed the lower part of the red-bed succession, but their base was not seen and they appeared to pass conformably up into the Carboniferous Limestone. Proponents of a Silurian age for the lowermost red-beds on Iveragh faced the dilemma of explaining away the lack of an angular unconformity such as is present on Dingle. Proponents of an 'Old Red Sandstone' age found it equally difficult to explain how the relatively thin 'Old Red Sandstone' on Dingle could undergo such extreme thickening southwards over such a short distance.

It was at this stage that the first detailed geological mapping of the Iveragh peninsula took place. This was carried out by officers of the Geological Survey of Ireland under the direction of J.B. Jukes, resulting in the publication of geological maps accompanied by an explanatory Memoir (Jukes et al., 1861). The term "Glengarriff Grits" was used to denote thick developments of greenish sandstones, which they believed to occur predominantly in the lower part of the Iveragh succession. The term "Dingle Beds" was used for the purple and green beds on the Dingle peninsula which lay above the fossiliferous Silurian but below the angular unconformity. The Survey maps showed the entire succession on Iveragh as 'Old Red Sandstone', but in the accompanying Memoir Jukes noted that the lower part contained thick green 'Glengarriff Grits' which were lithologically similar to the 'Dingle Beds'. Jukes stated that on Iveragh, unlike Dingle, it was not possible to clearly separate the green grits from the 'Old Red Sandstone'. He therefore elected to map the 'Dingle Beds' as a separate group in the Dingle area, where their distinctiveness could be proved, but did not attempt to make the distinction on Iveragh, where no clear evidence for it was to be found (Jukes et al., 1861).

The problem was revived by Kinahan (1878) and Hull (1879) who again put forward the idea that the 'Glengarriff Grits' and the 'Dingle Beds' could be correlated on the grounds of stratigraphical position and lithological similarity. Hull claimed to have found on Iveragh the same angular unconformity that is seen on Dingle, and proposed that the Carboniferous Limestone rested unconformably on top of a thick Silurian succession, with the 'Old Red Sandstone' completely absent. Kinahan did allow that some 'Old Red Sandstone' was present, but in his view the 'Old Red Sandstone' was merely a basal subdivision of the Carboniferous anyway.

The next major contribution came from Wright, in the Memoir on the geology of Killarney and Kenmare (Wright et al., 1927). He reviewed the previous work on Iveragh in some detail, and strongly criticised Hull's contribution, rejecting it in favour of the earlier work by Jukes and his colleagues.

Detailed work on Iveragh was resumed some time later with the publications of Capewell (1957, 1975) and Walsh (1968), essentially dealing with remapping large parts of the area previously examined by the original Geological Survey. Both authors expressed the opinion that any northwards correlation with the 'Dingle Beds' was most unlikely. Capewell particularly stressed that Hull's proposal of an angular unconformity on Iveragh was completely unfounded.

Review papers by Naylor and Jones (1967) and Gardiner and Horne (1972) attempted to present a general synthesis of current knowledge concerning the Devonian and Lower Carboniferous in southern Ireland. Naylor and Jones interpreted the red-bed succession on Iveragh as belonging entirely to the 'Old Red Sandstone', probably analogous to the Upper 'Old Red Sandstone' of Britain. Gardiner and Horne courageously attempted an ambitious regional correlation of existing local stratigraphies, but surprisingly chose to ignore what was by then the generally accepted view on the age of the

Iveragh succession. Instead they resurrected the ideas of Griffith and Hull and correlated the lower part with the Dingle Group of supposed Silurian age.

Recent work has now provided palaeontological evidence of the ages of both the Iveragh succession and the Dingle Group (Russell, 1978; Van der Zwan, 1980; Higgs and Russell, 1981), and is discussed elsewhere in this thesis in more detail. The work may briefly be summarised as demonstrating beyond any reasonable doubt that the Iveragh succession is considerably younger than the Dingle Group, and therefore the previous proposals to correlate the two are clearly no longer tenable.

6.2 Results of the present investigation

The area covered by the present investigation consists of selected sections on the western end of the Iveragh peninsula, and also along the southern side of the peninsula as far east as Sneem (Text Fig. 3). Each of the sections is described in turn below, and their relevance to problems of stratigraphical nomenclature and correlation is discussed.

There is a broad overall subdivision of the Iveragh succession into a lower extremely thick sequence of continental red-bed sediments, and an upper thinner development of marginal marine sandstones and shales. The red-bed sequence is subdivided into formations, but in view of its overall similarity and the sharp contrast with the overlying marginal marine sediments, the red-bed part of the Iveragh succession is designated as the Iveragh Group.

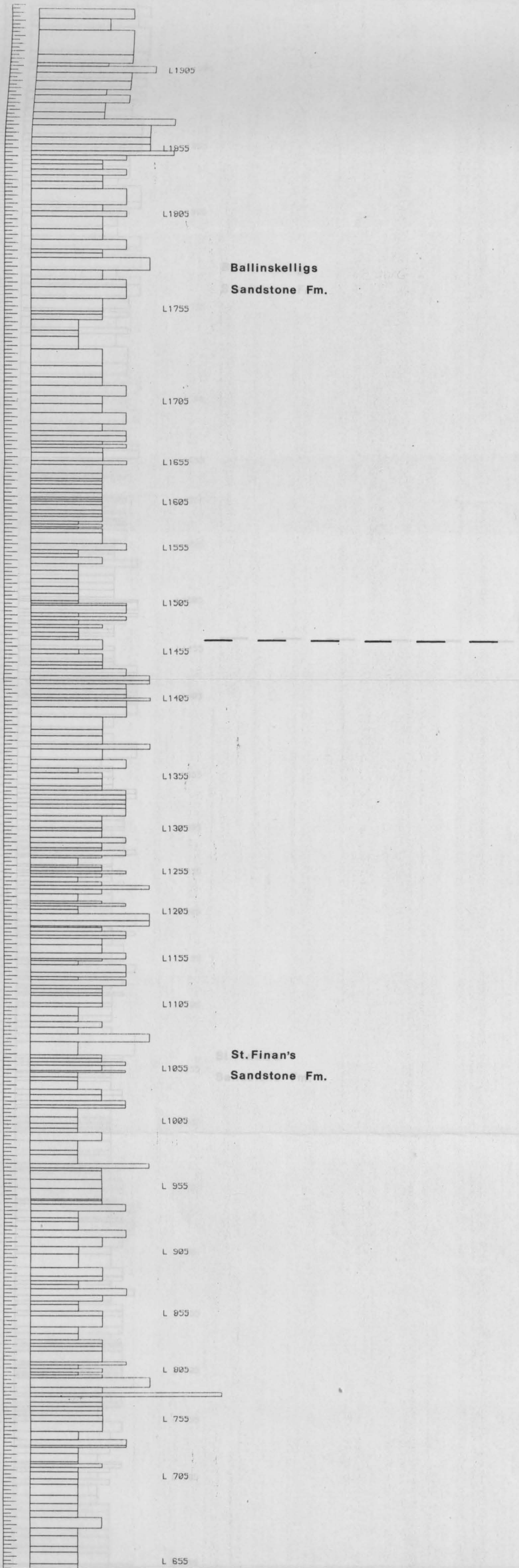
6.2.1 THE ATLANTIC COAST SECTION

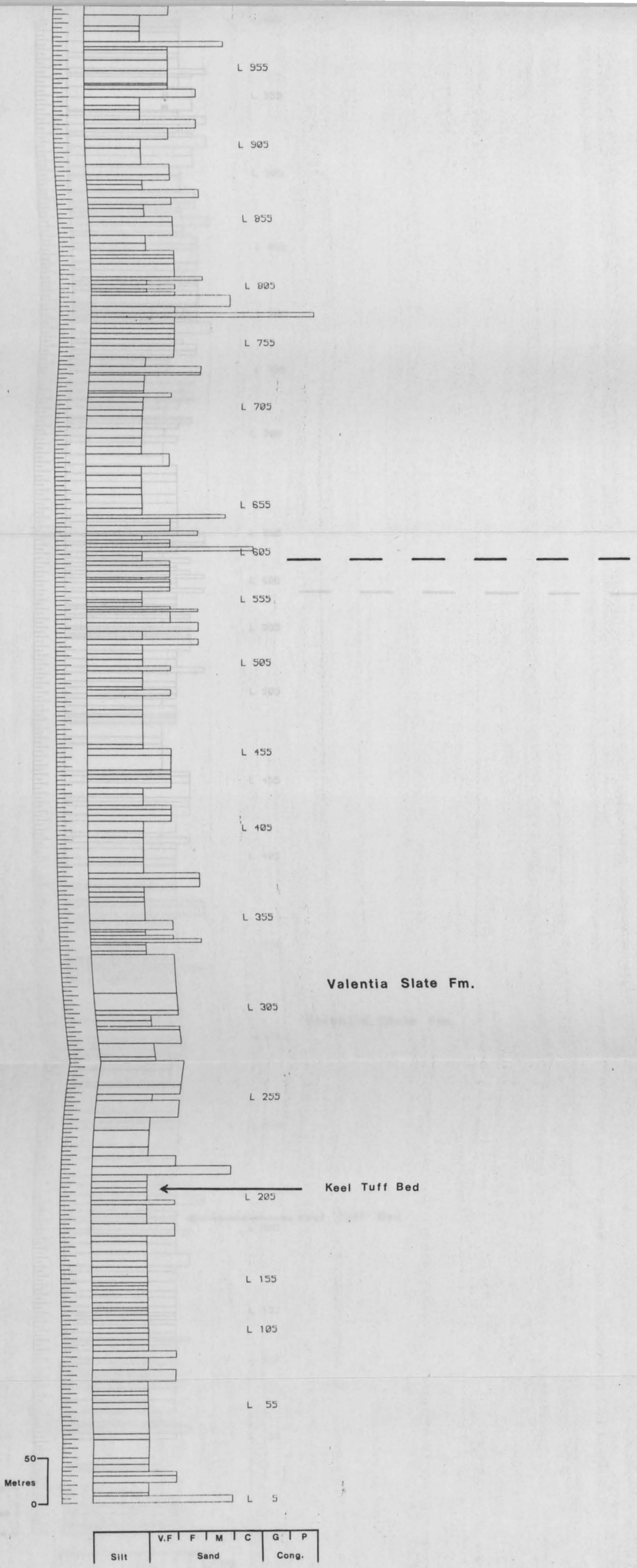
The Atlantic Coast section is located on the western end of the Iveragh peninsula (Text Fig. 3, SECTION 5; and Text Figs. 41-42). The section stretches along some 15Km of coastline lying to the north and west of the town of Waterville. Between the steep sea-cliffs at Dromgour (V 355 706) in the north and the rocky promontory of Bolus Head (V 383 615) in the south, the rocks young and bedding dips steeply in a southerly direction, forming the southern limb of the Portmagee Anticline (Capewell 1975). The rocks are very well-exposed and provide a continuous section through over 3700m of red-bed sediments, although the base and top of the red-bed sequence are not exposed.

Detailed logging of the section gives a measured thickness of 3555m, and a further 200m are calculated to lie between the lowest accessible point and the lowest exposed beds in the section, giving a total thickness of at least 3755m. The sequence has been subdivided by Capewell (1975) into three formations with typically gradational boundaries. The same subdivisions are adopted in this thesis, but the formation boundaries have been redefined to differ slightly from those used by Capewell. The Atlantic Coast section is the type-section for these three formations.

ATLANTIC COAST SECTION

GRAINSIZE PLOT
GROUPING N=5




L 955
L 905
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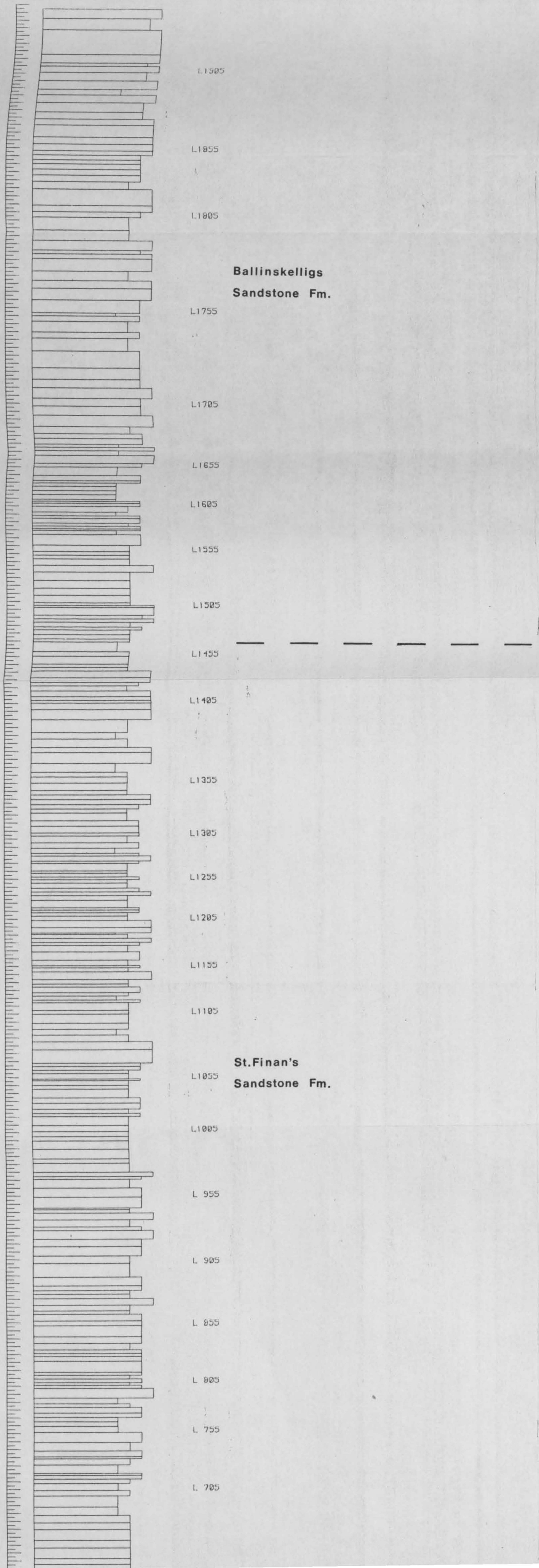
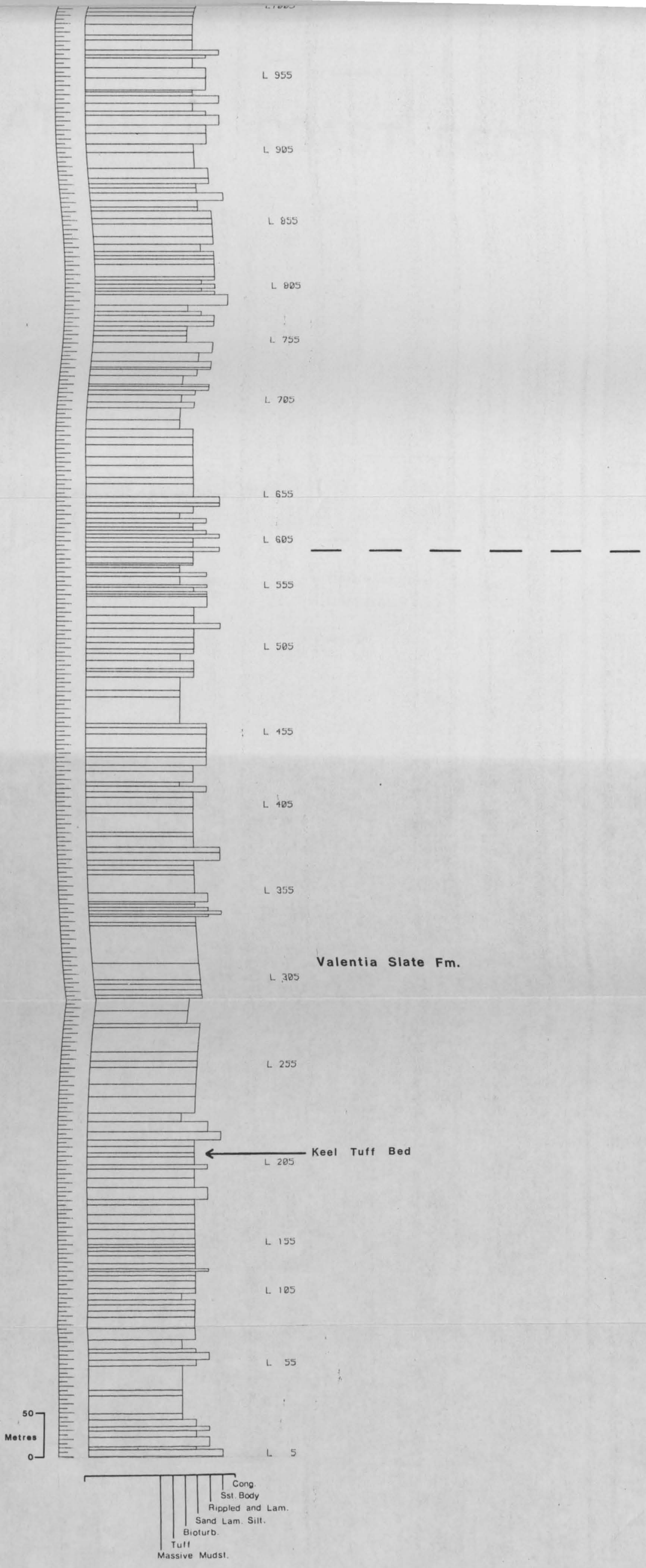
L 655
L 605
L 555
L 505
L 455
L 405
L 355
L 305
L 255
L 205
L 155
L 105
L 55
L 5
Valentia Slate Fm.
Keel Tuff Bed
50
Metres
0
Silt
V.F
F
M
C
Sand
G
P
Cong.

TEXT FIG.41

ATLANTIC COAST SECTION

FACIES PLOT
GROUPING N=5




L 955
L 905
L 855
L 805
L 755
L 705
L 655
L 605
L 555
L 505
L 455
L 405
L 355
Valentia Slate Fm.
L 305
L 255
Keel Tuff Bed
L 205
L 155
L 105
L 55
50
Metres
0
L 5
Cong.
Sst. Body
Rippled and Lam.
Sand Lam. Silt.
Bioturb.
Tuff
Massive Mudst.

TEXT FIG 13

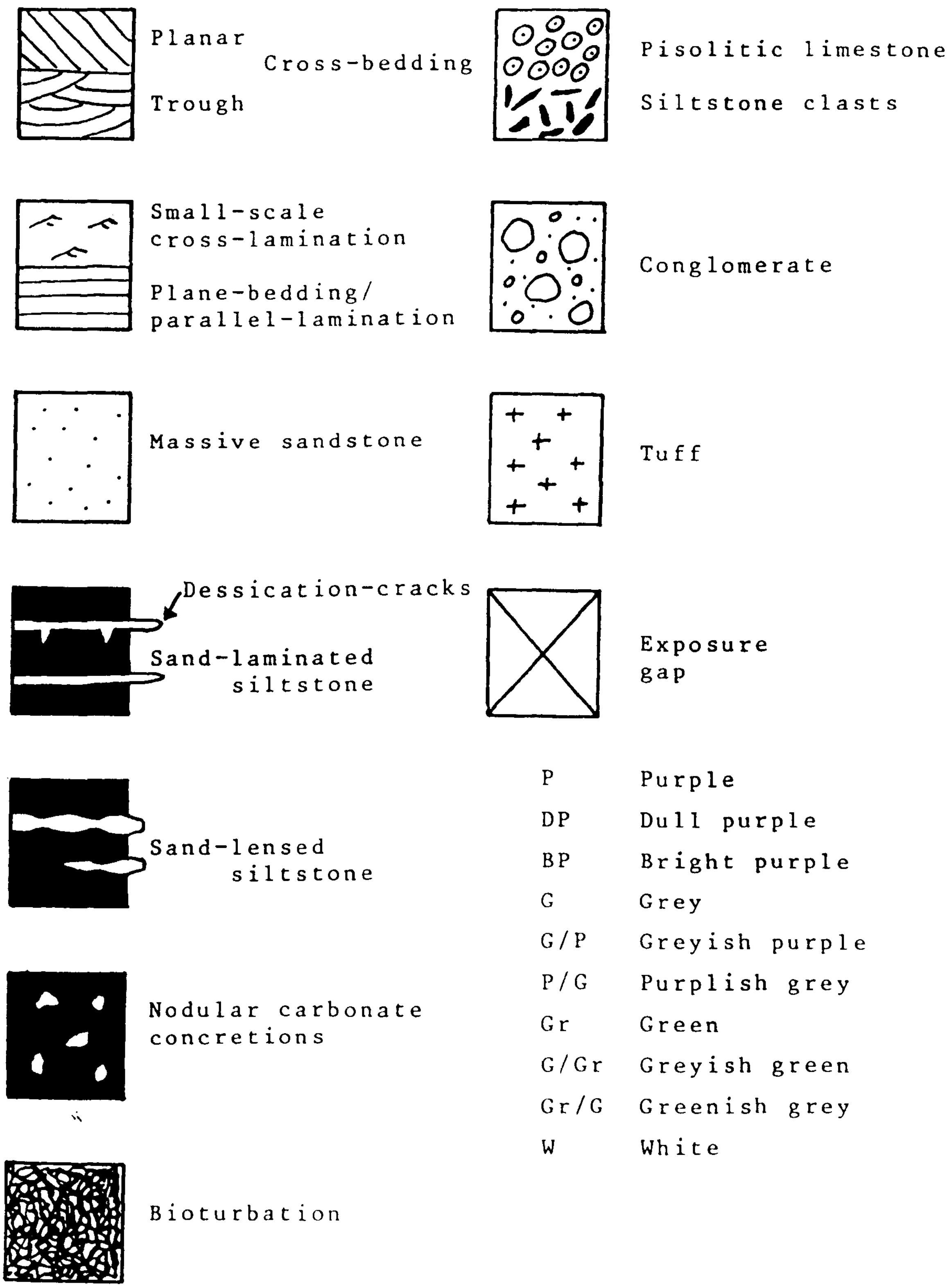
ATLANTIC COAST SECTION

BALLINSKELLIGS SANDSTONE FM.	756m +
ST. FINAN'S SANDSTONE FM.	1438m
VALENTIA SLATE FM.	1561m +
(Including the Keel Tuff Bed)	

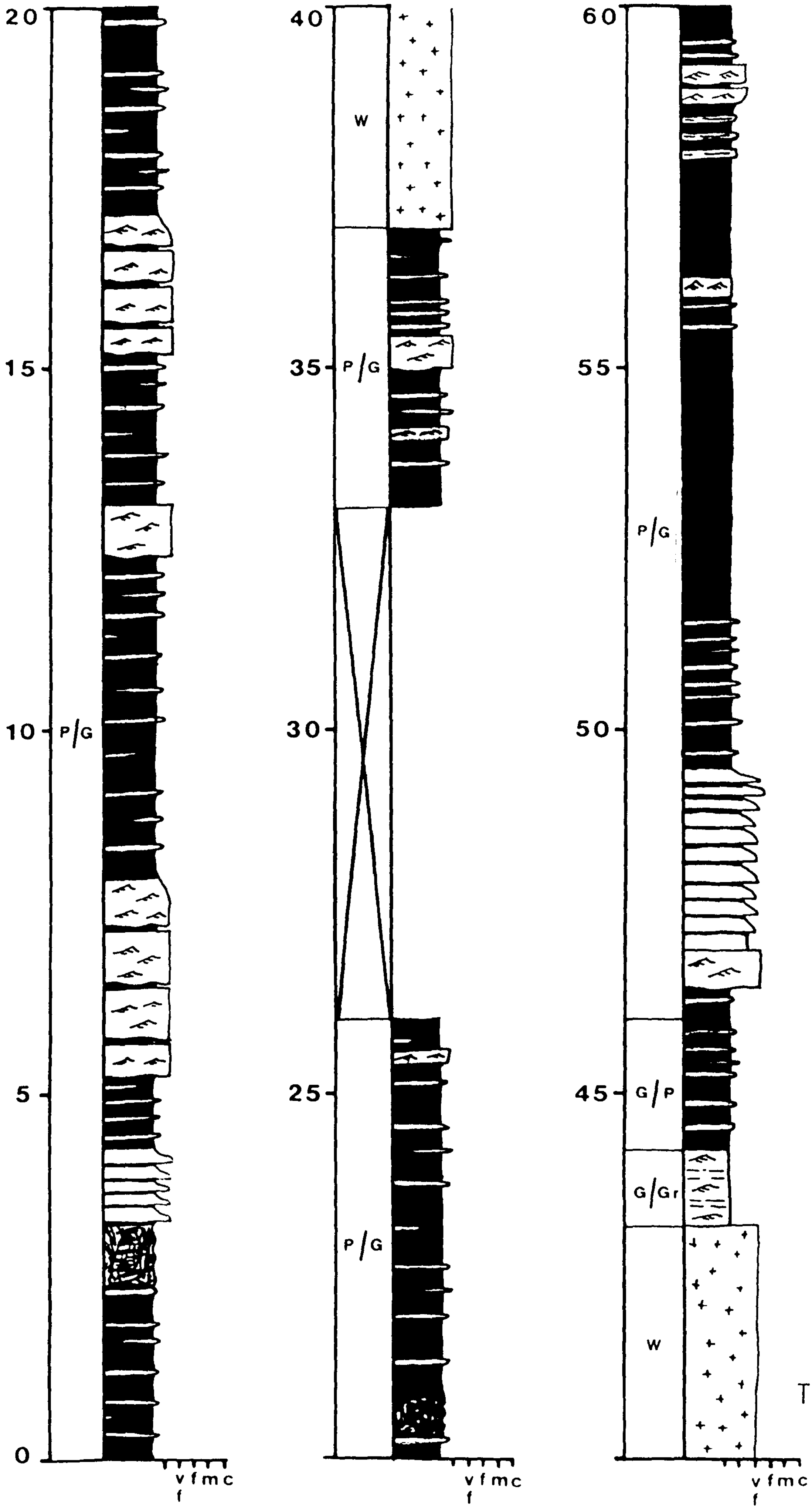
Valentia Slate Formation

The Valentia Slate Formation is stratigraphically the lowest and oldest of the three formations. The base is not seen, but structural and thickness evidence indicates that the lowest exposed beds are the oldest rocks seen on Iveragh. The formation is dominated by sand-laminated siltstone (61%), occasionally coarsening to rippled and laminated very fine silty sandstone (21%) (Text Fig. 43). The rocks are typically pale green to purplish grey in colour, with green rocks occurring most frequently in the lower parts of the formation. The formation coarsens slightly towards the top, due to an increase in the relative proportion of rippled and laminated facies, accompanied by the appearance of rare thin and rather silty units of sandstone body facies. At least five beds of concentrated fossil fish material have been observed at various levels in the formation (see CHAPTER 4), the lowest of which lies approximately 240m above the lowest exposed strata. A thin (30cm) tuff bed is poorly exposed 260m above the lowest exposed strata, and a thicker (6.3m) tuff bed of similar appearance occurs 766m below the top of the formation. The latter was originally noted by the

These Text-Figs. show a series of representative short logs from the various stratigraphic units on different sections, to illustrate the range and relative abundance of facies types. The vertical scale is in metres.



ATLANTIC COAST SECTION



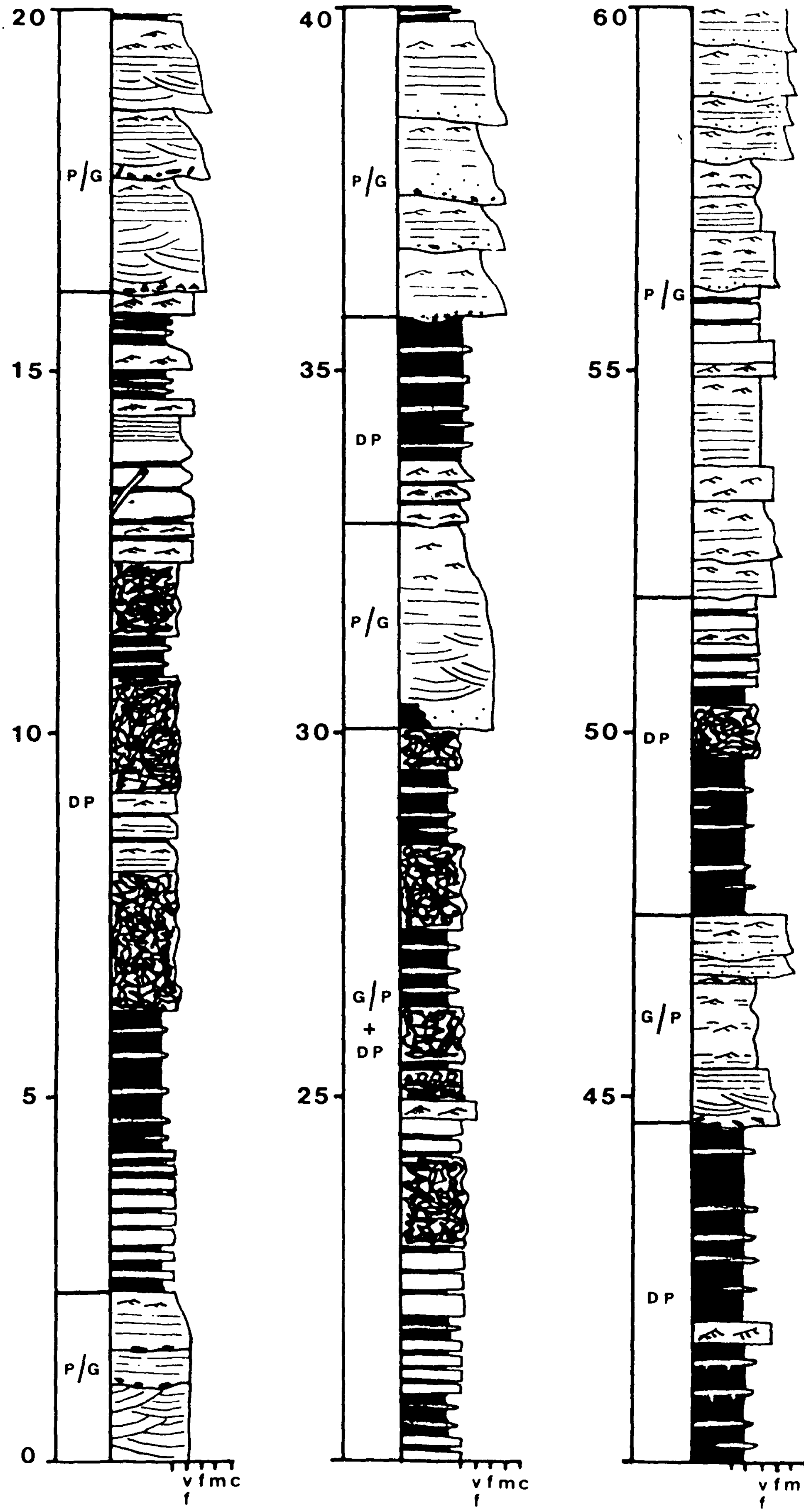
TEXT FIG.

Geological Survey (Jukes et al., 1861) and described as a 'felstone'. Mapping for this thesis has identified and correlated the same bed north of the Portmagee Anticline axis, and is is here designated the Keel Tuff Bed after the locality from which it was first described.

St. Finan's Sandstone Formation

The name introduced by Capewell (1975) is retained, although the formation is certainly not dominated by sandstones (Text Fig. 15) and is sandy only in contrast with the underlying Valentia Slate Formation. Capewell defined the base as "where sandstones become dominant", which in view of the previous point is clearly an unsatisfactory definition. The base is redefined here as the level at which significant quantities of sandstone body facies first appear in the section. This places the boundary approximately 670m south from Keel Strand, some 360m above Capewell's original boundary. The formation consists of greyish purple fine sandstones and siltstones of the same facies as the Valentia Slate Formation, but the proportion of sand-laminated siltstone has decreased to 42% and sandstone body facies has increased to 16% (Text Figs. 15 and 44). A thin conglomerate lag occurs at the base of a sandstone body near the middle of the formation, and rare granule-strewn bedding planes are also noted at several higher levels. With the exception of this coarser material, all of which is quartz, the entire thickness of the formation is dominated by sediments no coarser than fine sandstone. One fish-bed is recorded at a level of 142m above the base of the formation. Bright reddish purple siltstones are

ATLANTIC COAST SECTION



TEXT FI

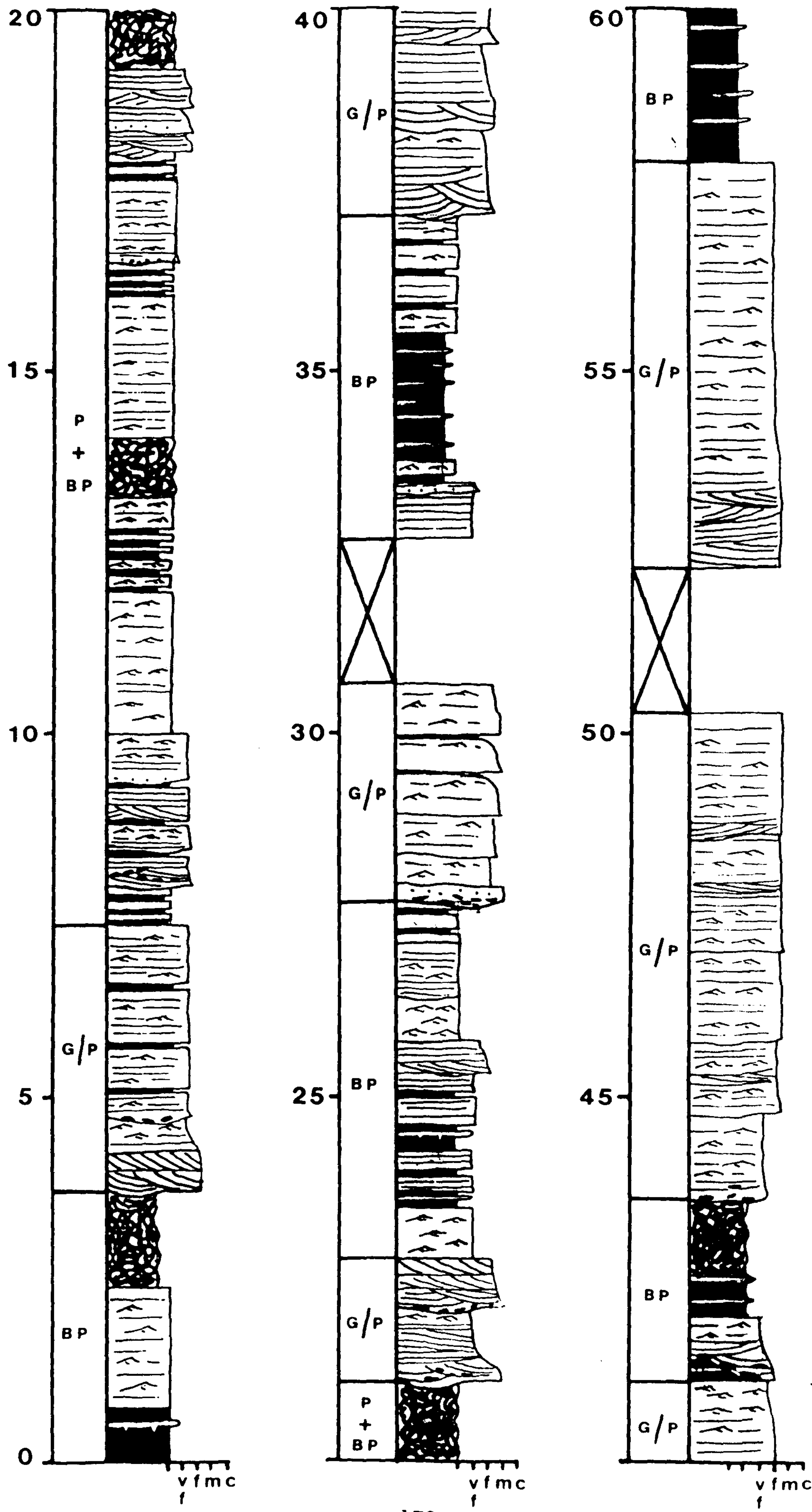
interbedded locally towards the middle of the formation, also appearing in increasing abundance towards the top of the formation in the uppermost 200m.

Ballinskelligs Sandstone Formation

As with the underlying St. Finan's Sandstone Formation, the name used by Capewell has been retained, and in this case sandstones make up around 50% of the total formation thickness (Text Fig. 45). Rippled and laminated facies here tends to be the coarse end-member type and therefore contains a considerable proportion of fine sandstone. Text Fig. 15 shows that the sandstone body facies and rippled and laminated facies together make up over 60%, while the finer (bioturbated, and sand-laminated siltstone) facies are reduced to 38%. The formation is a bright reddish-purple colour throughout, including the sandstone as well as the finer grained lithologies. Capewell defined the base as the point where purple sandstones become dominant. It has been noted above that reddish purple lithologies are locally present in the underlying formation, particularly in gradually increasing amounts towards the boundary between the two formations. Depending on interpretation, the boundary could lie anywhere within a gradational zone approximately 400m thick. There is no marked change in grainsize or relative abundance of facies across the zone to supplement the colour change criterion. The base of the Ballinskellings Sandstone Formation was therefore arbitrarily taken at a thick and particularly bright purple sand-laminated siltstone unit, forming the southernmost margin of Cangarriff Point. A calcrete horizon (none have been

BALLINSKELLIGS SANDSTONE FORMATION

ATLANTIC COAST SECTION



TEXT FIG.4

observed in the underlying formations) is present near the top of this unit, and the colour of the lithologies (which shows some purple to grey fluctuation below the unit) appears reasonably constant bright purple above it. This places the base of the Ballinskelligs Sandstone Formation approximately 400m above Capewell's original boundary. A single fish-bed is recorded 109m above the base of the formation. Rare calcrete horizons are developed as small carbonate nodules scattered sparsely in the finer grained lighologies. Sandstones are very generally slightly coarser than in the underlying formation, and medium and even coarse grainsizes are occasionally observed, particularly towards the highest part of the formation exposed on this section.

6.2.2 THE ESKINE-KNOCKNAGULLION SECTION

In the southeastern part of the study area, towards the village of Sneem, the red-bed sequence is exposed on the southern limb of the Kilcrohane Anticline (or its eastern continuation). The oldest sediments are exposed in the core of the anticline as it crosses the Eskine ridge (V 740 725), and a sequence of progressively younger sediments is exposed in south-dipping beds between this and the peak of Knocknagullion (V 760 697) (Text Fig. 3, SECTION 10). Due to drift cover, exposure is intermittent, generally averaging around 50%. Capewell (1957) originally subdivided the sequence into a lower fine-grained unit (the Lower Slate Group) and two upper sandstone-dominated units (the Chloritic Sandstone Group and the Purple Sandstone Group). The same subdivisions are used here, but the units are downgraded to formation level. The unit boundaries as defined by Capewell are impractical and have been redefined. Due to the intermittent nature of the exposure, the section was logged by recording a number of suitable short sections of typical lithology where reasonably long well-exposed sequences were available (Text Figs. 46-47). A detailed traverse was used to locate the formation boundaries and record dip, and apparent thickness on the ground was then used to calculate true formation thickness. The Lower Slate Formation is not sufficiently well-exposed for this to constitute a type-section, although the alternative section described by Capewell (1957) from a quarry on Esknaloughoge contains nearly fifty percent sandstones and is not typical of the formation.

ESKINE - KNOCKNAGULLION SECTION

PURPLE SANDSTONE FM.	600m +
CHLORITIC SANDSTONE FM.	1628m.
(Including the Green Sandstone Member	(413m))
LOWER SLATE FM.	1458m. +
(Including the Eskine Sandstone Member	(66m))

Lower Slate Formation

The Lower Slate Formation is dominated by purplish grey coarse siltstones and silty fine sandstones. At the base of the exposed section, in the core of the Kilcrohane Anticline, a distinctive unit

SNEEM AREA SECTIONS

GRAINSIZE PLOT
GROUPING N=5

TEXT FIG. 46

SNEEM AREA SECTIONS

TEXT FIG. 47

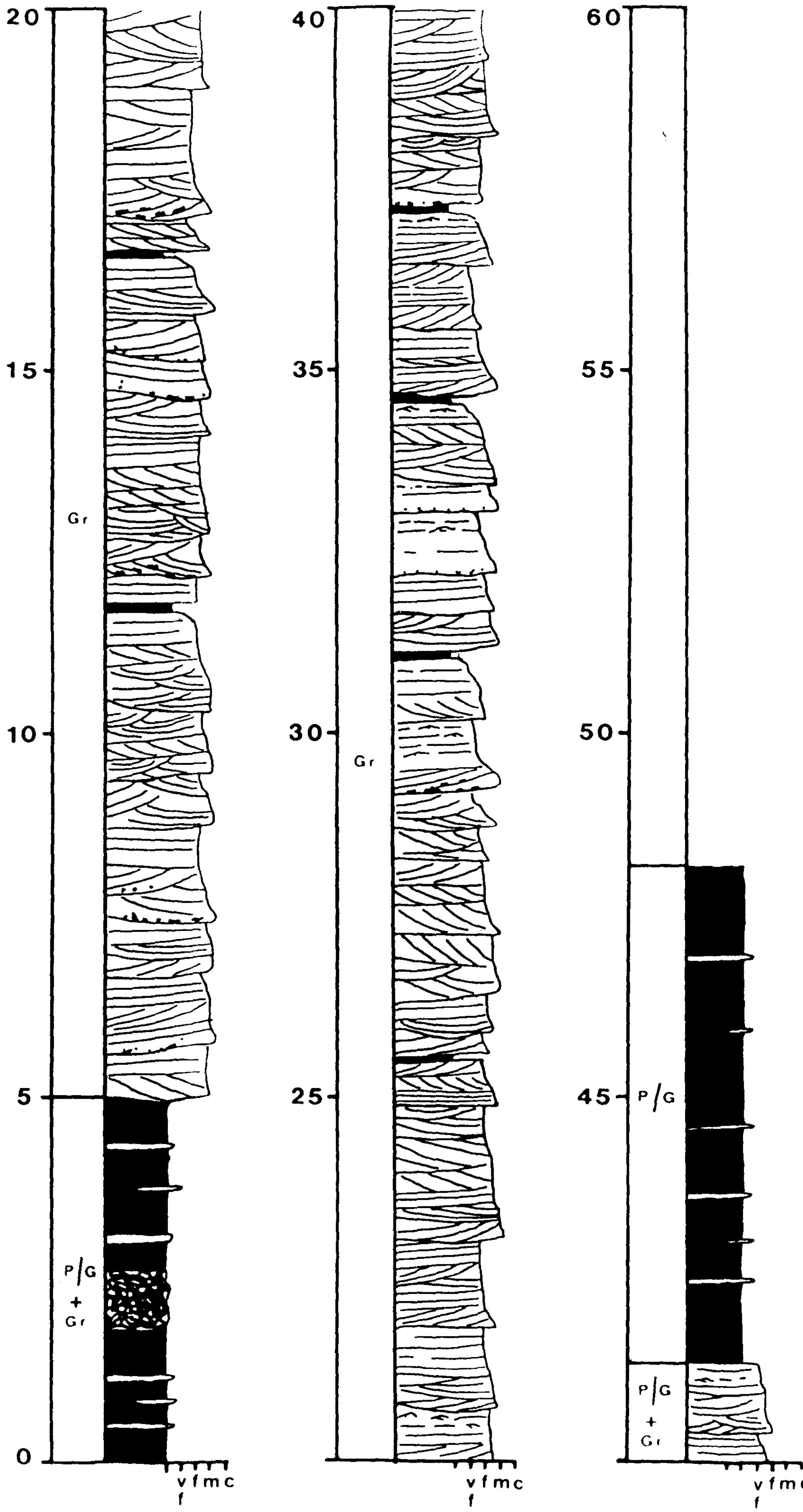
of very fine to medium green sandstones is developed (Text Fig. 48). The unit is 66m in thickness, including a 23m thick silty sandstone interbedded in the sequence. The sandstones are fairly typical sandstone body facies, showing plane bedding, cross bedding and multiple internal erosional surfaces. Intraformational siltstone clasts up to 10cm in diameter are present in some parts of the sandstones. The unit is sufficiently distinct from the remainder of the Lower Slate Formation to warrant recognition as a member, thickness and lack of laterally extensive exposure being insufficient to justify separate formation status. It is here defined as the Eskine Sandstone Member. The remainder of the Lower Slate Formation consists mainly of purplish grey silty and very fine sandstones of either rippled and laminated facies, or bioturbated facies with traces of rippled or laminated bedding (Text Fig. 49). Sand-laminated siltstone facies is also present but becomes less abundant as the formation coarsens gradually towards the top. Rare thin (1-2m) beds of green sandstone body facies occur throughout the formation.

Chloritic Sandstone Formation

Capewell (1957) did not define the base, preferring to describe the overall character of his 'Chloritic Sandstone Group' instead. He described it as dominated by dull, purplish-grey, medium grained siliceous sandstones, but stated that the unit was characterised by green medium to coarse grained quartzitic sandstones (the 'chloritic sandstone'). In fact, the readily identifiable green sandstones are limited to a relatively small part of the formation and are separated here as a Green Sandstone Member within the Chloritic

ESKINE SANDSTONE MEMBER

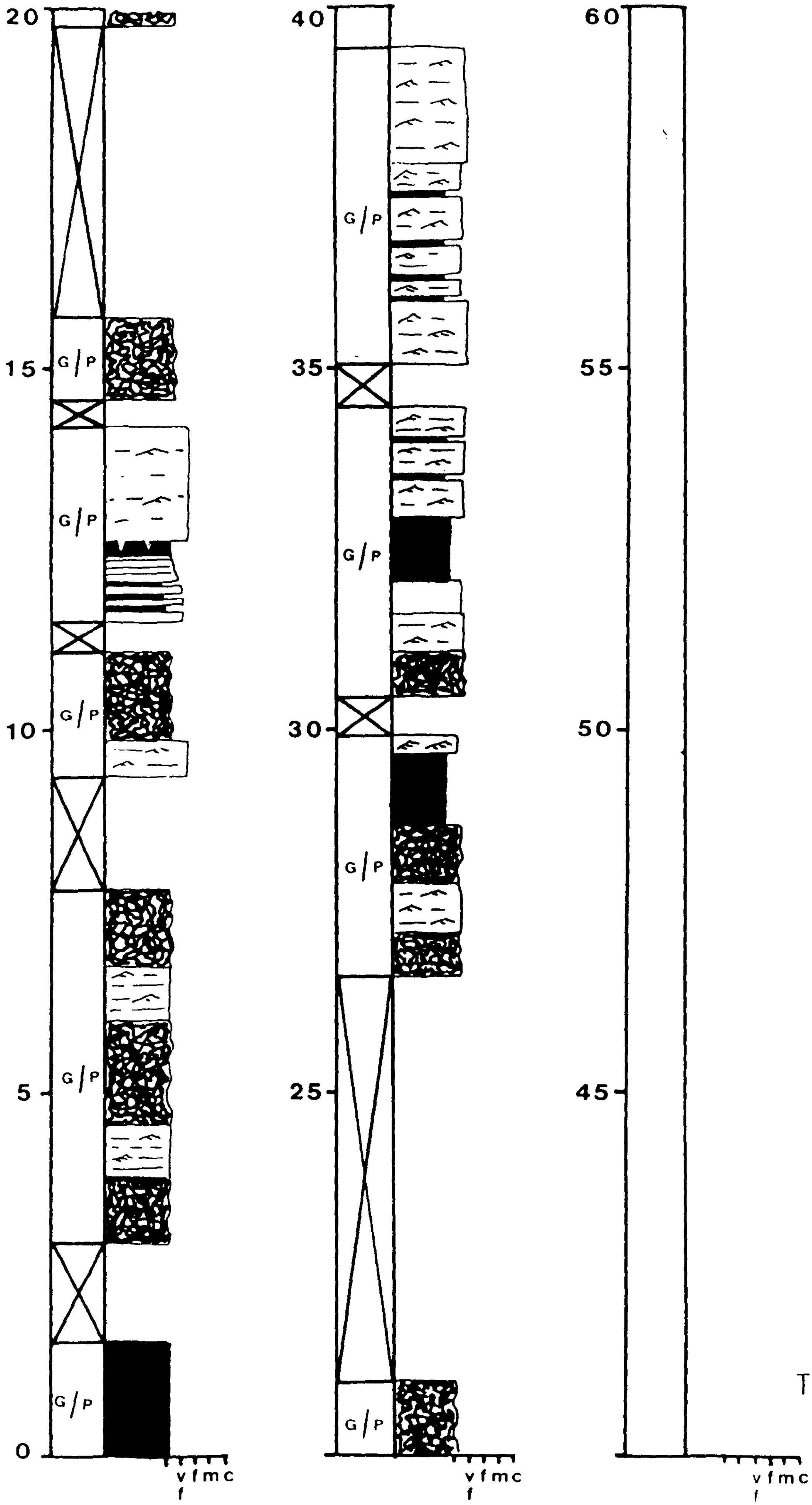
ESKINE-KNOCKNAGULLION SECTION



TEXT FIG.48

LOWER SLATE FORMATION

ESKINE-KNOCKNAGULLION SECTION



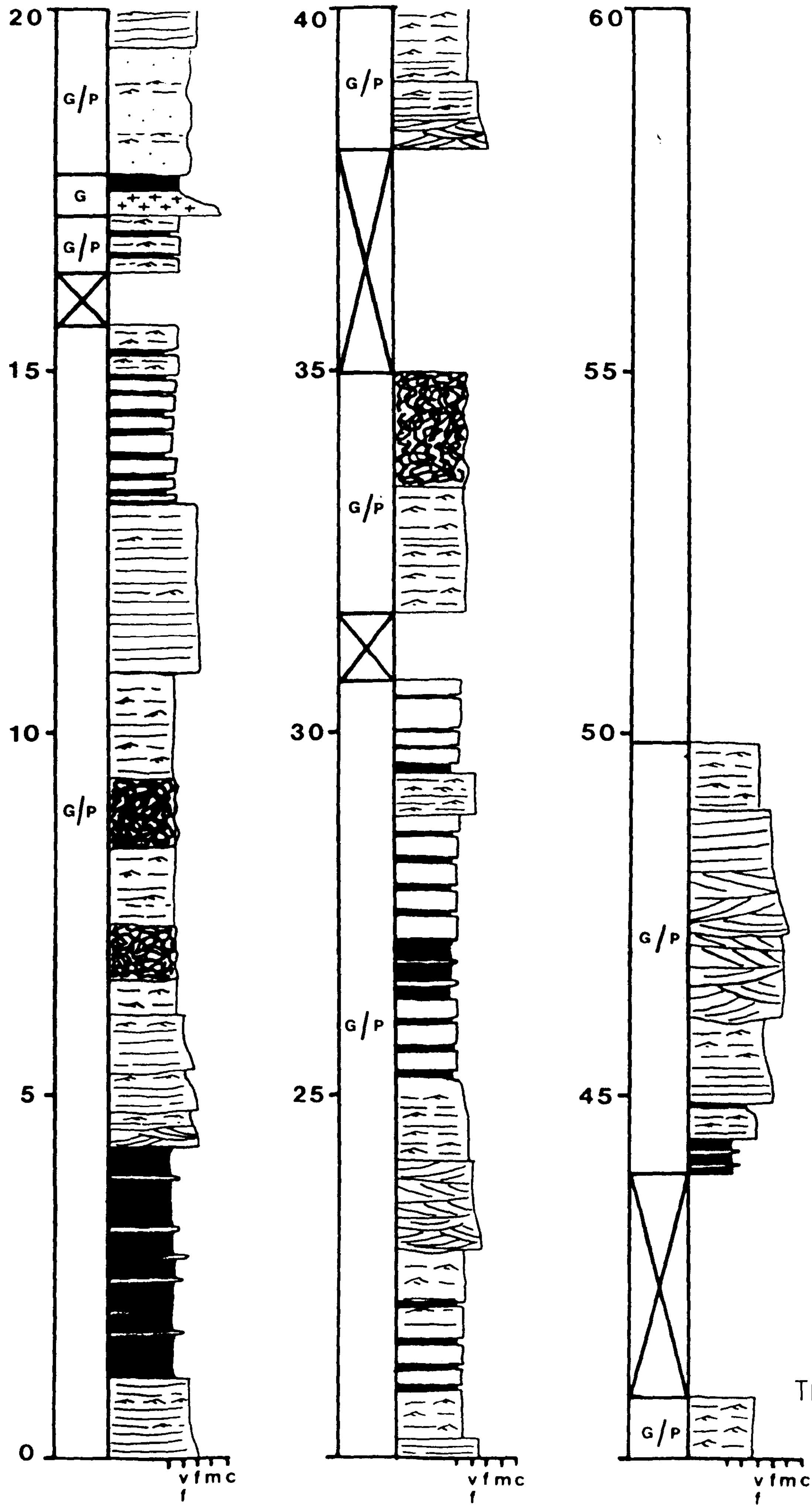
TEXT-FIG.49

Sandstone Formation. The base of the formation is defined here as the level at which significant quantities of sandstone body facies first appear and persist in the section. This occurs as a fairly rapid change just south of the 'B' road from Sneem to Killarney and can be readily identified in the field.

The formation is dominated by greyish purple silty to very fine sandstones of rippled and laminated facies (Text Fig. 50). Bioturbated and sand-laminated siltstone facies are present in smaller amounts. Both they and the rippled and laminated facies tend to be the coarser end-members of their facies types, with grainsizes ranging from silty to very fine sandstone. 185m above the base of the formation, a thin (3-4cm) tuff bed contains scattered medium sized crystals of quartz and pink feldspar. 900m above the base of the formation a 413m thick group of greenish sandstones is interbedded in the sequence. Where these are thickly developed, the sandstones coarsen to medium grainsize and contain scattered quartz and jasper pebbles. The sequence containing the green sandstones is sufficiently distinctive to warrant recognition as a member within the formation, and has been named the Green Sandstone Member (Text Fig. 51). The remaining 316m of the Chloritic Sandstone Formation above the Green Sandstone Member consists of similar interbedded greyish purple siltstones and sandstones to those in the lower part of the formation. The purple colours, particularly those of the siltstones, become perceptibly brighter towards the top of the formation.

CHLORITIC SANDSTONE FORMATION

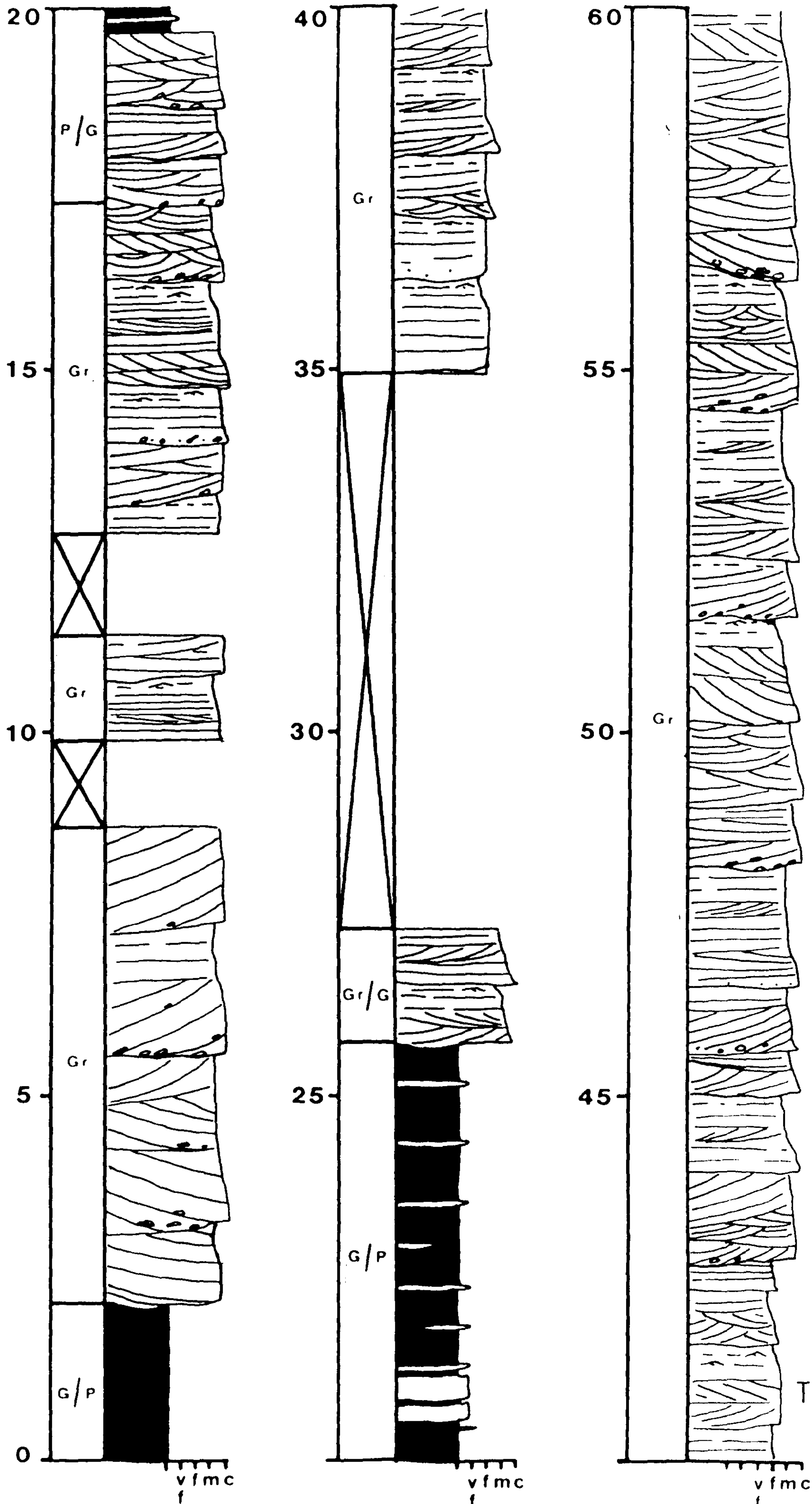
ESKINE-KNOCKNAGULLION SECTION



TEXT FIG.50

GREEN SANDSTONE MEMBER

ESKINE-KNOCKNAGULLION SECTION



TEXT FIG.51

Purple Sandstone Formation

The Purple Sandstone Formation becomes progressively less well-exposed above the base, so only the lower part has been investigated on this section. Capewell (1957) defined the base of his Purple Sandstone Group as the point above which grey and green sandstones die out, and stated that the overlying sediments are devoid of any green rocks. As indicated above, the Green Sandstone Member in the upper part of the Chloritic Sandstone Formation is overlain by more than 300m of greyish purple sediments which, in an area where the formation is absent, could not be distinguished from the remainder of the formation. The base of the Purple Sandstone Formation is therefore taken as the point above which bright purple rocks become predominant. This change also appears to coincide with a general reduction in grainsize which persists for a considerable distance above the base of the formation. Although less easy to identify in the field than the top of the Green Sandstone Member, the definition has the advantage that it may be mapped further to the west, where the Green Sandstone Member wedges out.

The lower part of the Purple Sandstone Formation is dominated by bright purple siltstones and silty very fine sandstone of rippled and laminated or sand-laminated siltstone facies. Exposure deteriorates upsection so that logging is impractical, but several hundreds of metres above the base of the formation the sediments gradually coarsen to include occasional beds of sandstone body facies, while maintaining the bright purple colour. An estimated

600m above the base of the formation a group of bright green sandstones at least 10m in thickness is exposed, but appears to be unique in its occurrence.

6.2.3. THE SNEEM RIVER SECTION

Coastal exposure along the eastern side of the Sneem River inlet provides a more or less continuous and well-exposed section through the middle and upper parts of the red-bed succession (Text Fig.3, SECTION 9). The Lower Slate Formation is not exposed, but the section overlaps with the Eskine-Knocknagullion section and continues still higher in the succession (Text Figs. 46-47). The section commences at Sneem Quay (V 688 682) and continues southeastwards as far as Rossdohan Harbour (V 715 636). Capewell (1957) subdivided the lower part of the sequence into his 'Chloritic Sandstone Group' and 'Purple Sandstone Group' mentioned previously. Above this he recognized a 'Coomhola Series' of grey shales and sandstones, separated from the underlying 'Purple Sandstone Group' by a 'Transition Group' with intermediate charcteristics. The two lower subdivisions are retained as discussed previously, downgraded to formation status. The 'Transition Group' is redefined here as the Derryquin Sandstone Formation. The 'Coomhola Series' is renamed and redefined as the Rossmore Sandstone Formation. Retention of the word Coomhola has been avoided due to regional connotations which have been placed on the term (Gardiner and Horne, 1972).

The section is the type-section for the Purple Sandstone Formation and Derryquin Sandstone Formation. The Chloritic Sandstone

Formation is only partly exposed, so a proper definition requires examination of the additional section between Eskine and Knocknagullion.

SNEEM RIVER SECTION

ROSSMORE SANDSTONE FM.	Base only
DERRYQUIN SANDSTONE FM.	661m
PURPLE SANDSTONE FM.	1934m
CHLORITIC SANDSTONE FM.	162m +
(Including the Green Sandstone Member (162m+))	

Chloritic Sandstone Formation

Only the uppermost 162m of the formation is exposed, all of which consists of the Green Sandstone Member. The highest bright green sandstone is immediately followed by predominantly bright purple sediments of the overlying Purple Sandstone Formation. The Green Sandstone Member here is dominated by 1-12m thick bright green fine to medium sandstones of the sandstone body facies. Several of the upper sandstones contain cross-bedded lenticular lags with intraformational siltstone clasts and reworked nodular carbonates. Subordinate amounts of bright purple and greyish purple siltstones and silty very fine sandstones of rippled and laminated facies and sand-laminated siltstone facies are also present.

Purple Sandstone Formation

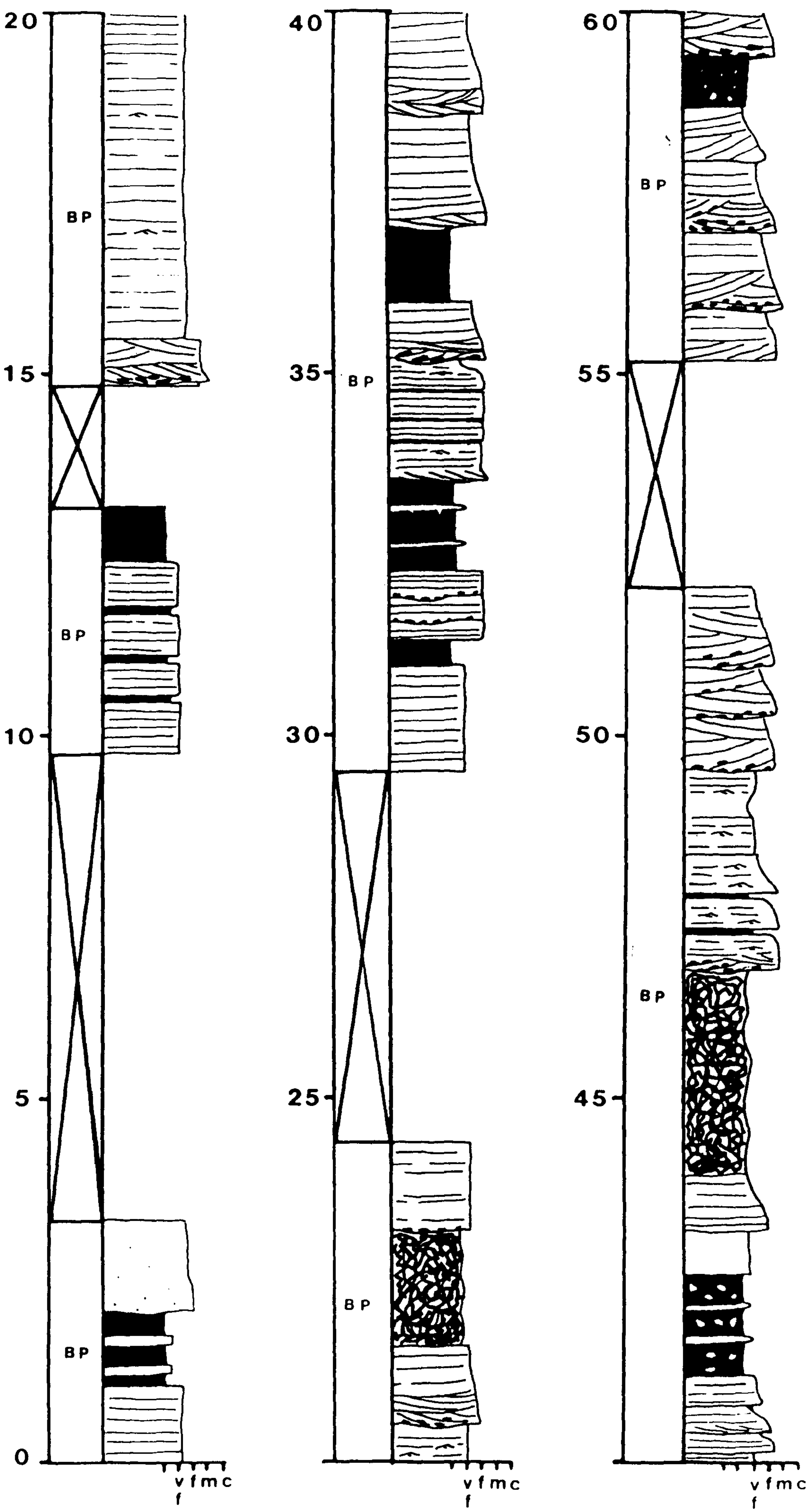
The base of the formation is defined, as previously described for the Eskine - Knocknagullion section, on the incoming of predominantly bright purple colours. This places the base 162m upsection from Sneem Quay (where the section commences), and a very considerable 620m downsection from the point on Capewell's geological map where he places his boundary. The formation is dominated by very fine bright purple sandstones, of both sandstone body facies and rippled and laminated facies (Text Fig. 52). The sandstone body facies here is relatively fine-grained, and only the presence of occasional cross-beds serves to distinguish it from the coarse end-member of rippled and laminated facies. Occasional thin lenticular lags are present in the sandstones, and contain intraformational siltstone clasts, or, more rarely, reworked nodular carbonates. The proportion of sandstone gradually increases upwards in the formation, producing an overall coarsening-upwards trend. Towards the top of the formation, siltstone beds tend to become finer and less distinctly bedded, and are occasionally completely massive. Approximately 30m below the top of the formation, at least three calcrete horizons are developed in beds of this massive siltstone facies.

Derryquin Sandstone Formation

The Derryquin Sandstone Formation overlies the Purple Sandstone Formation as a 661m thick sequence of green, buff and purplish-grey sandstones, interbedded with upwards decreasing amounts of typical

PURPLE SANDSTONE FORMATION

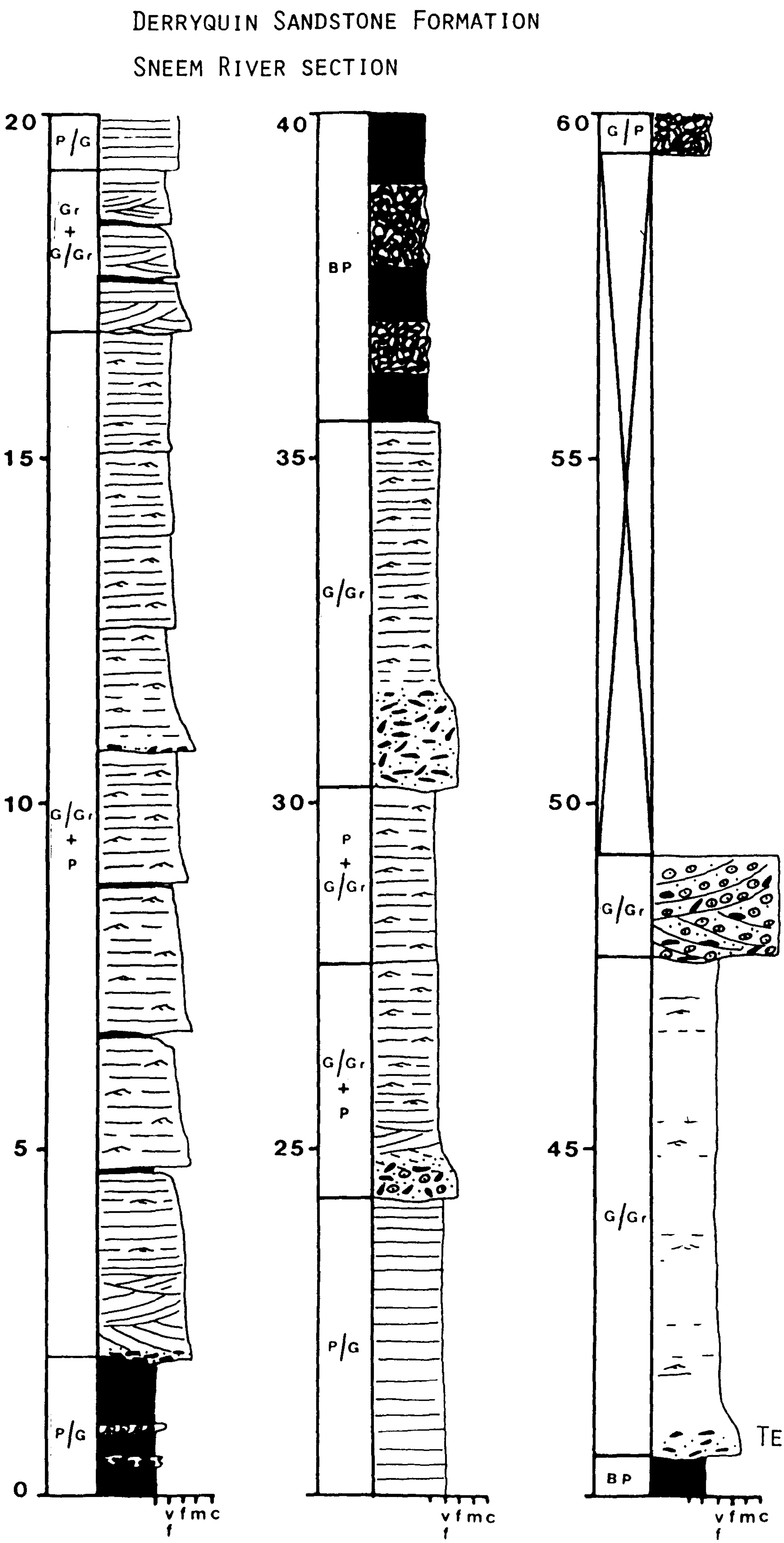
SNEEM RIVER SECTION



TEXT FIG.52

Purple Sandstone Formation type lithologies (Text Fig. 53). Capewell (1957), called this his 'Transition Group' and defined the base as the incoming of the first grey bed. This leaves a number of conspicuous pale green sandstones remaining with the Purple Sandstone Formation, when they obviously have a much closer affinity to the varicoloured sandstones above. The base is here redefined as the first appearance of green, buff or greyish sandstones, which includes the green sandstones noted above and places the boundary approximately 170m downsection from where it was drawn by Capewell. The name given to the unit by Capewell has interpretive connotations, and since it is not widely used or entrenched in the literature, has been replaced here by a purely descriptive name more in keeping with modern practice. It has been renamed the Derryquin Sandstone Formation after the lithology and local area which characterise it, and downgraded in status to match the adjacent formations.

Several calcrete horizons are developed at different levels within the formation. One is particularly noteworthy, being the thickest and most intense calcrete development observed in the entire study area. The horizon occurs 21m above the base of the formation and consists of 75cm of virtually pure carbonate. In the upper part of the formation, several lags contain limestone pisolites, as well as indeterminate fossil fish fragments. A conspicuous pisolitic lag over 1m thick occurs approximately 50m below the top of the formation. Directly overlying the lag is a greenish grey siltstone containing plant miospores of Uppermost Devonian age (Higgs and Russell, 1981 (see CHAPTER 4)).


DERRYQUIN SANDSTONE FORMATION
SNEEM RIVER SECTION
0
5
10
15
20
25
30
35
40
45
50
55
60
P/G
G/Gr + P
Gr + G/Gr
P/G
G/Gr + P
P + G/Gr
G/Gr
BP
BP
G/Gr
G/Gr
G/P
v f m c
f

TEXT FIG.53

The Rossmore Sandstone Formation

The base of the Rossmore Sandstone Formation occurs just inland from the highest coastal exposure on the Sneem River section. It is poorly exposed, and is included here only for completeness and to demonstrate that the logged sections have measured the full thickness of the underlying Purple Sandstone Formation. Capewell (1957) did not define a base for his 'Coomhola Series', but his description of the lithology of this unit implies that it must occur above the last purple bed. A number of changes take place around this level; purple beds die out upwards rather abruptly, dark grey mudstones and siltstones appear for the first time, and distinctive white-weathering well-cemented sandstones with a slight flaggy tendency become commonly interbedded in the sequence. From examination of better exposed areas to the east of Tahilla and along the coast towards Rossmore Island, isolated patches of purple siltstones and grey siltstones have been found to occur some distance above and below the levels at which they occur in bulk. The base of the Rossmore Sandstone Formation is therefore defined here as the first appearance of the white-weathering sandstones (grey quartzitic sandstone facies), while noting that the bulk disappearance of purple beds or bulk appearance of grey mudstones and siltstones can usefully serve as approximate markers. This places the boundary approximately 30m above the highest rocks exposed on the coast at Rossdohan Harbour, in the same position where Capewell mapped the base of his 'Coomhola Series'.

6.2.4 THE ROSSMORE ISLAND SECTION

The Rossmore Island section overlaps with the top of the Sneem River section, and extends considerably higher with an estimated minimum 525m of the Rossmore Sandstone Formation exposed. The section extends southeastwards from a point 0.8Km to the north of Lough Fadda (V 750 670), to the highest exposed beds on the southeastern coast of Rossmore Island (V 765 655). The section commences in the Derryquin Sandstone Formation, approximately 175m below the base of the Rossmore Sandstone Formation. Rocks of the Purple Sandstone Formation are exposed to the north beyond this point, but have been displaced across the Derreenrickard Fault (Capewell, 1957) which has an apparent dextral throw of over 1Km. In any case, exposure decreases rapidly north of the fault below small fields and poorly-drained areas. For these reasons, detailed investigation was confined to the area south of the fault.

The lower parts of the section are only intermittently exposed. The rocks young and bedding dips southeastward, towards the axis of the Kenmare Syncline. The upper part of the section is complicated by frequent minor folds, and on Rossmore Island the rocks are exposed in the axial zone of a broad synclinorium. The only continuously exposed part of the whole section which can be logged in detail is the coastal exposure along the eastern end of Rossmore Island.

The subdivisions identified here are the same as those recognized in the upper part of the Sneem River section. This section is the type section for the Rossmore Sandstone Formation.

ROSSMORE ISLAND SECTION

ROSSMORE SANDSTONE FM.	525m+
DERRYQUIN SANDSTONE FM.	175m+

Derryquin Sandstone Formation

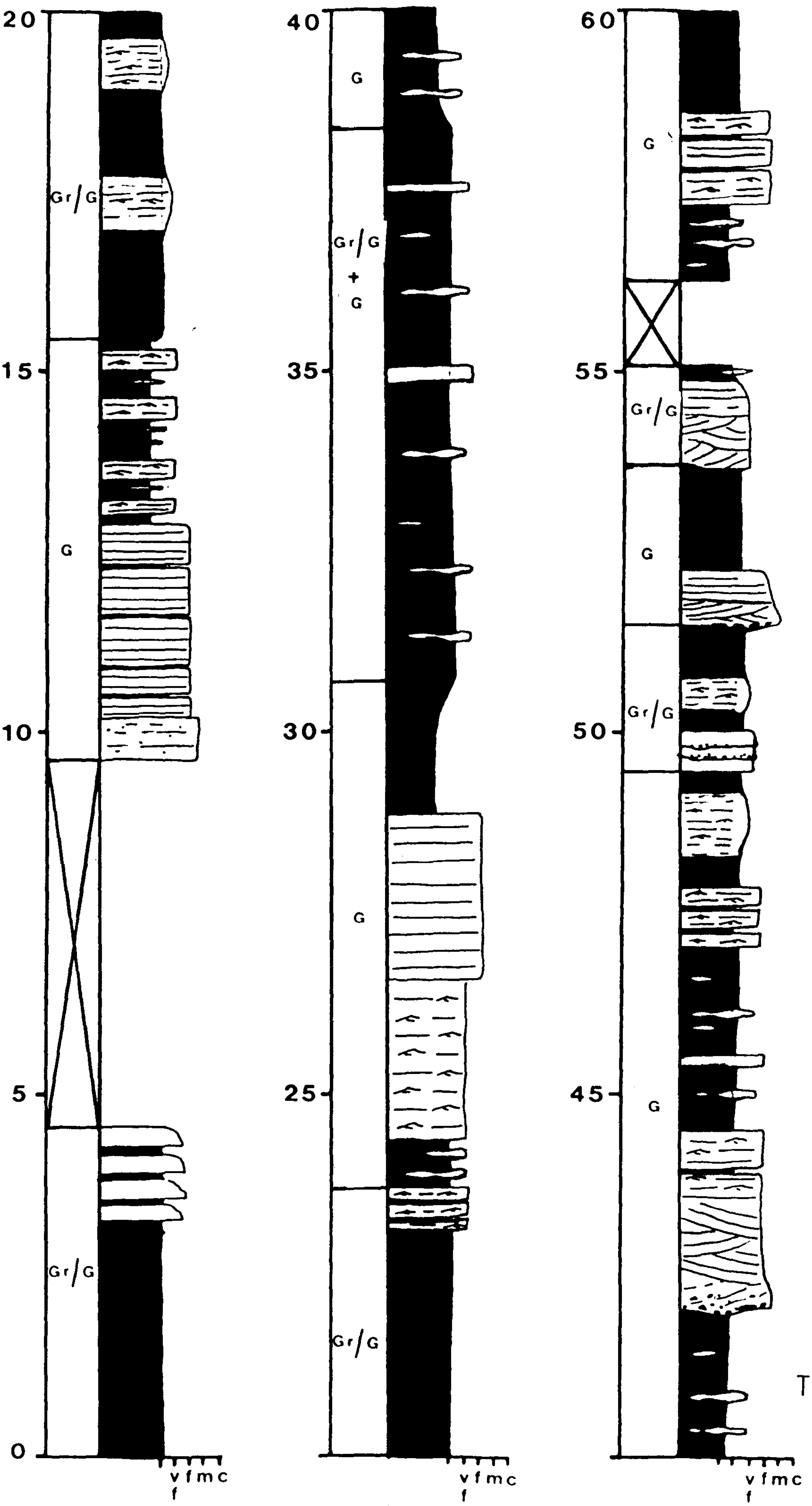
As noted above, the lower part of the formation is displaced by a major wrench fault and is poorly exposed. The uppermost 175m are intermittently exposed, and are dominated by bright purple siltstones and silty very fine sandstones. Interbedded with these are common grey and green siltstones, as well as grey-green and pale green fine sandstones. A particularly dark grey siltstone approximately 44m below the top of the formation yielded plant miospores of uppermost Devonian age (Higgs and Russell, 1981 (see CHAPTER 4)).

The Rossmore Sandstone Formation

The formation is dominated by grey sandstones and dark grey or greenish grey siltstones and silty sandstones (Text Fig. 54). The base, although poorly exposed, is easily identified in the field using the criterion previously described for the Sneem River section (i.e. the first appearance of white-weathering sandstones of the grey quartzitic sandstone facies). Purple rocks of the Derryquin Sandstone Formation are present up to the boundary but die out abruptly above it. Rare grey siltstones occur a short distance below the boundary, but their appearance in bulk coincides with the base of the Rossmore Sandstone Formation.

ROSSMORE SANDSTONE FORMATION

ROSSMORE ISLAND SECTION



TEXT FIG.54

In the lower part of the formation, where the section is not continuously exposed, the sandstones tend to be several metres thick with slight flaggy tendencies. Rare thin lenticular basal lags are lined with intraformation dark grey siltstone clasts. The siltstones and silty sandstones are massive or show traces of rippling or lamination.

Higher up towards the middle of the exposed thickness of the formation, the basal lags in the sandstones are observed more frequently on well-exposed coastal sections. Here they are nore thickly developed, in many cases composed dominantly of marble-sized limestone pisolites, as well as yielding occasional indeterminate fragments of fossil plant or fish material. Thin interbedded sandstones of sand-lensed siltstone facies are noted for the first time at this level, although they may exist unnoticed lower down in the poorly exposed part of the formation. Infrequent thin units of poorly developed heterolithic facies are also first seen at about this level. A dark grey siltstone from a heterolithic unit in this part of the formation yielded plant miospores of uppermost Devonian age (Higgs and Russell, 1981 (see CHAPTER 4)). The unit is estimated to lie 300m above the base of the formation, although, due to breaks in exposure and frequent repetition of the upper part of the section by folding, this estimate can only be regarded as approximate.

Above this, the succession contains all the various facies already noted. In addition, a solitary distinctly purple siltstone bed over 2m thick is present, 160m above the base of the formation! Around the level containing the spore sample, the section is dominated by grey siltstones and rare heterolithic facies, with occasional thin sandstones. Towards the top of the section the formation coarsens due to increased amounts of the grey quartzitic sandstone facies. and sand-lensed siltstone facies, and the interbedded grey siltstones are partly heterolithic facies. Along the coast to the southwest, between Carrigglass East and Rossmorebullig, a unit of well-developed heterolithic facies at least 10m thick is exposed at about the same level.

6.2.5 The VALENTIA HARBOUR SECTIONS: White Strand
Enagh Point
Doulus Head
Cooncrome Harbour

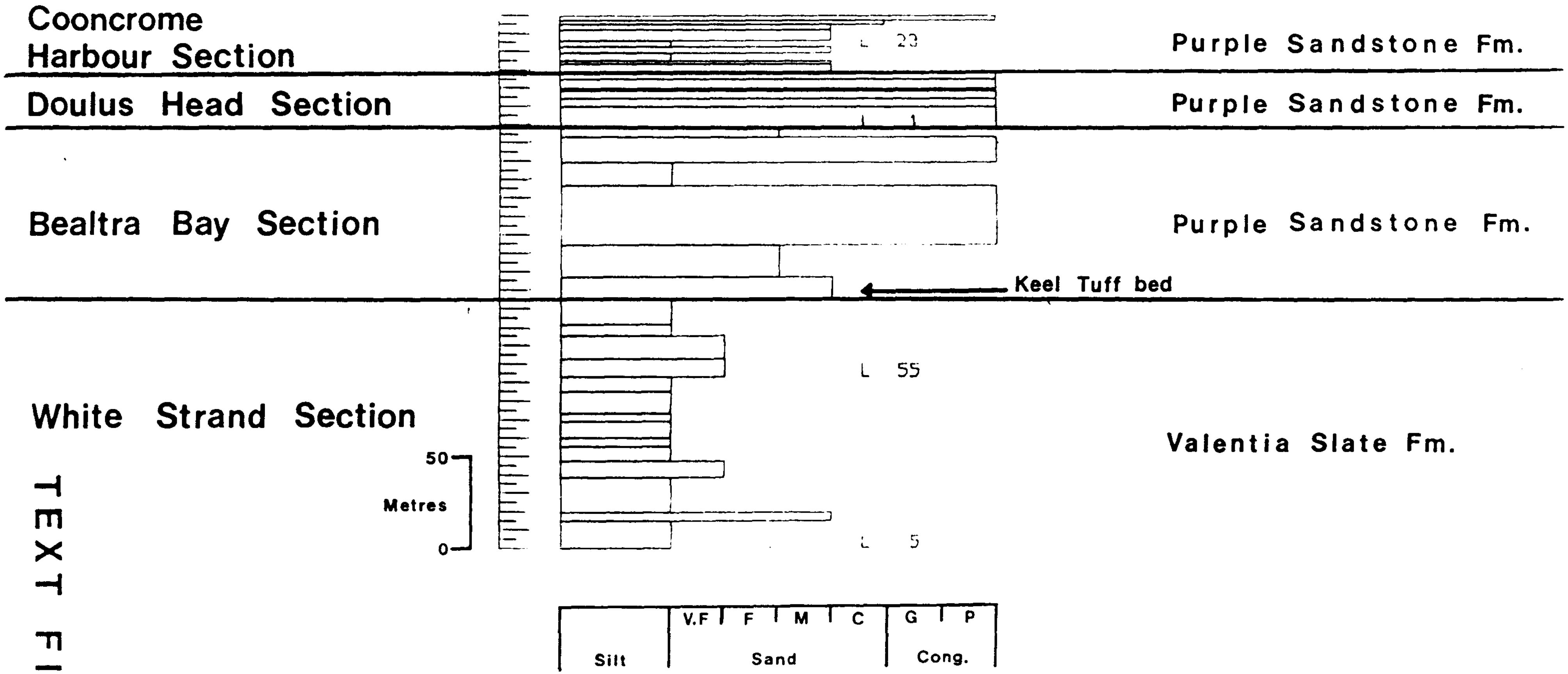
The succession on the northern limb of the Portmagee Anticline is best exposed along the northeastern shores of Valentia Harbour (Text Figs. 55-56). The rocks young northwards from White Strand (V 435 790) to Doulus Head (V 405 805), but there are several large breaks in exposure and frequent repetitions of section due to minor folding. Access along the northern sea-cliffs is too difficult to measure sections across the folds, but the lithology and structures may be identified. A continuation of the same succession is seen exposed along the stretch of coast which extends north from the eastern side of Cooncrome Harbour (V 440 820).

The four main well-exposed, continuous and accessible sections through the succession are described here together, since they effectively form a single composite section (Text Fig. 3, SECTIONS

VALENTIA HARBOUR SECTIONS

GRAINSIZE PLOT

GROUPING N 5



TEXT FIG.55

1-4). Capewell (1975) subdivided the succession in this area into the same three formations he recognised on the Atlantic Coast section. The lowest and highest of the three formations may still be recognised using the boundary definitions applied on the Atlantic Coast section, but the St. Finan's Sandstone Formation can no longer be differentiated. For this thesis, the succession in the Valentia Harbour area has been subdivided into the Valentia Slate Formation, overlain by the upper part of the Iveragh Group which is here identified as the Purple Sandstone Formation. Contained within the Valentia Slate Formation are two distinctive subunits, the Bealtra Agglomerate Member and the Keel Tuff Bed. The overlying Purple Sandstone Formation contains the Doulus Conglomerate Member.

VALENTIA HARBOUR SECTIONS

PURPLE SANDSTONE FM. 230m+ (Estimated)

(Including the Doulus Conglomerate Member (30m))

VALENTIA SLATE FM. 500m+ (Estimated)

(Including the Keel Tuff Bed (9.5m)

and Bealtra Agglomerate Member (22m))

Valentia Slate Formation

The Valentia Slate Formation is exposed along the coast between White Strand (V 435 790) and Enagh Point (V 470 800). Only the upper part is exposed, and due to folding, several hundred metres of the formation (at most) are seen. The formation here consists mainly of bright purple siltstones and silty sandstones, of rippled and laminated facies or sand-laminated siltstone facies (Text Fig. 57). Occasional green and dull purplish grey beds are interbedded in the formation.

The Valentia Harbour Sill extends into the section at two levels, as a 100m thick sill just above the base of the section and a further sill of similar thickness several hundred metres higher. Immediately overlying the upper sill is a 22m thick agglomerate, the Bealtra Agglomerate Member (see CHAPTER 5, Text Fig. 40). The member can be traced laterally along strike to the east, and is repeated further north along the coast by folding. It thins rapidly in both these directions and probably extends little beyond the limits of the exposed outcrop.

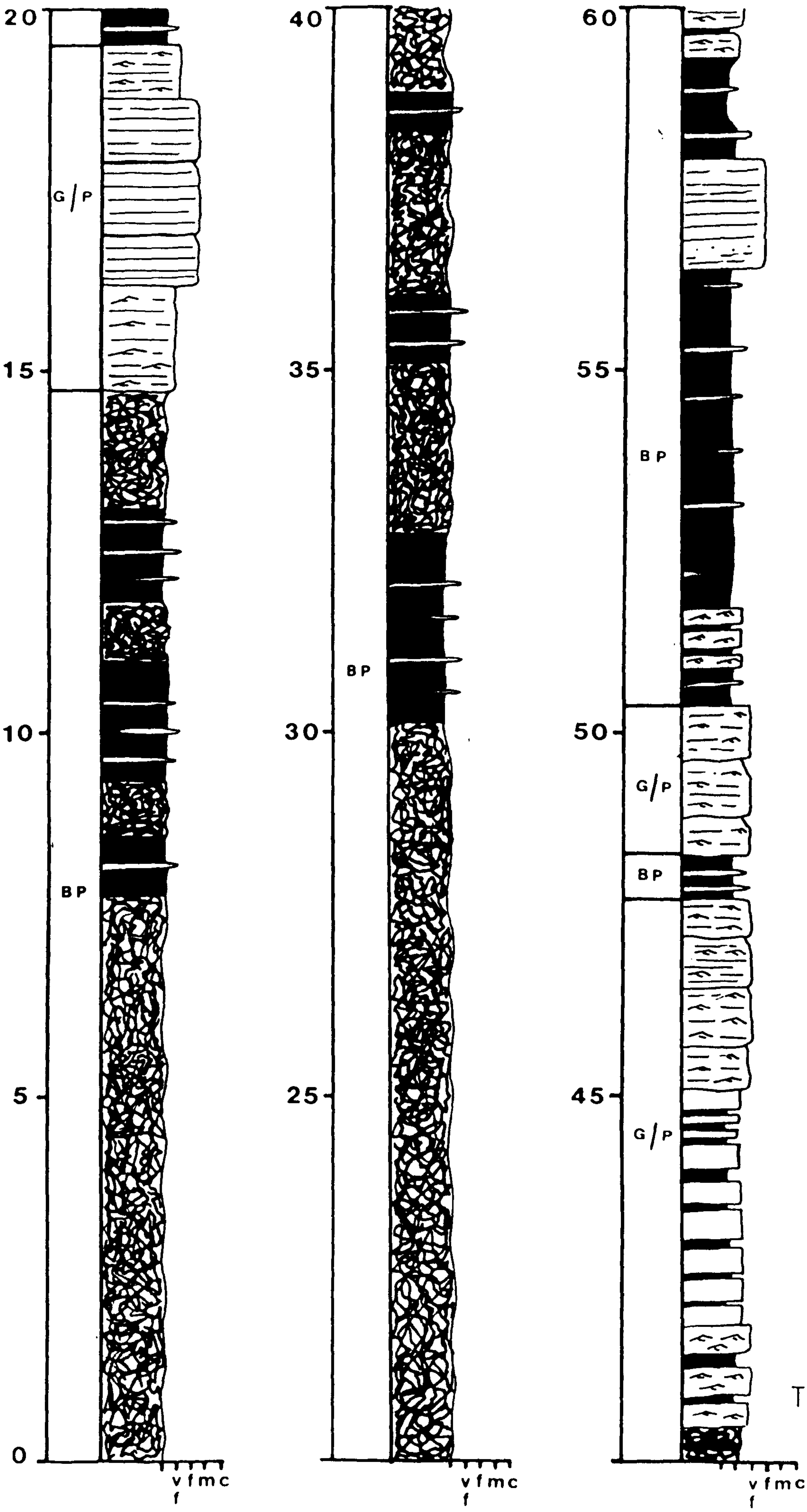
An estimated 100m upsection from the Bealtra Agglomerate Member, a 9.5m greyish purple tuff (the Keel Tuff Bed) occurs at the top of the formation. The same tuff bed is present on the Atlantic Coast Section where it occurs close to the top of the Valentia Slate Formation.

Purple Sandstone Formaton

Immediately above the Keel Tuff Bed at Enagh Point, the succession coarsens abruptly with a thick (20m) sequence of fine to coarse purple sandstones. This marks the base of a sandstone-dominant sequence in which fine to medium sandstones are interbedded with lesser or nearly equal amounts of coarse bright purple siltstones (Text Fig. 58). The sandstones are occasionally pebbly with exotic quartz, jasper and schist clasts. Doulus Point marks the highest

VALENTIA SLATE FORMATION

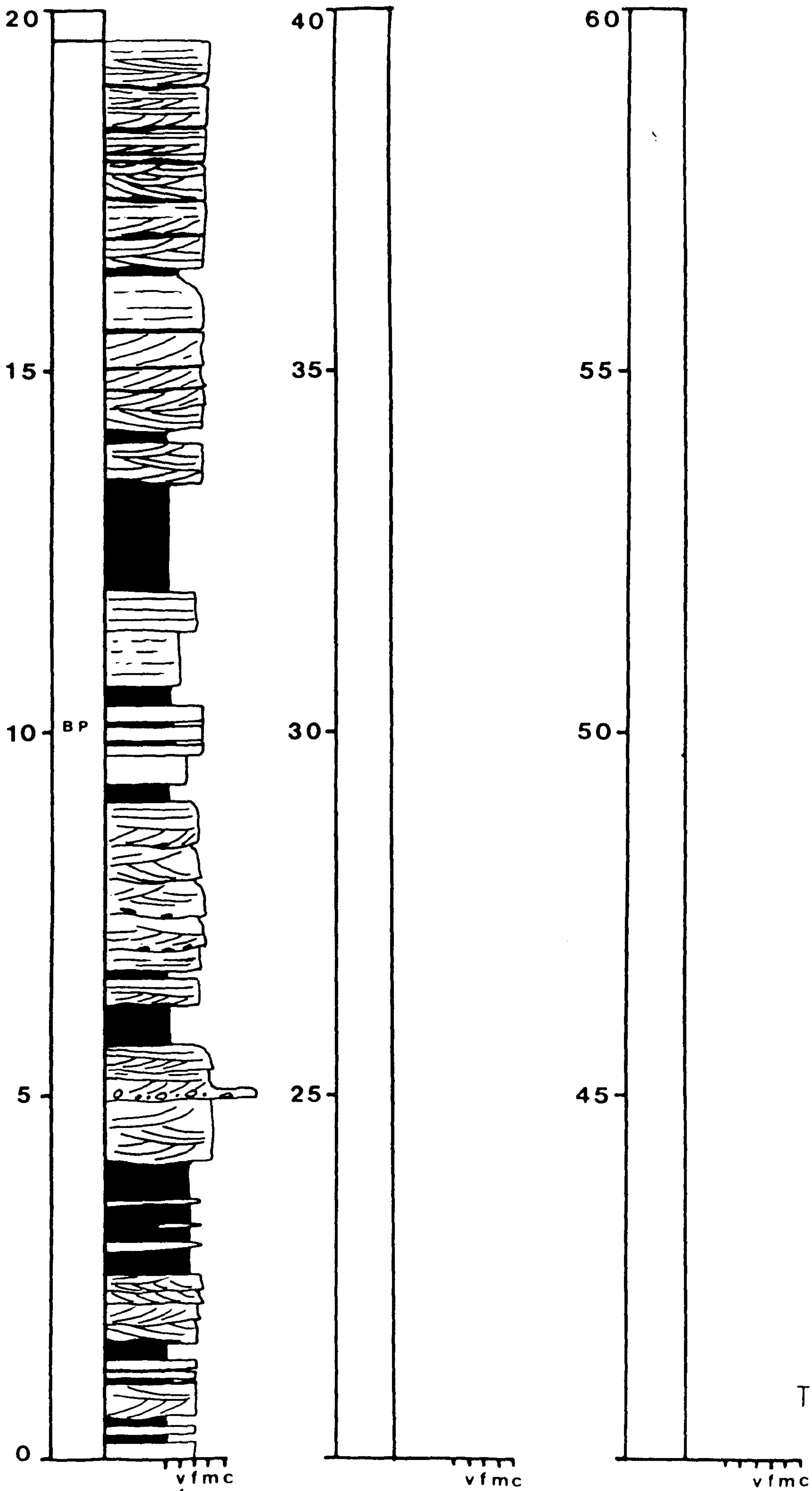
VALENTIA HARBOUR SECTION



TEXT FIG.57

PURPLE SANDSTONE FORMATION

VALENTIA HARBOUR SECTION



TEXT FIG.58

part of the section locally, although approximately the same level is exposed 2km to the east at Cooncrome Harbour, where by following cliff sections around the coast to the northeast a further gradual increase in section is obtained.

An estimated 200m above the boundary with the underlying Valentia Slate Formation, a 30m thick massive and bedded conglomerate is interbedded in the sequence on Doulus Head (Text Fig. 59). The unit can be traced 2km to the east, where at Cooncrome Harbour it has wedged out into pebbly sandstones. It is defined here as the Doulus Conglomerate Member.

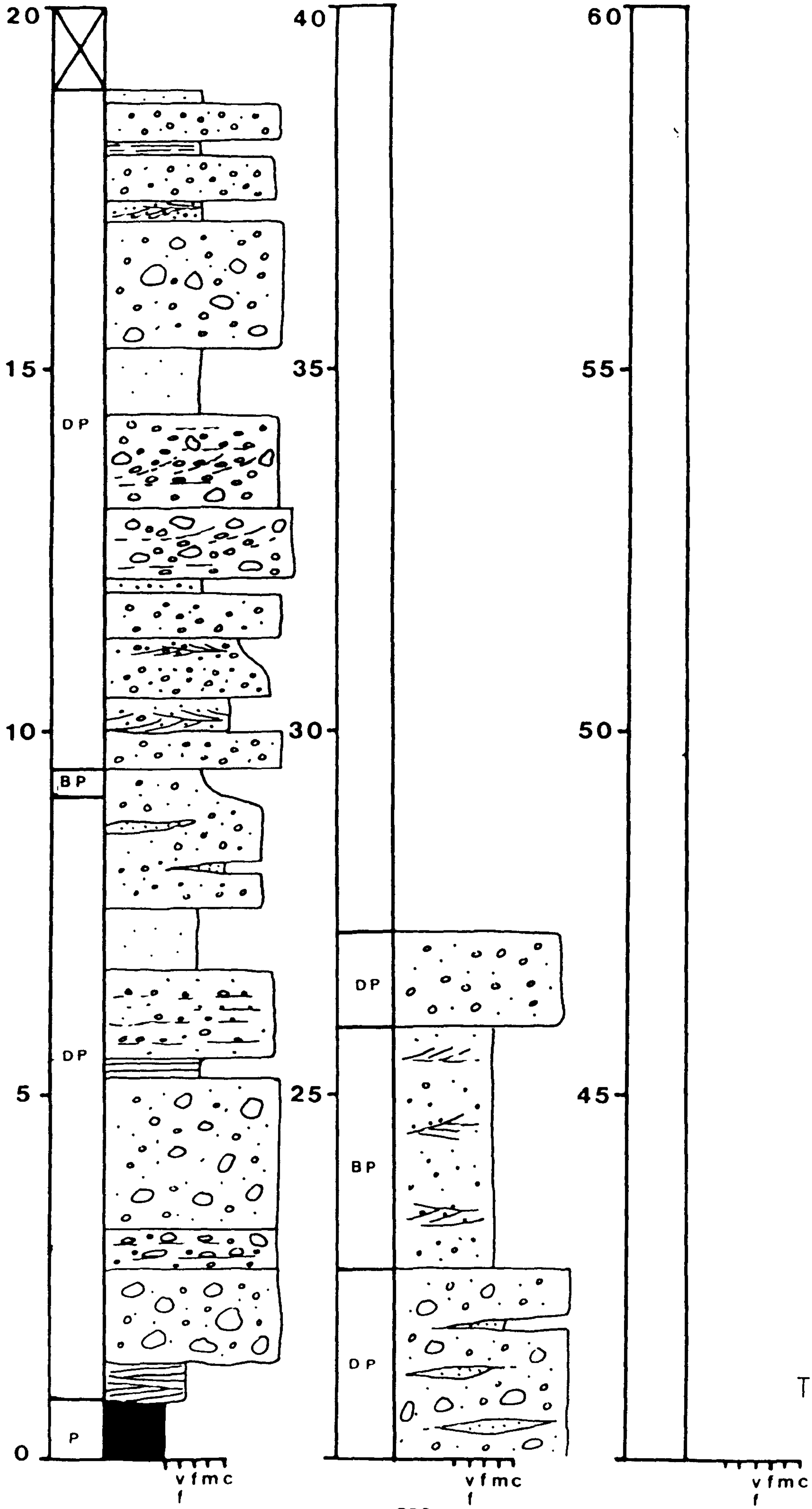
Capewell (1975) mapped the Doulus Conglomerate Member and the sandstones above the Keel Tuff Bed as St. Finan's Sandstone Formation. From the description given above it is apparent however that purple and bright purple rocks are predominant throughout the sandstone-dominant part of the succession. The lower 'non-purple' subdivision established on the Atlantic Coast Section cannot be applied in this area, and it is identified here as the Purple Sandstone Formation.

6.2.6 The HOG'S HEAD SECTION

In the southwestern part of the study area, on the northern limb of the Kilcrohane Anticline, the red-bed sequence is exposed on the cliff-sections around Hog's Head (Text Fig. 3, SECTIONS 6 and 7; and Text Figs. 60-63). The rocks along the southern side of Hog's Head, and the adjacent coastline extending to the southeast, are exposed in a series of minor gentle folds plunging at an angle around thirty

Doulus Conglomerate Member

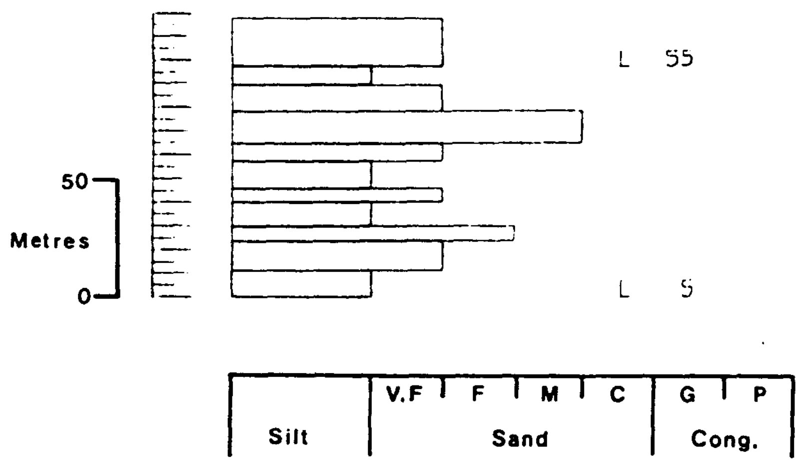
Valentia Harbour section



Text Fig.59

HOGS HEAD SECTION 1

GRAINSIZE PLOT
GROUPING N = 5

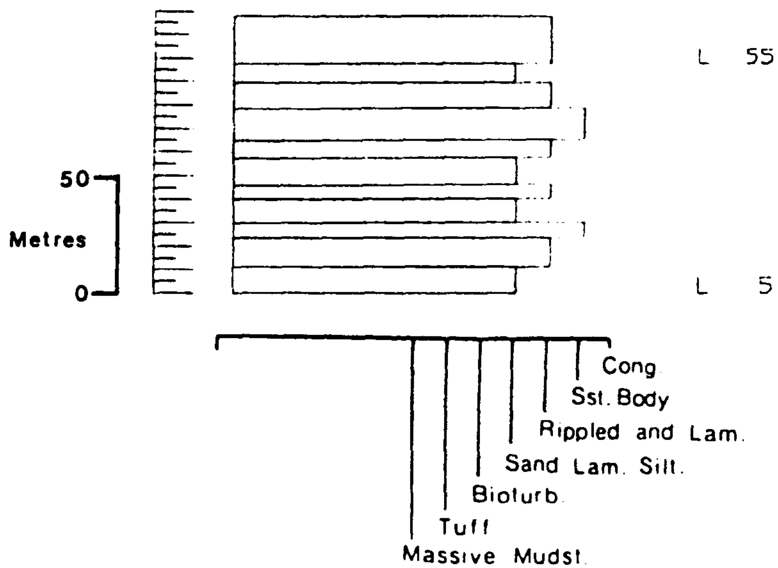


Iveragh Group
(undifferentiated)

TEXT FIG.60

HOGS HEAD SECTION 1

FACIES PLOT
GROUPING N = 5

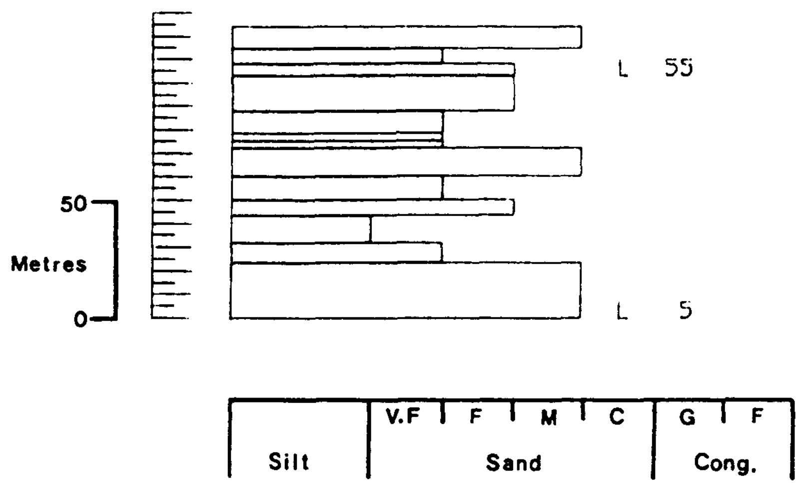


Iveragh Group undifferentiated

TEXT FIG. 61

HOGS HEAD SECTION 2

GRAINSIZE PLOT
GROUPING N = 5

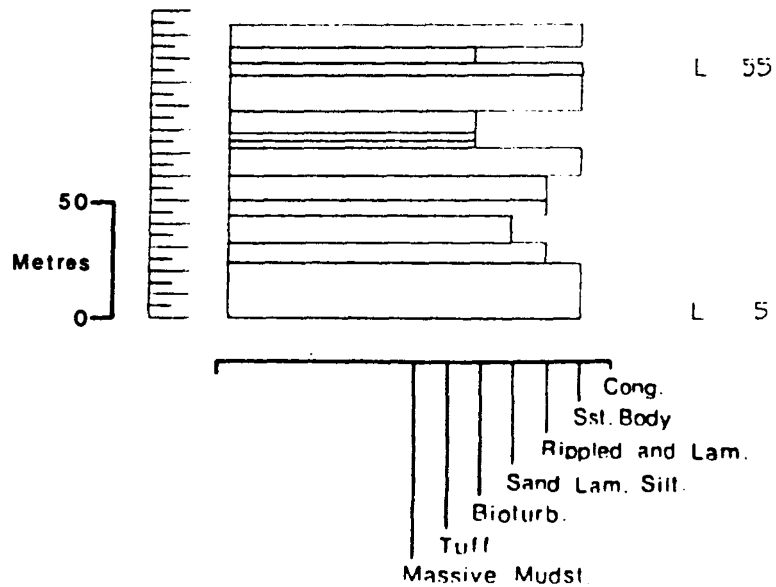


Iveragh Group
(undifferentiated)

TEXT FIG. 62

HOGS HEAD SECTION 2

FACIES PLOT
GROUPING N = 5



Iveragh Group
undifferentiated

TEXT FIG 63

degrees to the southwest. Structural evidence (i.e. the distance from the axis of the Kilcrohane Anticline, and the gain in section due to a westerly fold plunge) suggests that the rocks on Hog's Head are in the upper part of the Iveragh Group.

HOG'S HEAD SECTION

Upper part of the IVERAGH GROUP (undifferentiated)
(Thickness not estimated)

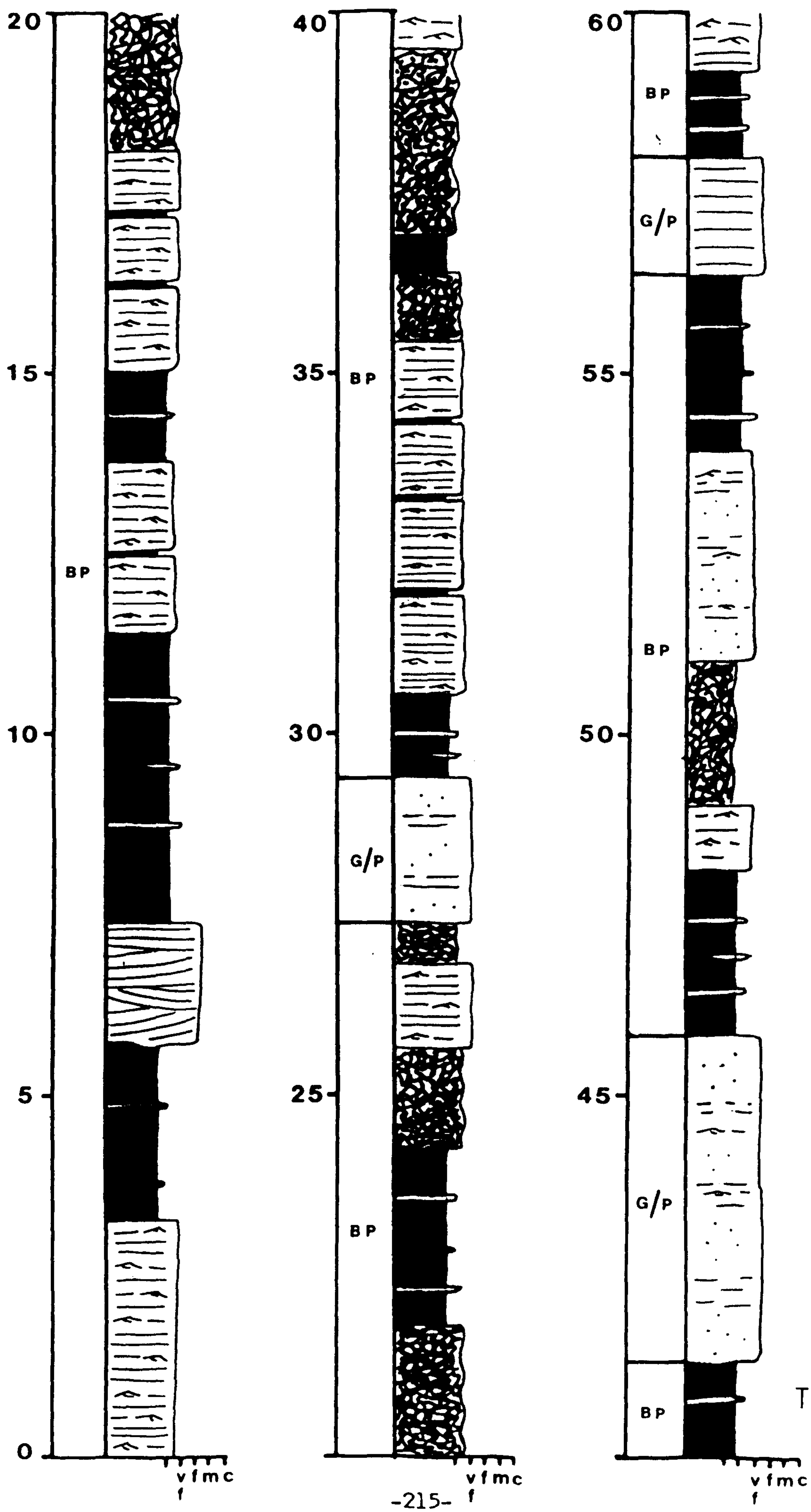
Capewell (1975) on his geological map interpreted Hog's Head to consist of Ballinskelligs Sandstone Formation, faulted against St. Finan's Sandstone Formation to the southeast.

Rocks exposed on Hog's Head to the northwest of this fault are dominated by bright purple coarse siltstones and silty very fine sandstones, of sand-laminated siltstone facies and rippled and laminated facies (Text Fig. 64). Rare thin fine sandstones of sandstone body facies are interbedded in this sequence. Compared with the Ballinskelligs Sandstone Formation on the Atlantic Coast Section, these rocks appear finer and lacking in sandstones. They do however appear quite similar to finer grained parts of the Purple Sandstone Formation from the Sneem River Section.

The coast southwest of where Capewell mapped his faulted contact exposes a similar (or slightly finer) sequence, still unquestionably dominated by bright purple coarse siltstones and silty very fine sandstones (Text Fig. 65). Examples of sandstone body facies are even less frequent than northwest of the fault. On the basis used to

NW. OF FAULT

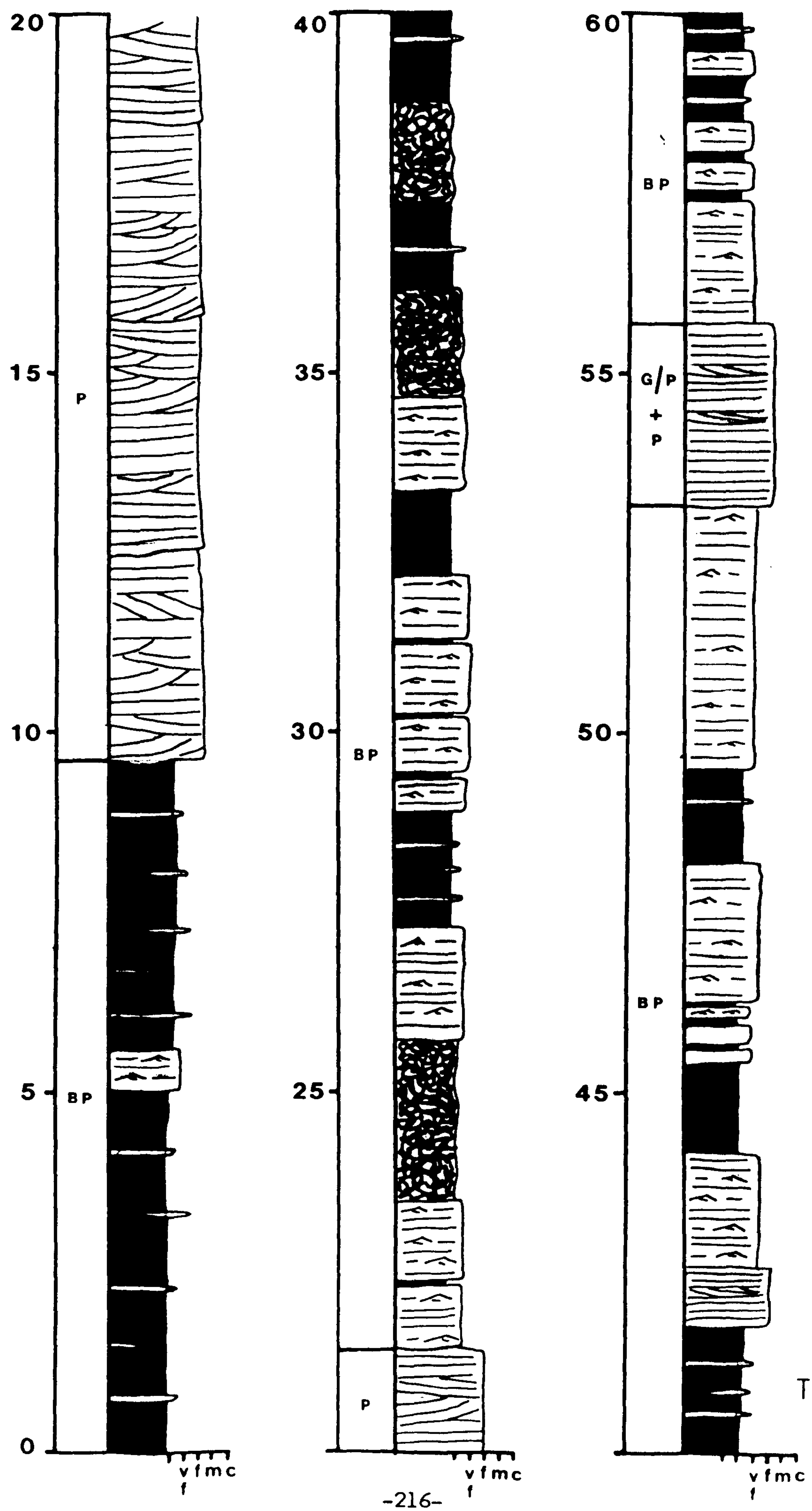
HOG'S HEAD SECTION



TEXT FIG.64

SE. OF FAULT

HOG'S HEAD SECTION



TEXT FIG.65

differentiate the Ballinskelligs Sandstone Formation from the St. Finan's Sandstone Formation (i.e. predominance of bright purple colours), there is no reason to suggest that St. Finan's Sandstone Formation is present at this point.

An attempt was made to establish the presence of St. Finan's Sandstone Formation by examining inland exposures which are structurally downsection along the fold plunge. Even 2Km inland (approximately 500m downsection), exposures along the Sneem-Waterville road are dominated by bright purple lithologies. Tracing the coastal exposures further east towards Lamb's Head results in little gain or loss of section due to broad gentle folds which continue to plunge to the southwest at an angle of around thirty degrees. The rocks occasionally contain slightly duller purple beds, but also present are rare in-situ calcrete horizons which elsewhere have only been noted in the Ballinskelligs Sandstone or Purple Sandstone Formations.

The conclusions of this investigation may briefly be summarised as follows:

1. The field evidence from well-exposed coastal exposures conflicts with the interpretation made by Capewell, and his geological model for the Hog's Head area is unsatisfactory.
2. The area is structurally complex, and detailed mapping of a large area (beyond the scope of the present study) is required to clarify the geology on the western end of the Kilcrohane Anticline.

3. Until such remapping is carried out and the geological problems are resolved, the rocks of the area are best referred to as the upper part of the Iveragh Group (undifferentiated).

6.2.7 The LAMB'S HEAD SECTION

In the southwestern part of the study area, on the southern limb of the Kilcrohane Anticline, the red-bed succession is well exposed on the coast around Lamb's Head (Text Fig. 3, SECTION 8; and Text Figs. 66-67). The northern coast forms a strike section for most of its length. On the southwestern corner of the Head a series of beds dip uniformly at about forty-five degrees to the southeast, younging in the same direction. Frequent oblique strike-slip faults cut the section, with minor (3-4m) displacements in most cases. Beyond this to the southeast, the rocks are seen in a series of broad gentle folds plunging northeast at an angle of about thirty degrees. The southeastern coast provides a plunge section along which progressively higher levels in the sections are exposed.

LAMB'S HEAD SECTION

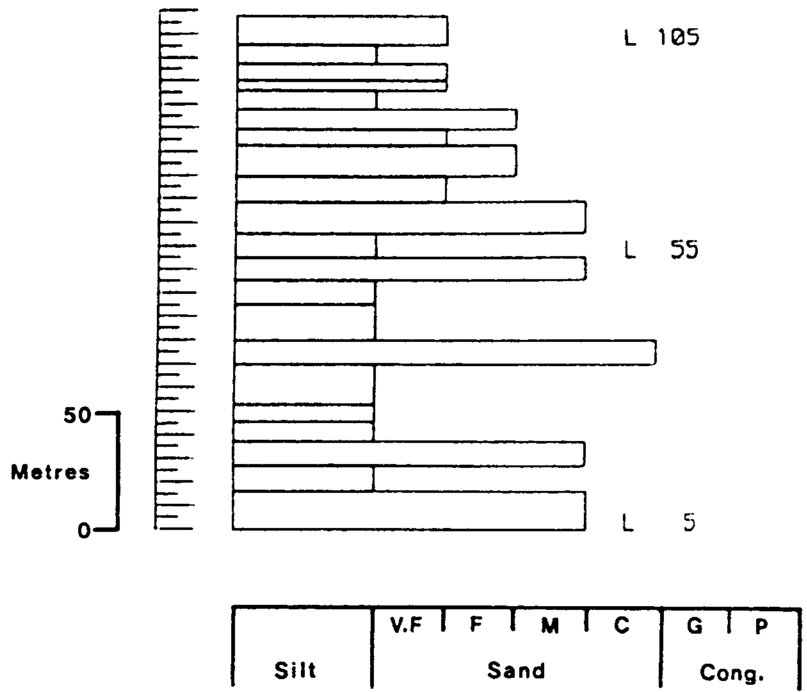
Upper part of the IVERAGH GROUP (undifferentiated)
(Thickness not estimated)

Capewell (1975) mapped the rocks on Lamb's Head as Valentia Slate Formation.

A conspicuous scarp and gully feature cuts Lamb's Head on the

LAMBS HEAD SECTION

GRAINSIZE PLOT
GROUPING N=5

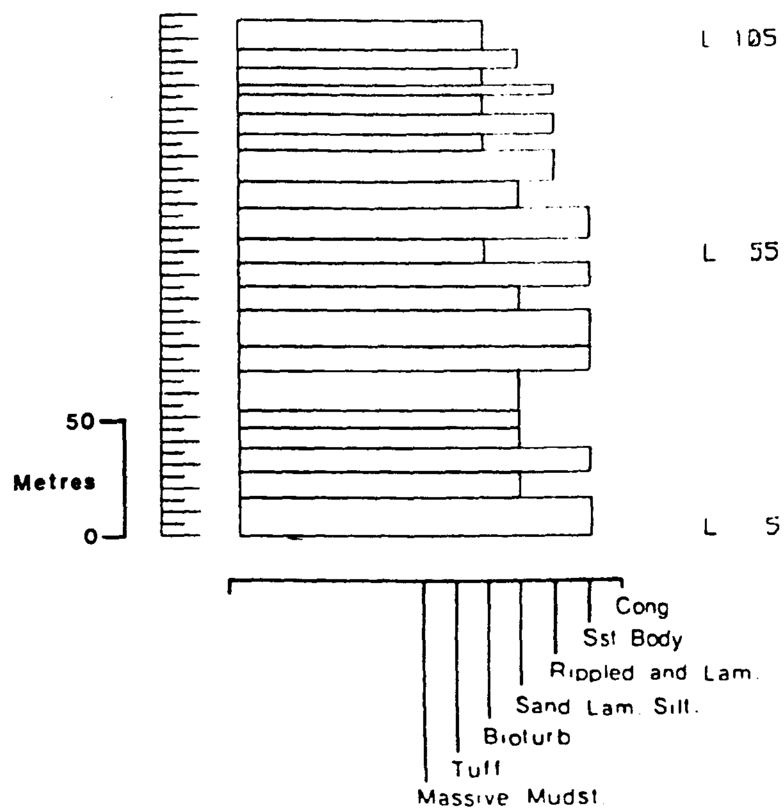


Iveragh Group
(undifferentiated)

TEXT FIG. 66

LAMBS HEAD SECTION

FACIES PLOT
GROUPING N = 5



Iveragh Group (undifferentiated)

TEXT FIG. 6

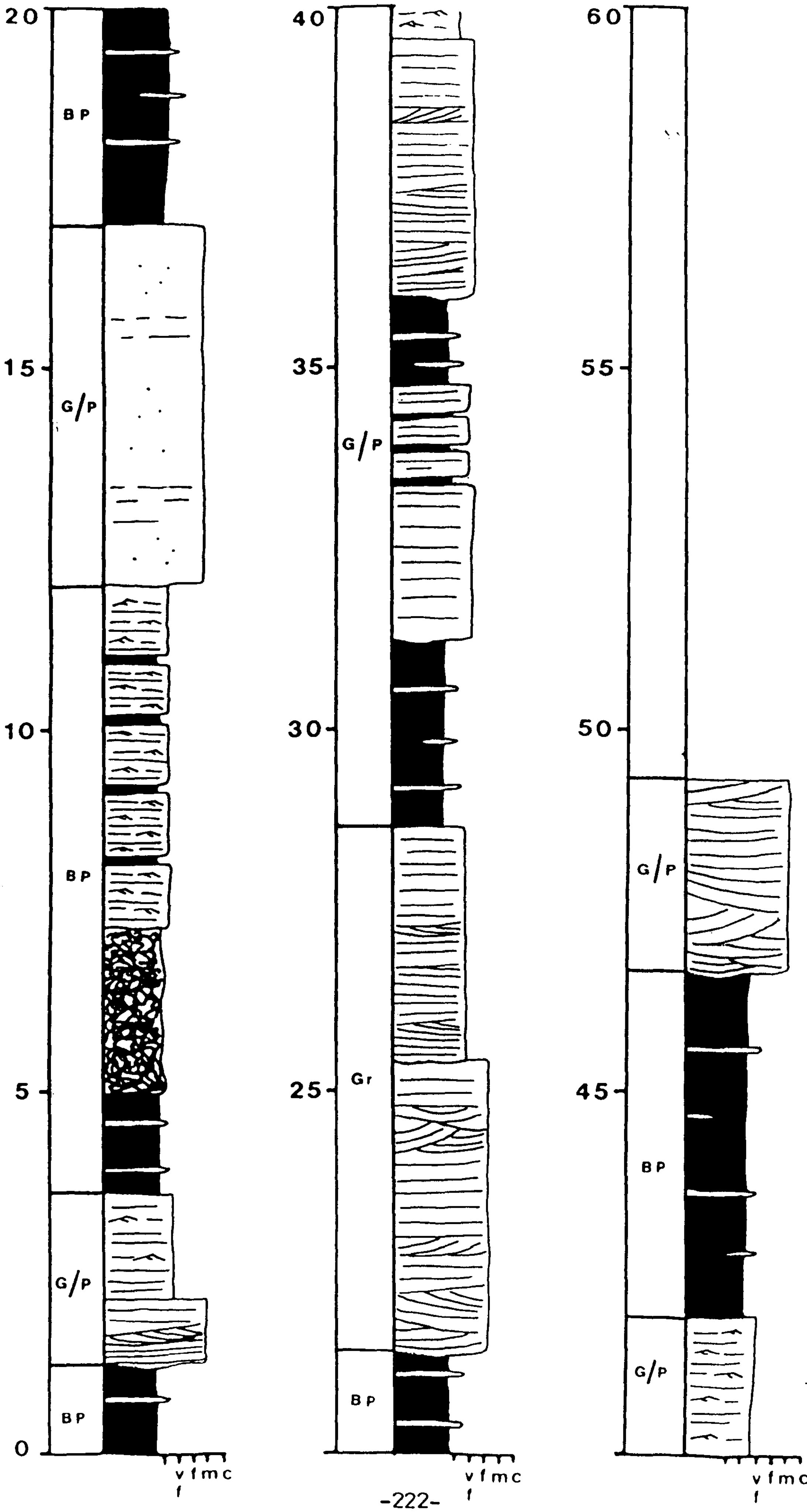
northern coast, parallel to strike of bedding. It forms a part of Capewell's 'Caherdaniel Fault-Zone' which he suggested was responsible for the reversal of fold plunge across the axis of the Kilcrohane Anticline. It is shown here that juxtaposition of opposed fold plunges is frequently observed in clearly unfaulted areas on the western end of Iveragh (see CHAPTER 7, section 7.5) and displacement on a fault is not strictly necessary. The rocks on both sides of the feature are lithologically similar, and contain interbedded green sandstones.

The rocks exposed along the northern coast and in the homoclinal zone on the southwestern corner consist of coarse bright purple siltstones, interbedded with frequent green fine to medium sandstones similar to the 'chloritic sandstones' on the Sneem River section. In the homoclinal zone, sandstones comprise up to thirty percent of the succession in some parts (Text Fig. 68). Higher up the succession to the southeast, where the rocks become gently folded and start to plunge northeastwards, the rocks are predominantly bright purple coarse siltstones and silty sandstones, with occasional fine or medium sandstones. Traced along the coast to the northeast, the succeeding beds continue with the same lithologies and a constant bright purple colour is maintained. Rare in-situ calcrete horizons are noted.

From the description of the Lamb's Head section given above, it should be clear that the succession consists of a lower part containing significant quantities of green 'chloritic' sandstones, and an upper part dominated by bright purple coarse siltstones and silty sandstones. Neither of these resemble the Valentia Slate

UPPER PART OF THE IVERAGH GROUP

LAMB'S HEAD SECTION



TEXT FIG. 68

Formation as described from the Atlantic Coast Section; the lower part due to its coarseness, and the upper part due to its colour. A more likely interpretation is that the lower part is a lateral equivalent of the Chloritic Sandstone Formation seen in the Sneem area, while the upper bright purple beds represent the overlying Purple Sandstone Formation. The presence of rare in-situ calcrete horizons in the upper part support this, since elsewhere they appear generally restricted to the upper parts of the red-bed succession.

The conclusions listed at the end of the Hog's Head section description apply to this section also. Until further detailed mapping can resolve the geology at this western end of the Kilcrohane Anticline, the rocks exposed on Lamb's Head are best referred to as the upper part of the Iveragh Group (undifferentiated).

6.3. Local and regional correlation

Local correlation

The work of Capewell (1957, 1975) resulted in the establishment of two local stratigraphies within the study area, one applying to the area around Sneem in the southeast, and the other dealing with the western end of the peninsula around Waterville. His work in the Sneem area (accepted here with modifications) divided the red-bed succession into four mapping formations, based principally on colour and grainsize changes. A fifth formation, now designated the Rossmore Sandstone Formation, overlies the red-beds and is clearly distinguished from them by obvious facies and colour changes. Somewhat later, Capewell divided the red-beds occupying the western end of Iveragh into three formations again based on colour and grainsize changes. Although Capewell suggested an equivalence between his three formations on the western end of Iveragh and the lowermost three mapping units identified by him at Sneem, the characteristics he used to identify the mapping units show a considerable change between the two areas.

Similarly Walsh (1968), working in the Reeks a short distance to the northeast of Sneem experienced problems in attempting to correlate his succession with that described by Capewell at Sneem. He was forced to infer considerable lateral changes in facies to explain the absence at Sneem of his 'Grey Sandstone Formation', less than 8Km away from the area in which it had been defined.

The problem to be overcome is the same which faced all the earlier workers in this area, that is correlation between sections across faulted, structurally complex or poorly exposed gaps. A number of different criteria may be used and are discussed briefly here.

1) COLOUR: The major problem is that the processes which governed it are not fully understood. It was suggested that the upwards change to predominantly bright purple colours could have been related to slowing in the rate of sedimentation (CHAPTER 3, Section 3.11). From the Valentia Harbour sections it is apparent however that other local factors are involved and operated at earlier times in the basin's history, since bright purple colours are present in the Valentia Slate Formation.

It also appears to vary in intensity between sections, so that relative rather than absolute changes need to be used (i.e. a change from purplish grey to purple on the Atlantic Coast Section appears to equate with a change from purple to bright reddish purple on the Eskine-Knocknagullion Section).

2) FACIES TYPES: Within the Iveragh Group there is a lack of distinctive facies types, and formation changes reflect changes in the ratio of facies types rather than appearance or disappearance of a characteristic type. Conglomerate facies is an exception but is not developed extensively enough to be useful for correlation. In any case, conglomerate facies is likely to show rapid lateral facies changes and so is particularly unsuitable for correlation purposes. The Rossmore Sandstone Formation does reflect the appearance of new facies, but is only exposed south of the Kilcrohane Anticline and is thus of no use for correlation with sections to the northwest. Where sections can be correlated using the Keel Tuff Bed as a marker horizon, the formation boundaries defined using facies arguments occur at considerably different levels (i.e. the top of the Valentia Slate Formation occurs 766m above the Keel Tuff Bed on the Atlantic Coast Section, but almost coincides with it on the Enagh Point section at Valentia Harbour).

3) TUFF MARKER BED: As previously noted, several tuff-beds are recorded in the succession. A particularly thick bed, the Keel Tuff Bed, appears distinctive on the grounds of sheer thickness and a well developed shard-texture in thin section. It has

been identified on both the Atlantic Coast and Valentia Harbour sections and can be used to correlate across the axis of the Portmagee Anticline.

A thin tuff-bed has been identified in the southeastern part of the area, on the Eskine-Knocknagullion Section. Using facies arguments (incoming of significant amounts of sandstone body facies), the Knocknagullion tuff appears to lie at very approximately the level at which the Keel Tuff Bed occurs on the Atlantic Coast and Valentia Harbour sections. It is possible that the Knocknagullion tuff is the same as the Keel Tuff Bed, but if so the considerable change in thickness of the tuff across the area requires explanation.

4) STRUCTURE: In theory, it should be possible to attempt or at least considerably constrain correlations by careful mapping of the structure of the area, matching known thicknesses from one section to another. In practice, the area is structurally complex in some areas (e.g. the presence of small closely spaced folds and fractures with unknown displacement make this approach unworkable).

5) PALAEONTOLOGY: Stratigraphically significant fossils are rare in the red-bed succession, and those which are present are not particularly sensitive. Fish fossils date the lower part of the succession but only one section yielded identifiable material. Plant miospores are identified only from the uppermost part of the red-bed succession, and data points are

limited to the sections in the southeast around Sneem. A Frasnian age from fish material on the Atlantic Coast section and spore assemblages in the Chloritic Sandstone Formation equivalent at Moll's Gap, could be use to suggest that the St. Finan's Sandstone Formation correlates with the chloritic Sandstone Formation. This in turn supports Capewell's equation of the three formations on the western Atlantic Coast section with the lower three formations exposed in the Sneem area. However these correlations are not precise, and simply represent what appears (within the limits of the data) to be the most probable correlation at the present time.

The conclusions drawn from the points listed above are as follows.

The most reliable criterion for correlation within the study area is the Keel Tuff Bed. Using it to correlate the Atlantic Coast and Valentia Harbour sections shows that bright purple colours are predominant throughout the Iveragh Succession at Valentia Harbour, and the incoming of significant amounts of sandstones was considerably earlier in that area than in the Atlantic Coast section.

The correlation of the Atlantic Coast section with the Sneem sections to the southeast must depend on the facies (incoming of significant sandstones) and colour (incoming of predominantly purple colours) arguments, since the Keel Tuff Bed cannot be identified with certainty in this area. The correlation appears to work reasonably well in the sense that the formations are the same order of magnitude in thickness; it is also supported by a possible equivalent to the Keel Tuff Bed at approximately the same level in both areas, similar coarsening upwards trends in the Ballinskilligs and Purple Sandstone Formations, restriction of calcrete development to those two formations, and palaeontological correlation of the St. Finan's Sandstone Formation with the Chloritic Sandstone Formation.

The incoming of significant amounts of sandstones is interpreted as due to slowing in the rate of subsidence allowing coarser sediments to prograde further southwards into the basin. In a low-relief setting such as that proposed for the deposition of the red-bed sediments, the amount of diachroneity observed in an area of this size need not be significant, and could easily be outweighed simply by local facies variation. It is important therefore not to attach undue significance to an apparently "later" or "earlier" appearance of this change in different localities. In short, it is a trend which may be observed over the whole area, and should be used only for correlation in the broadest sense of the word.

Regional Correlation

On a more regional basis, the dates obtained from fish fossils and plant miospores as part of this study now allow correlations to be made with other Devonian sequences in adjacent areas (see Text Fig. 32 for clarification of spore zones). The late Middle to early Upper Devonian age from fish fossils in the Valentia Slate Formation, near the base of the Iveragh succession, matches with a similar age from plant miospores in the Sherkin Formation on Clear Island (Clayton and Graham, 1974). In both cases the sediments dated are from the lowest exposed parts of the basin-fill. The top of the red-bed sediments can be dated in both areas also. LE Subzone spore assemblages correlate the top of the Derryquin Sandstone Formation at Sneem with the top of the Toe Head Sandstone Formation to the south at Dunmanus Bay (Naylor, 1975). LN Subzone assemblages correlate the base of the Rossmore Sandstone Formation at Sneem with the base of the Old Head Sandstone Formation at south Dunmanus Bay (Naylor, 1975) and the top of the Toe Head Formation at north Dunmanus Bay (Naylor et al, 1977). This implies that the sediments between the Toe Head Formation and the Sherkin Formation (i.e. Castlehaven Formation) in southwest Cork, are at least part-equivalent to those between the Derryquin Sandstone Formation and Valentia Slate Formation (i.e. Purple Sandstone/Chloritic Sandstone Formations) on Iveragh. The succession is markedly thinner in southwest Cork, which confirms the earlier suggestion by Naylor and Jones (1967) that the depocentre of the Munster Basin lies nearest the northern margin, and also suggests that the basin may have had a southern margin lying not a great distance further to the south beyond Clear Island. The Chloritic Sandstone Formation on Iveragh is dated from spore assemblages as Frasnian, while the top of the Purple Sandstone is dated as Upper Famennian.

Slightly closer to the south, in the Bantry Bay area, Van der Zwan and Van Veen (1978) obtained LE Subzone assemblages from the top of the West Cork Sandstone Formation which therefore correlates with the top of the Derryquin Sandstone Formation on Iveragh. Similarly, a LN Subzone assemblage from the base of the Coomhola Formation at Bantry correlates with the base of the Rossmore Sandstone Formation on Iveragh.

To the north, the equivalence of the Iveragh succession to the sediments exposed on the Dingle Peninsula can now be resolved rather more satisfactorily than the previous attempts reviewed at the beginning of this chapter. A spore assemblage obtained from the Eask Formation, in the middle of the Dingle Group, yielded a Lower Devonian (late Emsian) age (Van der Zwan, 1980). Van der Zwan considered the upper part of the Dingle Group to range up into the Middle Devonian, but only as far as the Eifelian. The suggestion that the Dingle Group might be a correlative of the lower part of the succession on Iveragh can now be discounted, since work arising from this thesis has shown from fish and spore evidence that the latter is entirely Upper Devonian in age, or at most extends down into the topmost Givetian (Russell, 1978; Higgs and Russell, 1981).

The correlative significance of the remaining upper part of the Dingle succession remains uncertain. Previous workers have recognized a continuous succession of red-bed sediments unconformably overlying the Dingle Group, which pass conformably up into marine transitional rocks below the Carboniferous Limestone. Horne (1974) states that a gentle angular unconformity exists in the middle part of this sequence and divides it into the Glengarriff Harbour Group above and the Caherbla Group below. As no independent data concerning the age of the Caherbla Group are yet available, this Group cannot be dated chronostratigraphically.

Distinctive clasts of metamorphic provenance occur in the conglomeratic facies of the Caherbla Group on Dingle and in rare conglomeratic lenses to the south on Iveragh (the Doulus

Conglomerate Member). However, in the latter area there is no evidence of their being overlain by an angular unconformity. Two possibilities are suggested:

1) The conglomerates of metamorphic provenance both north and south of Dingle Bay are laterally equivalent, the angular unconformity does not extend south of Dingle Bay and the Caherbla Group is no older than latest Givetian or early Frasnian.

2) The conglomerates of metamorphic provenance north and south of Dingle Bay are independent events, the gentle unconformity of it extends south of the bay occurs below the lowest exposed strata, and the Caherbla Group may range in age from Eifelian to Givetian.

The metamorphic clasts from both the Doulus Conglomerate Member on Iveragh and the Dingle Caherbla Group are shown to have a common source from a clast comparison study. There is a fundamental problem in that there is no presently known source area for such clasts apart from the Connemara metamorphic province a considerable distance to the north. The size of clasts and the degree of sorting (particularly in the case of the Dingle conglomerates) suggests a much closer source area. Horne (1970, 1975) has proposed a possible source in the form of a contemporaneous ridge of basement material in the Dingle Bay area, and suggests that imbrication in the Dingle conglomerates support this by indicating a source from the south. The results of the present study neither confirm nor deny this proposal. If such a feature did exist, however, it must have been relatively short-lived, since the bulk of the sediments deposited on Iveragh must have been transported from a very large catchment area to the north beyond the ridge, and one would expect palaeocurrent evidence to show evidence of flow diversion by such a positive ridge feature.

CHAPTER 7

STRUCTURE

7.1 Approach

The main objective of this study was to investigate the sedimentology and stratigraphy of the area. Structural aspects of the rocks were examined in order to trace sedimentary units over the main fold axes, and to assess where displacement had taken place along fracture planes. The following sections are not intended as a detailed structural analysis of the area, they are simply an outline of the general strutural setting, together with a discussion of the main deformational styles and features observed during the study.

7.2 Background

The study area forms part of the major Devonian feature known as the Munster Basin (Naylor and Jones, 1967). The basin was a half-graben, with the Iveragh peninsula lying close to the northern fault-controlled margin. Significant structural, thickness and facies changes across the northern margin of the basin in some areas (particularly towards the western end) have historically given rise to suggestions that it represents the northern limit of the Hercynian fold belt. Some workers have applied this concept in the sense of a narrowly defined and laterally continuous zone, marked by major overthrusting of mobile fold belt sediments on to the stable northern foreland. In practice however, Hercynian folding and cleavage extend further to the north and thrust faulting has only been demonstrated locally, so the importance of this line as an orogenic cut-off is not substantiated (Sevastopulo, 1981).

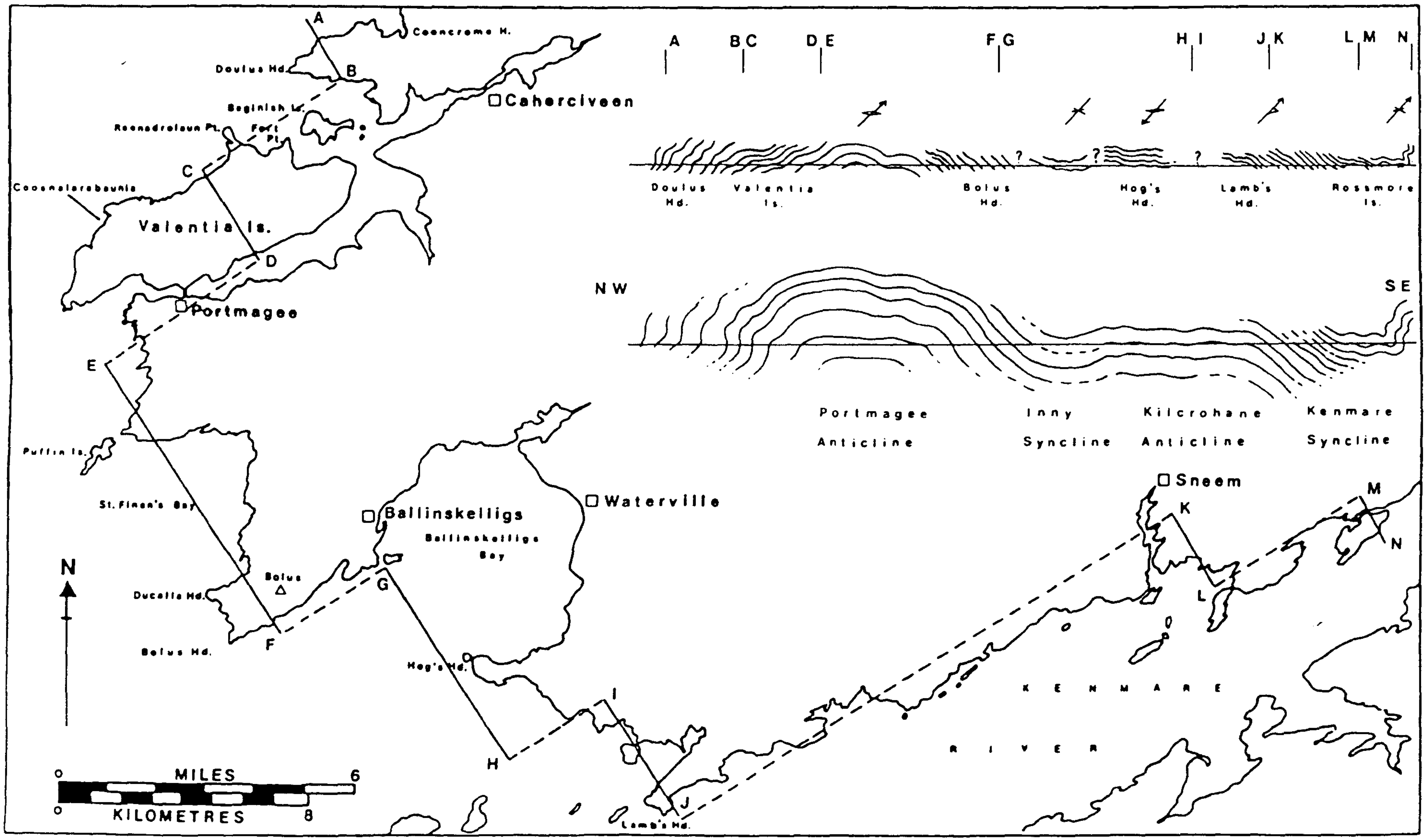
The structure of the peninsula is dominated by folding, faulting and regional cleavage developed during the Hercynian orogenic event. Earlier Caledonian structures in the underlying Lower Palaeozoic rocks have caused a regional swing in orientation, so that Hercynian structures in this area trend NE-SW. Sevastopulo (Ibid.) gives a useful summary of Hercynian tectonic activity in Ireland, placing particular emphasis on areas in the southwest.

Capewell (1957, 1975) mapped the southern and western parts of the Iveragh peninsula, and his maps and sections provide a good general description of the structure of the area. The overall pattern of folding consists of two major anticlines and corresponding synclines, with generally NE-SW trending axes plunging gently in either direction. These major fold-axes are distinct tectonic elements which may be traced the full length of the peninsula, although the axial zones may become less clearly defined locally. Minor folds occur on the limbs of the major structures. Slaty and fracture cleavages related to the folding are developed, dipping near vertically in the southern and central areas but becoming overturned along the northern coast to dip gently southeast. A pattern of wrench faults in the Sneem area cut across the fold axes at almost ninety degrees, while on the western end of the peninsula these are replaced by a system of vertical fractures running parallel to the fold-axes.

The large scale pattern of folding and axial plunge controls the age of the exposed rocks. The oldest sediments form the core of the Portmagee Anticline on the northwestern end of the peninsula. The youngest sediments occur in a synclinal axis running through the Kenmare River, and outcrop very locally along the southern coast near Sneem.

7.3 Folding

As already noted, folding in the area has a NE-SW axial trend. The scale of structures is hierarchical, ranging from major folds with wavelengths of up to 13km, through smaller folds of wavelength 200-500m. (PLATE 104), down to outcrop sized folds of less than 10m wavelength (PLATE 105). The majority of the folding is upright or steeply inclined and gentle (180-120 degree interlimb angle), with axial plunges typically ranging from 0-20 degrees. Axial zones of the major folds tend to be broad anticlinorium/synclinorium zones containing numerous small anticline/syncline pairs. On the limbs of the major folds, uniformly dipping beds are occasionally interrupted by minor monoclinal folds (PLATES 107 and 108) or minor anticline/syncline pairs (PLATE 105). These are always asymmetric, with the shorter limbs of the minor folds indicating the direction and type of the nearest major fold-axis (see Text. Fig. 69).

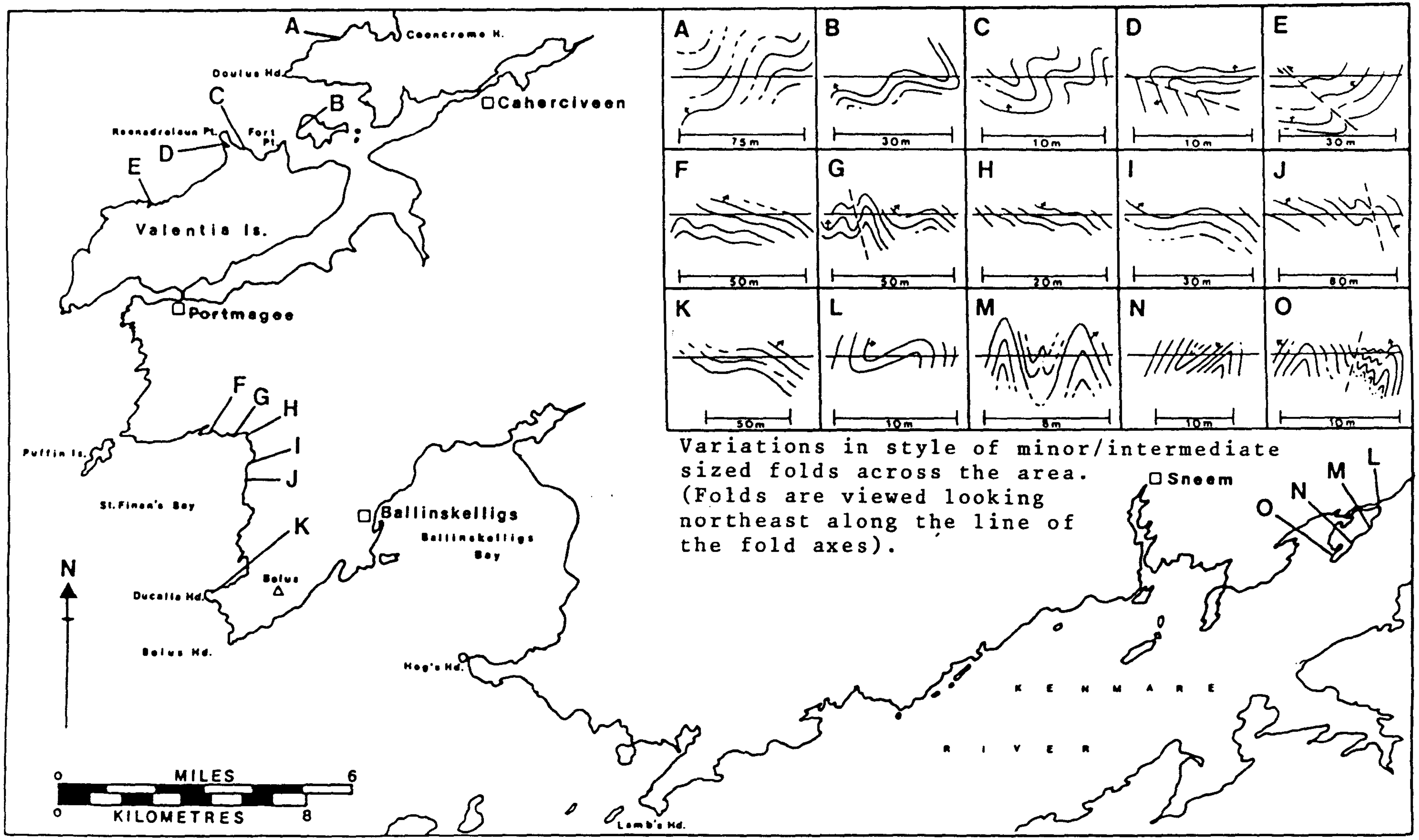


TEXT FIG. 69 Structural cross-section.

The axial traces of the major folds are laterally persistent, although as already noted there may be a change in style from a large simple axis to a broad poorly defined zone of minor folds as the axis is traced along. In the case of the smaller folds, anticline/syncline pairs tend to change along axis into increasingly gentle monoclinal folds which eventually die out into uniformly dipping beds. Minor folds with greater amplitude and wavelength show correspondingly greater axial persistence. The plunge of the fold-axes (major and minor) ranges from horizontal to gentle in either direction, and it is not uncommon to find a minor fold pair with axes less than ten metres apart, both plunging ten degrees in opposite directions.

Where minor folds are reasonably well exposed, the folding is seen to be disharmonic (PLATE 105) with differences in movement taken up by the less competent siltstones and claystones. Thin sandstone beds generally show Ramsay type I_C folding with thickening on the fold noses. In the Rossmore Sandstone Formation where thinly bedded sandstones and siltstones are folded together, the fold hinges become locally more sharply angular to produce chevron-style folds (PLATE 103 (Text Fig. 70, N)). The latter appear due to a combination of thin bedding and very high competence contrast, and have not been recorded from any other area or part of the succession.

A generalised cross-section (Text Fig.69) shows the pattern of folding across the western end of the Iveragh peninsula. In the north, the Portmagee Anticline has a broad NE plunging axis. The northern limb, seen on Valentia Island and around Valentia Harbour



Variations in style of minor/intermediate sized folds across the area. (Folds are viewed looking northeast along the line of the fold axes).

TEXT FIG. 70

towards Dolous Head, is complicated by frequent minor folds with bedding steepening and locally overturning to the north. The southern limb in contrast dips homoclinally south at about 55 degrees, around the shores of St. Finan's Bay as far as Bolus Head. The Inny syncline is largely concealed in low-lying drift-covered areas in the Inny valley, but is locally exposed at Boolakeel, near Ballinskelligs, where it is a broad poorly defined zone of minor folds plunging gently NE. The Cummeragh Anticline, Currane Syncline and Kilcrohane Anticline are well-defined major-fold axes inland, but on the coast between Hog's Head and Lamb's Head they consist of a series of broad gentle minor folds. The Cummeragh and Currane axes plunge to the SW at approximately thirty degrees. The Kilcrohane axis disappears in a zone around Caherdaniel complicated by vertical NE-SW fractures and a fairly abrupt return to a northwesterly axial plunge. The next major syncline to the south is the Kenmare River Syncline, part of the axial zone of which is exposed around Rossdohan Harbour and Rossmore Island to the east of Sneem. Fold-axes here continue to plunge NE, with angles of plunge ranging between ten and twenty degrees.

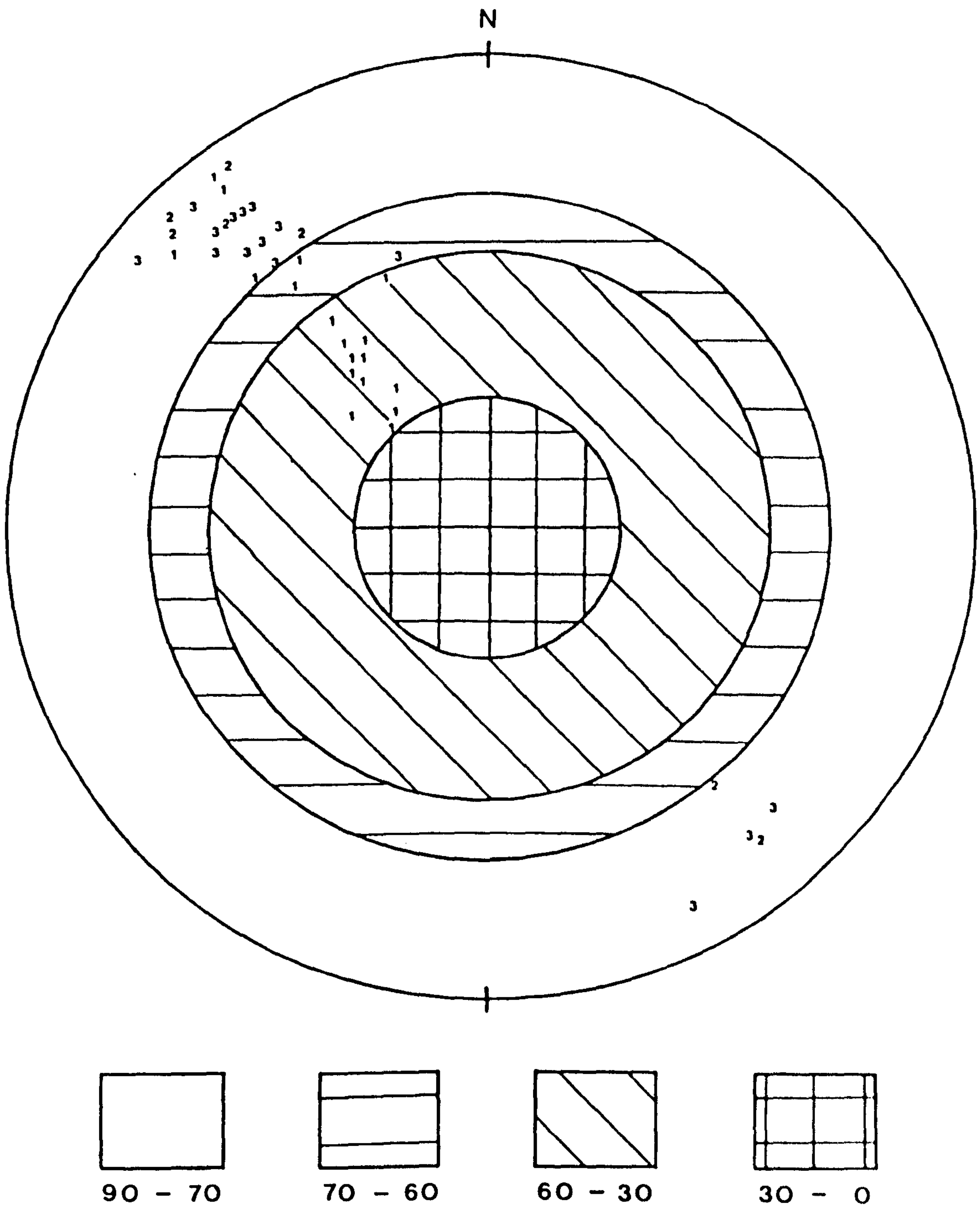
7.4 Cleavage

Associated with the folding, a regional cleavage fabric was developed. In the siltstones and finer-grained rocks this takes the form of a penetrative slaty cleavage (PLATE 116), while in the sandstones a spaced 'fracture' cleavage is developed (PLATES 113 and 114). Although the cleavage is in the most general sense axial-planar to the folds, PLATE 106 shows clearly how it tends to be divergent or convergent depending on the lithology in which it is formed.

Text Fig. 71 illustrates a general tendency for cleavage to become progressively overturned towards the north as the northern coast of the peninsula is approached. In some areas around Dolous Head and the northern coast of Valentia Island, cleavage dips as low as thirty degrees towards the SE were recorded.

There is some evidence to suggest that the cleavage may to some extent be a product of pressure solution processes. PLATE 117 shows a fine siltstone bed in which calcite veins parallel to bedding are clearly truncated by spaced cleavage planes. The features are strikingly similar to those seen in Devonian slates along the south Devon coast, where flattening deformation has been accommodated by solution taking place along regularly spaced cleavage planes. The proportion of crustal shortening due to solution can be estimated if regularly shaped fossils or reduction spots are present, or if thin marker beds are inclined obliquely to the cleavage. Unfortunately in this case, none of the calcite veins could be correlated with certainty across solution cleavage planes, and apparent displacements cannot be used to estimate shortening.

The fracture cleavage (PLATES 113 and 114) is particularly well-developed in the very fine sandstones, where it is impressively picked out by weathering. On bedding-plane surfaces and in



ANGLE OF CLEAVAGE DIP, MEASURED IN DEGREES.

1 Poles to cleavage from northern limb and axial zone of the Portmagee Anticline.

2 Poles to cleavage from southern limb of the Portmagee Anticline.

3 Poles to cleavage from areas south of the axis of the Inny Syncline.

TEXT FIG. 71

sections normal to bedding it is seen to have an anastomosing pattern, with cleavage planes spaced at roughly 2-3cm intervals. Thin-sections show the cleavage planes to be lined with a zone of white micas up to 5mm wide. This is in strong contrast to the quartz/feldspar composition of the sandstone, and is selectively picked out by weathering. For such a quantity of mica to be concentrated as a result of pressure solution selectively removing detrital quartz and feldspar, very considerable solution shortening of the rock would be required. Where bedding lies oblique to the cleavage an apparent displacement of the beds across cleavage solution planes would be obvious in such a case, but has not been observed. An alternative mechanism, proposed by Beach and King (1978), is that limited pressure solution indeed takes place, but that extensive recrystallisation of feldspars and clay minerals during solution results in formation of authigenic micas in the solution zone. This mechanism is consistent with the evidence from field observations and thin-sections, and is considered a reasonable possibility.

A locally observed phenomenon of crenulation cleavage (PLATE 115) is restricted to a few areas, mainly around the Valentia Harbour area, usually in the vicinity of wrench faults showing minor displacement. The effect is restricted to fine-grained rocks originally possessing a penetrative slaty cleavage, and appears to develop where shear-stress responsible for the fault has been directed so as to cause compression along the cleavage.

Also related to the fine-grained rocks possessing slaty cleavage, is the presence of occasional kink-banding (PLATE 116). All the examples recorded were individual 'envelopes' showing a sinistral sense of dislocation, no conjugate sets were observed. The kink-bands are formed by compressive stress directed along the schistosity, with the deformation taken up by flexure and slip on the cleavage planes (Ramsay, 1967). These features obviously formed at some time after the regional Hercynian cleavage development, possibly due to early post-cleavage stress adjustment. Three-dimensional data from conjugate sets are required to derive the principal stress orientation, so no measurement was possible in this case.

7.5. Faulting

Faulting in the area consists of three distinct patterns:

1. NW-SE oriented wrench-faults.
2. NE-SW oriented fractures, with displacement in some cases.
3. Southerly dipping thrust or low-angle reverse faults.

NW-SE wrench faults

Originally observed by Capewell (1957, 1975) to occur mainly in the area around Sneem, where dominantly dextral movements show apparent displacements of up to 2400m, these faults occur throughout the study area. Apparent displacements of between 10 and 200m are commonly observed, with both sinistral and dextral senses of movement. Similarly oriented fractures have been observed in coastal sections lacking prominent marker beds, where it is not possible to say if significant movement has occurred. Slickensides indicating a near-horizontal movement are seen on exposed faces of some of these fractures, but experience shows that in other cases where significant movement has been established, slickensliding is not preserved. Displacement of minor fold-axes is not generally reliable for mapping faults, as fold character may change rapidly along the trend of the fold axis. PLATE 111 shows an exception to this where a narrow fault plane is clearly visible and movement has undeniably taken place. PLATE 112 shows close-up details of another similarly oriented fault-plane where brecciation shows movement, but the amount and direction of displacement are unknown.

NE-SW fractures

These fractures are near vertical, aligned parallel with the prevailing fold axial trend. Capewell (1975) commented that this pattern predominates on the western end of the peninsula, replacing the NW-SE wrench faulting which he considered developed mainly in areas further to the east. Displacement is difficult to identify since on steeply south dipping fold limbs the fractures are more or less parallel to bedding, and there is no way of estimating the amount of movement.

These features are clearly visible lineaments on aerial photographs in the area designated by Capewell as the 'Caherdaniel fault-zone'. There is no unambiguous evidence to support his suggestion that they may be normal faults. His use of juxtaposed opposing plunge directions to map 'faults' is unwarranted, since as noted in the previous section on folding, axial plunge may readily reverse direction between adjacent folds. Similarly, attempting to map displaced formation boundaries (defined on the type sections at Sneem and St. Finan's Bay, see CHAPTER 6) are difficult to apply here at the limits of their extent.

Southerly dipping thrust or low-angle reverse faults

Rare examples of these are noted on the shores of St. Finan's Bay and along the northern coast in the Valentia Island-Doulus Head area. The St. Finan's Bay example is shown in PLATE 110, where the path along the east side of the cove picks out a thrust plane dipping at an angle of twenty-two degrees to the SSE. Marker sandstone beds do not match across the fault, and the thrust plane is lined with quartz gouge. Slight flexure of beds above the thrust plane suggest reverse throw, and a minimum displacement of 10m produces a possible rather poor match of sandstone beds across the fault.

On the northern coast of Valentia Island, a fracture may be traced between coves at Coosnalarabaunia and Skrone Point. A similar feature cuts the cliffs at Reenadrolaun Point, south of the Signal Station. Both features are fractures dipping southeast at approximately forty-five degrees, and the fracture planes are marked by a zone of green chloritised fine-grained rock. At Skrone Point the fracture is seen to mark the hinge zone of an inclined fold, with obvious reverse faulting displacing beds by several metres (Text Fig. 70, E).

PLATE 109 shows a further example from Valentia Island, on Reenadrolaun Point. Minor folding is locally recumbent, and shearing along the fold axis has resulted in the upper limb being overthrust on top of the lower limb, by approximately 10m. Similar situations are seen east of Doulus Head, on the northern coast, where a number of folds show minor shearing and displacement along southwards dipping axial planes.

Age of faulting

The thrusting, reverse faulting and NW-SE wrench faults can all be related to the same compressive stress responsible for the regional pattern of folding and cleavage development. The development of crenulation cleavage adjacent to some minor wrench-fault planes requires movement to have taken place after the cleavage had been formed. This, however, could equally be due to brittle deformation having followed directly after ductile folding and cleavage development (and hence part of the same stress pattern), or simply represent later reactivation on some of the faults.

No evidence exists to show whether any of the NE-SW trending major fractures truncate or are truncated by the NW-SE wrench faults, so relative dating of movement (if any) is not possible.

7.6 Jointing

Jointing is well-developed in the area, with two major patterns in evidence. One set is almost vertical, oriented NW-SE, and the other dips at approximately forty-five degrees to the northwest. Both are shown in PLATES 119 and 120, with the latter showing particularly well how the intersection of joints and bedding combine on steeply dipping fold limbs to produce a rhomb-shaped pattern picked out by weathering.

7.7 Tension Gashes

Quartz-filled tension gashes are developed in some areas. PLATE 118 shows a particularly fine example with conjugate en-echelon sets intersecting at approximately sixty degrees. The acute bisectrix corresponding to the principal compressive stress forming the gashes shows that they formed under the same stress pattern as the 'fracture' cleavage in the sandstone. Presumably they formed at the same time as the other brittle wrench and thrust faulting features, soon after ductile folding was completed.

7.8 Summary

The tectonic features of the area are remarkably simple. Folding, cleavage, faulting and the majority of minor structures can be related to the same major compressive event of the Hercynian orogeny. There remains some uncertainty about the role of the NE-SW oriented fracture system, since local evidence is unable to demonstrate clearly the amount and sense of any displacements. Mapping experience of a similar area south of the Kenmare River shows that movement on wrench faults is often accommodated by the fault-plane curving to strike parallel to bedding. Horizontal movement on these NE-SW fractures therefore appears quite probable, although identifying where it has occurred remains a major problem.

Folding is disharmonic, and minor folds are particularly variable when traced along the axis. Coupled with this, axial plunges are capable of changing direction either along the axial trace, or between adjacent folds, to an extent which may have been previously underestimated.

The progressive northwards overturning of folds, and accompanying development of minor thrusting and reverse faults suggests the margin of the mobile belt is indeed being approached. There are however no grounds to support the previously noted suggestion that this margin is sharply defined or is in the form of a major thrust.

CHAPTER 8

CONCLUSIONS

The Old Red Sandstone rocks on the Iveragh Peninsula were deposited as part of a thick extensive deposit of continental red-bed facies, which accumulated in an elongate basin trending east-west over most of western and central Munster (Naylor and Jones, 1967). The results of the present investigation are consistent with the structural model first outlined by Naylor and Jones, who suggested it was a half-graben, fault-controlled along the northern margin. The facies patterns outlined here, together with isopach evidence from Naylor and Jones (1967) and Graham (1983), show sediment fining southwards away from a hinge-line where rapid thickening of the succession occurs across the basin margin. Conglomerates developed near the basin margin wedge out rapidly to the south, and are absent from most of the study area. The sediments were derived from a northerly source.

The age of the sediments infilling this part of the Munster Basin was previously uncertain due to lack of fossil evidence. Arising from this study, the oldest exposed part of the Iveragh succession is now attributed a maximum age of latest Givetian on the evidence of fish fossils (Russell, 1978). Plant miospores from the Moll's Gap Quarry give a basal Frasnian age for rocks from the middle part of the succession (Higgs and Russell, 1981). Although the base of the Old Red Sandstone in not seen away from the basin margins, the evidence from Iveragh shows that even in this area where the basin-fill is thickest, the oldest beds exposed are Upper Devonian in age. From analysis of the sedimentary facies, it is apparent that the majority of the red-bed sediments were deposited by episodic shallow sheetflood events. Highly seasonal rainfall probably prevented the formation of permanent incised fluvial channel systems, and the presence of occasional calcrete horizons suggests a semi-arid climatic setting. There is ample evidence to show that large amounts of sediments were deposited very rapidly during flood events; individual beds over 30cm thick show uninterrupted steeply climbing ripple-drift cross-lamination, and represent single depositional episodes. Published accounts of Recent and modern analogues for the type of environment described above are relatively scarce, but recent descriptions of 'terminal-fans' and their deposits (Mukerji, 1976; Parkash et al, 1983) offer what appears to be a reasonable sedimentological model for the Iveragh Group. The sedimentary facies described by Parkash et al are almost directly comparable with those described from the study area. Williams (1970) described terminal-fan deposits from the arid Biskra region of the Sahara, in which the proximal to distal fan-profiles show strong similarity to the proximal/distal trends observed in this study area.

The northern fault-margin controlling sedimentation in the Munster Basin remained active throughout the Upper Devonian. Towards the end of the basin's life, there are indications that movement on the fault slowed, allowing coarser proximal sediments to be transported further out into the basin. At the same time, the rate of sediment deposition was reduced so that calcrete horizons were able to form and possibly greater oxidation and reddening of the sediments could occur.

The fault controlling the basin margin appears to have been a deep-rooted structure and may be linked to Late Devonian and early post-Devonian igneous activity evident from Iveragh and adjacent areas to the east. Several tuffs, suggested in this study to reflect acid igneous eruptions, are interbedded in Upper Devonian sediments on the Iveragh Peninsula. Probably contemporaneous acid extrusives and ash-beds are known from the Lough Guitane area to the east (Wright et al, 1927; Clayton et al, 1980). Basic igneous intrusions of late Upper Devonian or slightly younger age form sills and dykes on the western end of Iveragh. The igneous activity presently lacks examples of andesitic composition, but is otherwise a reasonable example of the calc-alkaline suite of intrusive and extrusive igneous rocks which are frequently developed towards or soon after the end of an orogenic phase.

Previous workers have given the impression that the major part of the succession on Iveragh is lacking in signs of organic life. This investigation has demonstrated the ubiquitous presence of a reasonably diverse assemblage of trace fossils in the finer grained sediments, often in sufficient abundance to obliterate the primary bedding. At least four distinct burrowing or crawling organisms are represented. Semi-permanent lakes supported a fairly diverse fish fauna, and there is also evidence of a possibly sparse and localised plant community. In general, a surprising amount of organic life is shown to have been present, and the Upper Devonian palaeoenvironment evidently supported an ecosystem of moderate complexity.

Towards the end of the Munster Basin's history, the area was overrun by a marine transgression from the south (Clayton et al, 1974). The onset of this event is marked on the Iveragh Peninsula by deposition of the Rossmore Sandstone Formation. The formation reflects estuarine deposition with marine influences, rather than fully marine conditions. Plant miospores date the first marine influences in this area as Uppermost Devonian (Strunian Tn 1) (Higgs and Russell, 1981).

Attempts to produce a regional stratigraphy for correlation purposes have met with limited success. The work of Capewell (1957, 1975) established similar but distinct stratigraphies for two main areas; one of which applies to the southeasterly district around Sneem, and the other covers the western end of the peninsula around Waterville. Walsh (1966), working in the Reeks area only a short distance to the northeast of Sneem, was forced to modify the stratigraphic terminology used by Capewell. The results of the present study show that the stratigraphies established by Capewell break down away from the type-sections on which they have ben defined. Particular problems are encountered on the northern limb of the Portmagee Anticline and on the western end of the Kilcrohane

Anticline, where the local stratigraphies are at the limits of their extent. A revision of Capewell's stratigraphic nomenclature has been necessary to standardise the status of his stratigraphic subdivisions, and two units (the 'Transition Group' and the 'Coomhola Group') are renamed to avoid undesirable interpretive or correlative associations. The term 'Iveragh Group' is introduced to identify the complete succession of red-bed sediments underlying the Rossmore Sandstone Formation. In areas where the previous mapping is regarded as invalid, or incorrect but structurally complex, the rocks are referred to undifferentiated Iveragh Group. Certain distinct anomalies within some of the formations demand recognition and are defined here for the first time as members.

Although the formations (as rigidly defined) may not be widely mappable, the incoming of significant amounts of sandstones and the upwards change to predominantly bright purple colours are events which are broadly recognizable over much of the study area. In attempting to correlate between sections, these criteria need to be weighted against their reliability as stratigraphic markers. A distinctive marker horizon, the Keel Tuff Bed, is present on both northern and southern limbs of the Portmagee Anticline and allows a direct correlation between sections in both areas.
Palaeontological evidence suggests that the St. Finan's Sandstone Formation on the Atlantic Coast section may be correlated with the Chloritic Sandstone Formation in the Sneem area. This supports Capewell's equation of the three formations on the Atlantic Coast section with the lowest three formations exposed in the Sneem

area. Interestingly, this places a thin tuff in the Sneem area at more or less the level of the Keel Tuff Bed on the Atlantic Coast and Valentia Harbour sections. Further work is required to test whether this is actually an extension of the Keel Tuff Bed into the Sneem area.

Palaeontological data, mainly from spore assemblages, now allows correlation of the Iveragh succession with outcrops in other parts of the Munster Basin. To the south, the lower part of the Iveragh succession (the Valentia Slate Formation) is correlated with the lowest exposed part of the red-bed succession on Clear Island (the Sherkin Formation), both dated as late Middle/early Upper Devonian. At the top of the red-bed succession, LE Subzone spore assemblages correlate the top Derryquin Sandstone Formation on Iveragh with the top West Cork Sandstone at Bantry, and the top Toe Head Sandstone Formation at Dunmanus Bay. Similarly, LN Subzone spore assemblages correlate the base Rossmore Sandstone Formation on Iveragh with the base Coomhola Formation at Bantry, the top Toe Head Sandstone Formation at Dunmanus Bay (north), and the base Old Head Sandstone Formation at Dunmanus Bay (south).

To the north, spore assemblages from the Dingle Group on the Dingle Peninsula give a lower Devonian (Emsian) age, which is clearly much older than the late Middle/Early Upper age of the lower part of the succession exposed on Iveragh. Previous attempts to correlate the Dingle Group with the lower part of the Iveragh succession can now be confidently refuted.

Arising from the present work, a number of interesting questions are raised which are recommended here as promising areas for further investigation.

The stratigraphy of the area has been shown unsatisfactory in the structurally complicated area of the Kilcrohane Anticline, and further detailed and structural mapping should be carried out to resolve the problems in this area.

The terminal fan model proposed for the deposition of the sediments in the area raises the question of how far it may be extended beyond the area of study; an investigation of the Killarney area to the east, and the Beara Peninsula to the south, is obviously the next step in further testing the model.

The main emphasis of this study was placed on understanding the red-bed part of the succession. The Rossmore Sandstone Formation although limited in exposure, offers ideal material for a study using palynofacies techniques to further refine the depositional environment and extent of marine influence.

The fish material described from the Atlantic Coast section is in sufficient abundance and in a reasonable state of preservation (particularly in the lowest fish-bed) to warrant detailed work by an expert vertebrate palaeontologist. Much material remains to be collected. Personal communication with other workers in Irish Devonian continental deposits indicates that fish fossils are less rare than previously believed. The material from the Atlantic Coast section would be an ideal starting point for a review of fish fossils in the Irish Devonian, which could be of considerable value in areas where oxidation has destroyed all plant spores, but fragmentary fish fossils could be used to date the succession.

Finally, the Keel Tuff Bed offers the possibility of accurate correlation on a regional scale. Further work to determine whether it is of ash-fall or ash-flow origin is needed, and comparison with the Lough Guitane igneous rocks to the east may provide a fuller picture of the igneous processes operating at this time. Attempts should be made to identify the Keel Tuff Bed in adjoining areas, with the adjacent Dingle and Beara Peninsulas as obvious starting points.

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