The Stratigraphy and Coral Fauna of the Ilfracombe Beds in North Devon.

by

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ABSTRACT

Early work relating to the Ilfracombe Beds of North Devon is reviewed and it is shown that many problems remain unsolved, for example, the age of the beds, the stratigraphical succession, and the structure. The coastline between Combe Martin and Ilfracombe has been mapped on the scale of 50 ins = 1 mile, and it is found that there are only two important limestone developments, each about 30 feet thick; the lower is the Jenny Start Limestone, which is of Upper Givetian age, and the higher is the David's Stone Limestone of Lower Frasnian age. There are two other thin, but mappable, limestone horizons, each between 2-5 feet thick; these are the Rillage Limestone (about 200 feet below the Jenny Start Limestone), and the Combe Martin Beach Limestone (lying between the two main ones).

N.W.-S.E. dextral tear faults, probably of Tertiary age, and E-W normal and reverse strike faults, probably related to an early orogeny, displace the strata. The faults, combined with the very intense folding, have resulted in numerous repetitions and occasional omissions in the local successions. The full succession between the Hangman Beds and the top of the Ilfracombe Beds is summarized in tabular form.

The second part of this thesis is a detailed study of the coral fauna, including a complete morphological study and revision of the genus Metriophyllum. 51 species of corals belonging to 23 genera are figured and described. Of these 20 are new species and many are recorded for the first time in North Devon. The coral fauna establishes the age of the main limestones with moderate certainty, but the intervening beds are unfossiliferous and it is, therefore, impossible to draw absolute boundaries.

PART I. STRATIGRAPHICAL RESEARCH IN NORTH DEVON

INTRODUCTION

The history of research on the rocks of North Devon falls into three well-marked periods. Until 1835, geological descriptions were in the broadest possible terms and little was understood about the relative ages of the rocks. The calcareous slates and limestones now known as the Ilfracombe Beds were distinguished from other lithologies at an early date however (e.g. Vancouver 1808) and they were assigned to the Grauwacke or Transition Series (Berger 1811).

The second period starts with the papers of Sedgwick and Murchison (1835⇒) who suggested a stratigraphical succession and established the Devonian System. There were subsequent attempts to change the relative order of succession (e.g. Jukes 1865 and Hicks 1890), but most geologists were prepared to accept it. The boundaries of the main lithological units were later established with more precision and correlations made between the Old Red Sandstone and Devonian rocks both in Britain and on the continent.

The third period is concerned with the detailed subdivisions of each of the main lithological units but progress has been slow for two main reasons. (a) The structure is extremely complex as a result of folding and faulting - particularly strike faulting. (b) The tectonic deformation has resulted in the distortion or complete obliteration of any fossils which may once have existed. The complications of the structure were not appreciated by most workers in the last century (Champernowne 1879 was an exception) and there

was little reward for the painstaking work needed to study the details of the fauna. Valpy (1867) was the first writer to give a detailed succession for the Ilfracombe Beds, but it was a series of papers by Evans (1912⟹) which marked the real start of the detailed subdivision of that formation. So unrewarding were the results obtained by Evans that no detailed description of the Ilfracombe Beds has been published since his last contribution in 1929.

Period I. EARLY RESEARCHES ⟹ 1835

Stratigraphical research in Devonshire may be traced back to the beginning of the nineteenth century though the earliest writers were concerned with generalities embracing the geology of the whole South-western Peninsula and it was not until the middle of the century that papers began to appear specifically on the stratigraphy of North Devon.

At the end of the eighteenth century rocks were classified into 'Primary', 'Transition' and 'Secondary', and the term 'grauwacke' was used to describe slates within the 'Transition' rocks (see Lehman 1756 and Werner 1780). In 1811, Berger, reading a paper before the recently formed Geological Society of London applied the word 'grauwacke' to the slates and sandstones of Devon:

> "I give the name grauwacke to a rock composed of separate siliceous particles united by an argillaceous cement with a little magnesia and iron.... Though formed by mechanical precipitation, grauwacke is one of the oldest of the secondary rocks... it is divided into two species, common grauwacke and grauwacke slate."

The limestones of Devon are referred to as 'Transition rocks'

and thus it seems that Berger regarded them as older than his grauwacke rocks.

Vancouver 1808. Vancouver (1808) produced a map showing the distribution of limestone in Devonshire. His concern was not primarily geological but he paid some attention to the distribution of the limestones because of their value to agriculture - most of the Devonshire soils being deficient in lime. His map shows two bands of limestone in the Ilfracombe-Combe Martin area, but he clearly did not regard them as part of the sedimentary sequence for he referred to them as 'veins' and stated:

> "...they seem embedded in the shillot and stratified rocks of the country".

He states also that the limestone

> "nowhere partakes of the regular dip or inclination of the stratum in which it is embodied.... The lime rock is found without any regularity or order save that of the course it holds with the common strata of the hills."

Vancouver probably mistook the cleavage for the bedding in the slates and he did not detect the contorted nature of the bedding.

Vancouver's map shows two limestone bands running across North Devon. The more northerly, in its course between Samson's Cove and Combe Martin, includes most of the limestone outcrops which were extensively quarried during the last century. Eastward from Combe Martin it is doubtful if any limestones ever existed along the band shown; most of the area across which it passes is occupied by the arenaceous succession of the Hangman Beds. The more southerly band includes no massive limestones though the

slates are slightly calcareous and contain occasional, very thin (1"-2") limestone beds. It is interesting to notice that this southern band follows a very similar course to that of the boundary between the Morte Slates and Ilfracombe Beds as mapped by Etheridge (1867) and Hall (1867).

Smith 1815. William Smith's map (1815) shows a threefold division of the rocks in North Devon - 'Killas' (slaty rock), 'Red and dun stone' (sandstones), and 'Limestones'. The limestones are shown as lenticular outcrops lying entirely within the killas; the map also shows limestone occurring South of Blackmore Gate, West of Challacombe, and North-west of Simonsbath. At the present time there are no limestone outcrops in these areas, but several writers in the last century referred to limestones cropping out in these localities, and it seems likely that the limestones do in fact extend further East than exposures at the present time would suggest.

The boundary between the dunstone and killas on Smith's map runs South-east up the Umber (Combe Martin) valley and then trends eastward through Parracombe. This is in close agreement with the Hangman Grits-Ilfracombe Beds boundary as mapped by Etheridge (1867) and accepted by most later workers; the only significant difference is that Etheridge places the sandy beds (=Lester series (Evans 1922)) in his Ilfracombe Beds.

Conybeare 1823. Conybeare (1823) proposed a fourfold division of the rocks in Devon and Cornwall - the Granite, to which he does

not assign a stratigraphical position, and then, in ascending order

3 Sand slate

2 Superior slate

1 Inferior slate

This classification is based largely on the mineralization of the rocks together with associated intrusions. The Inferior Slate, for example, is said to be "cupiferous and stanniferous" and to include elvans and greenstones. The Superior Slate, on the other hand, is identified by being without elvan dykes but abounding much more in greenstone and in dark coloured limestone; it is sparingly metalliferous, containing no tin, but is more productive of lead than the Inferior Slate; it also contains occasional organic remains. From the Sand Slate metalliferous veins are completely absent, and its lithology is said to be generally a conglomerate or sandstone, alternating with 'tender slate' and occasionally associated with coralline or shelly limestone.

Boase 1832. Boase (1832) objected to Conybeare's 'Inferior' and 'Superior' terminology on the grounds that they are "too theoretical when strata often dip in opposite directions towards each other". He classified the rocks (principally with reference to Cornwall) as follows:

2 Calcareous Series

1 Porphyritic Series

The 'Porphyritic Series' is that portion of the slate in which feldspar rocks and porphyries abound. It is, therefore, the

approximate equivalent of Conybeare's 'Inferior Slate'. The 'Calcareous Series' is said to include all the schistose group of Primary rocks in which "calc spar is a frequent constituent and which also alternate with limestone".

Period II. 1835 - 1900 A RELATIVE SUCCESSION AND A GEOLOGICAL AGE IS ESTABLISHED

Sedgwick and Murchison 1836. The complexities of the stratigraphy and structure of Devon and Cornwall only allowed the early workers to make a generalized classification of the rocks and it was a tremendous contribution that Sedgwick and Murchison made when they produced the following stratigraphical succession for North Devon, together with the revolutionary suggestion that the Culm rocks lay in a great syncline and were the equivalent of the Carboniferous rocks of South Wales:

	Modern terminology
6. Carbonaceous system of Devonshire	=Culm
5. Lower Silurian resting with conformity on the following...	=Pilton & Baggy Beds
4. Greenish & lead coloured roofing slate with sandstones & micaceous flagstones in the upper parts	=Morte Slate & Pickwell Down Sandstone
3. Calcareous slates of Combe Martin & Ilfracombe	=Ilfracombe Beds
2. Hard thick bedded red sandstone & red micaceous flagstone	=Hangman Grits
1. Slaty rocks with a vast abundance of organic remains	=Lynton Beds

They were mistaken in suggesting a Lower Silurian age for the rocks underlying the Carbonaceous System but this error was corrected in 1840. Their succession is still acceptable to the majority of workers in North Devon. They placed the 'Slaty rocks' (=Lynton Beds) at the base of the succession and equated the Foreland and Hangman Grits.

It is interesting to note that, while the formations now termed the Lynton Beds, the Hangman Grits, and the Ilfracombe Beds are all regarded as separate units by Sedgwick and Murchison, those now termed Morte Slates and Pickwell Down Sandstone have been grouped together in division 4, and the Pilton and Baggy Beds are placed together in division 5 (see comparative table above). Later workers have regarded the Morte Slates either as a separate formation (e.g. Phillips 1841, Etheridge 1867, Evans 1919) or have grouped them together with the slates and limestones of the Ilfracombe Beds (e.g. Williams 1837, Champernowne 1878, Ussher 1879). Also, with regard to the Ilfracombe Beds, Sedgwick and Murchison state that the beds have "a great aggregate thickness", are "abounding in organic remains" and "contain at least nine distinct ribs of limestone". These observations are repeated in their paper to the Geological Society read in 1837, but not published until 1840 (1840), and it is stated that this group can easily be traced inland "especially with the help of the calcareous bands". This is a remarkable statement in view of what can be seen at the present time; the limestones are readily followed between Ilfracombe and the Umber valley, but eastwards from there, they appear to die out completely. Their map shows a double band of lenticular limestones between Ilfracombe

and Combe Martin and then a series of elongated outcrops trending S.E. to Blackmore Gate; thereafter the bands bifurcate with one branch swinging abruptly N.E. towards Lynmouth, and the other continuing to the S.E. of Challacombe and E. of Simonsbath. There is no evidence at the present day for the continuation of the limestones towards Lynmouth, and such a trend would be highly suspect since it cuts across the strike of the rocks at right angles. The outcrops shown at Challacombe and Simonsbath do not correspond with the limestones shown in similar areas by Smith (1815). They occur along the line of strike where one would expect a continuation of the limestones, but they are certainly not present in such force as in the neighbourhood of Combe Martin. During the cutting of the Barnstaple-Lynton railway a thin calcareous band was recorded near Blackmore Gate (Ussher 1879) and it could be that the other outcrops shown by Sedgwick and Murchison are also thin calcareous developments and not massive limestones as at Combe Martin and Ilfracombe.

The following section, taken from Sedgwick and Murchison (1840) shows their interpretation of the structure and succession.

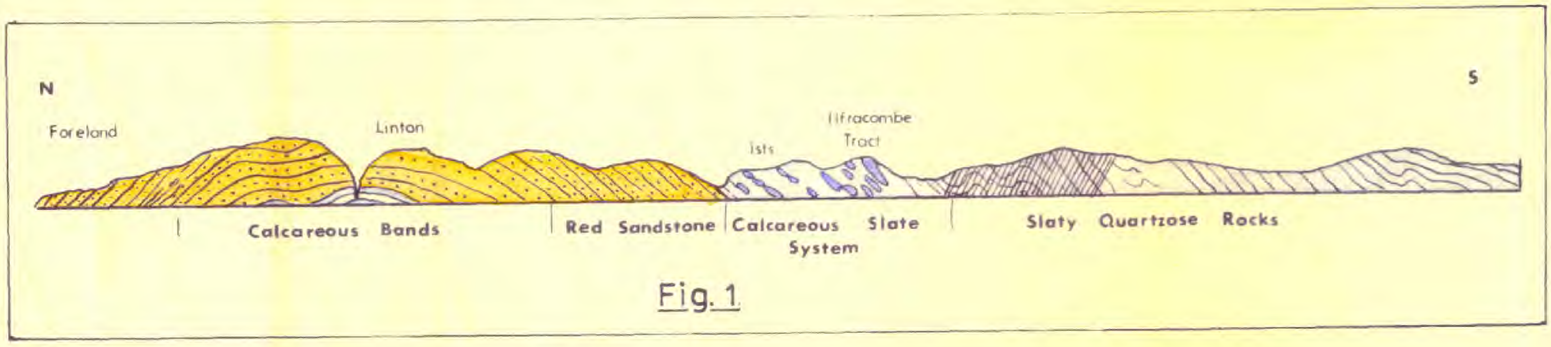


Fig. 1

The lower limit of their Calcareous Slate System (Group 3) is clearly taken below the 'Stringocephalus Limestone'(Evans 1922) of Wild Pear Beach, for they wrote: "The first beds are coarse and siliceous and contain fragments of large heart-shaped bivalve shells". The upper limit of these calcareous beds is not clearly defined but it must be taken West of Ilfracombe since the authors mention "thin limestones made up of crinoid fragments" from West of Ilfracombe.

Although the limestone bands shown on the section are probably not intended to correspond with actual limestone bands, it is clear that the authors regarded them as lenticular and in no way repetitions of the same band.

Williams 1837. At the British Association meeting the same year (1837) the Rev. D. Williams gave a succession for the rocks of North Devon which is similar to that of Sedgwick and Murchison but differs from the latter in some important aspects.

		Sedgwick & Murchison
CULMIFEROUS	9. Floriferous & culmiferous sandstones & shales + anthracite	
	8. Wavellite schistus & limestones, the former cleaving into parallelograms	
GRAUWACKE	7. Trilobite slates – abundantly fossiliferous	Group 5
	6. Woolacombe sandstones & purple slates – containing fossil wood & plants	Group 4 (in part)
	5. Mortehoe quartz & roofing slates & subordinate limestones	Group 3 (+4, in part)
	4. Hard red siliceous slate rock of Trentishoe	Group 2
	3. Linton slates & limestones with arenaceous slate & conglomerate bed of limestone pebbles	Group 1
	2. Foreland & Dunkery sandstones Doddington & Overstowey limestones Foreland & Dunkery sandstones	
	1. Cannington Park Limestone	

The succession contains some errors (for example, the position of the Cannington Park Limestone, which was shown by Wallis(1924) to be of Carboniferous age). Williams was the first worker, however, to place the Foreland group of sandstones at the base of the succession below the Lynton Slates (Sedgwick and Murchison had regarded them as younger - see section above). In this he was followed by de la Beche (1839) and most subsequent workers. It is also significant that Williams did not recognise the Combe Martin and Ilfracombe limestones as a separate unit, but merely as a minor calcareous development within a dominantly slate succession. Although few workers have followed him in this, there is much to commend the interpretation, as the slates of the Ilfracombe and Morte Beds are essentially similar lithologically and there is no readily distinguishable break; the limestones occur only in the lower parts of what are at present termed the Ilfracombe Beds.

Regarding the upper part of his succession (i.e. beds 8 & 9), Williams disagrees with the interpretation of Sedgwick and Murchison that they are the equivalents of the Carboniferous rocks of Pembrokeshire. He expresses the opinion that the Culmiferous rocks cannot be separated from the subjacent rocks of the Grauwacke series "either by mineral characters, relation of the strata or organic remains"(Williams 1837). This is the first expression of a disagreement which was never resolved and which constantly appeared in the subsequent papers of the two parties; Williams persisted obstinately in his opinion despite overwhelming evidence to the contrary on both palaeontological and stratigraphical grounds. (Williams 1839, 1842a, 1842b, 1846) - ~~see Appendix I~~.

Weaver 1838. In 1838 Weaver published the following succession:

COAL MEASURES	8. Culmiferous shales
	7. Wavellite schistus and limestone
TRANSITION SERIES	6. Trilobite Slates
	5. Woolacombe Sandstones, flagstones and slates
	4. Morte Slates
	3. Trentishoe quartzy slates and sandstone, including the Combe Martin Limestone
	2. Linton Calcareous Slates
	1. Foreland Sandstones

Weaver concluded that "the strata from 1 to 6 belong to a system distinct from that which includes beds 7 and 8, the former constituting a peculiar transition group and the latter belonging to the true coal measures of England, the old red sandstone being alone wanting". In this he agreed with Sedgwick and Murchison in separating the Culmiferous series from the Transition or Grauwacke Group, but he followed Williams in placing the Foreland Sandstones at the base of the succession. He grouped the Combe Martin Limestone with the underlying grits and presumably included in his Morte Slates all the slaty rock which occurs above the massive limestones.

It is clear from the extract quoted above that Weaver had no thought of his "peculiar transition series" being the equivalent of the Old Red Sandstone. He also claimed to have detected unconformity between the Trilobite Slates and the Wavellite Schistus. It would seem, therefore, (though not expressly stated in his paper)

that Weaver would have placed the Old Red Sandstone between his Culm and Transition series.

De La Beche 1839. In 1839 the report of de la Beche on the geology of Cornwall, Devon and Somerset was published, and although he does not give a table of strata, it is possible to infer from the text that the author recognised seven subdivisions in the strata of North Devon. It is essentially the same succession as that given by Williams (1837) in that the Ilfracombe and Combe Martin limestones are grouped with the overlying (Morte) slates, and the reddish sandstones of the Foreland area (Foreland Grits) are placed below the 'Grey Beds' (=Lynton Beds). The following table summarizes his views:

Carbonaceous Deposits

7. Shales and grits with fossil plants
6. Arenaceous beds with nodular limestones near the top
5. Arenaceous beds with some argillaceous slates
4. Grey slates with some grits and limestone bands in the lower parts
3. Reddish sandstones
2. Grey Beds
1. Reddish sandstones

(De la Beche 1839)

De la Beche finds it more desirable to use this non-commital nomenclature than

> "by prematurely assigning them names supposed to mark given geological epochs, assist in prejudging or retard a correct view of, the place they may be eventually found to occupy in the great series of European sedimentary deposits".

~~He was, however, of the opinion that there was a simple upward~~

He was, however, of the opinion that there was a simple upward succession of the beds between the lowest sandstones (Foreland Grits) and the shales and grits with fossil plants and, further, that there was no unconformity between his Grauwacke Series and his Carbonaceous Deposits.

> "On the contrary", he writes, "we constantly find a passage of the one system into the other, so that in order to define the limits of the systems upon the accompanying Ordnance maps, it has been necessary to take a mean distance between the marked portions of the two where they join each other and there trace an imaginary line for the sake of convenience - one nevertheless which nature has not traced".

Sedgwick and Murchison 1839. The publication of de la Beche's report immediately provoked a spirited paper from Sedgwick and Murchison (1840b) in order, as they put it

> "to state immediately and concisely what our views have been and what they are now, in order that our scientific brethren ... may have it in their power to draw a just conclusion as to the part we have taken in the new classification of the rocks of Devon and Cornwall."

However, the importance of this paper lies not in its attempt to establish the previous work of its authors, but in the fact that for the first time the rocks of North Devon are assigned to the Devonian System and are no longer referred to indefinitely as 'Grauwacke' or 'Transition' series. The authors write thus:

> "So long as we were unprovided with a typical suite of fossils from the older system of Devon, it was impossible to propose for it any name; but now having discovered a great many of its fossils, and that too in regions wherein

> the red arenaceous character gives way to the slaty impress and a very different mineral aspect, the necessity of adopting a new name becomes apparent and we propose the term 'Devonian System' as that of all the great intermediate deposits between the Silurian and Carboniferous Systems".

The new Devonian System thus held the same stratigraphical position as the Old Red Sandstone and the authors regarded the one as a lateral facies equivalent of the other. Already, in Pembrokeshire, they had noticed a lateral variation in the Old Red Sandstone - "the concretionary limestone disappears and a hard brown schistose rock replaces the soft marls and large tracts are occupied by yellow and grey hard siliceous sandstones".

In a more detailed paper to the Geological Society later the same year (1839) (Sedgwick and Murchison 1840c) the two authors amplified their views outlined above. They made no change to the succession given in 1837 (Sedgwick and Murchison 1840a) i.e. the Foreland Grits and Hangman Grits are still equated. Their error in regarding the Pilton and Marwood Beds as of Caradocian age is corrected, though they suggested the possibility that "the lowest rocks of the two counties" (i.e. Devon and Cornwall) "...belong to a still lower system" (than the Devonian). A faunal list for North and South Devon is included in their paper, but this is discussed elsewhere; it was the first such list to be published.

The faunal list was largely the work of Lonsdale, and Sedgwick and Murchison (1840) admitted that they owed much to his palaeontological labours in recognising the true position of the North Devon succession. Lonsdale's work (1840) was confined to the

limestones of South Devon which Sedgwick and Murchison had already correlated with the Combe Martin and Ilfracombe limestones (Sedgwick and Murchison 1840a). Lonsdale showed that the fauna from South Devon had an aspect intermediate between that of the Silurian and Carboniferous; this fact, together with the correlation of the Culm and Carboniferous rocks (Sedgwick and Murchison 1836) and the recognition of the stratigraphical sequence in North Devon, was sufficient evidence for Sedgwick and Murchison to establish the Devonian System.

Phillips 1841. In 1841 Phillips reached conclusions similar to those of Sedgwick and Murchison and Lonsdale after a study of all the known fossils from Devonian rocks (Phillips 1841). He also gave a stratigraphical succession which was similar to that of Sedgwick and Murchison except that he included Groups 4 and 5 of Sedgwick and Murchison in his Pilton Group.

6. Carbonaceous Group
5. Pilton Group - slates, sandstones, thin limestones
4. Morthoe Slates - unfossiliferous slates
3. Ilfracombe Group - slates and limestones
2. Martinhoe Group - grits and slates
1. Linton Group

He was most cautious, however, in using the new term 'Devonian' to denote a system equivalent to the Old Red Sandstone. He abandoned the term 'Grauwacke' completely, but usually referred to the 'North Devon Series' or "rocks of Devonian type".

Sharpe 1853. Sharpe also found it impossible to accept the conclusions of Sedgwick and Murchison and, like Williams, placed the 'Devonian System' between the Old Red Sandstone and the Carboniferous (Sharpe 1853). His opinion was based on the Belgium succession where rocks of Old Red Sandstone facies occur below a marine succession with abundant reef limestones.

> "It now becomes unnecessary to force the O. R. S. of England into a parallelism with the schists and limestones of South Devon as was done in 1837 by Mr. Lonsdale, Prof. Sedgwick and Sir R. I. Murchison. And our Old Red Sandstone appears on a parallel with the Belgium formation of red sandstone and conglomerate - the poudingue, psammite et schiste rouge of M. Dupont."

Sharpe's correlation table seems to be based on nothing more substantial than lithological considerations but it is given below in full as it was the first attempt to establish Devonian correlations outside the S. W. of England.

Système houiller		Coal Measures
	Limestones with productus, etc.	Upper Carboniferous Limestone
	Sandstones with anthracite	Carboniferous Sandstone of Derbyshire, Shap, etc.
Système Condrusien		Lower Carboniferous Limestone
	Limestone and shale	Lower Limestone Shale of Northumberland & Scotland, & the Culm of Devonshire, incl. the Petherwin & Pilton Beds
	Limestones of the Eifel	South Devon Limestone
Système Eifelien	Schistes - occasionally calcareous	Shales & schists below the South Devon Limestone
	Red Sandstones & conglomerates	Old Red Sandstone
Système ahrien	Grey & red psammites & schistes	Ilfracombe & Linton Series / Sandstones & schists S. of Plymouth
Système Coblenzien	Grey schistose grit	? in South Cornwall
Système Gedinnien	Red & grey sandstones	Tilestones of Upper Ludlow

As far as the English succession is concerned there appears to be no regard for stratigraphical or faunal relationships between the beds. Series from North or South Devon are included at random in the table so long as the lithologies matched those seen in Belgium.

Pengelly 1862. Pengelly (1862) joined Williams and Sharpe in opposing the correlation of the Old Red Sandstone and Devonian rocks, and he based his opinion on vertebrate remains. Phillips (1841) recorded a scale of Holoptychius from the Meadfoot Beds, while Pengelly recorded Phyllolepis concentricus, both of which occur in the Upper Old Red Sandstone of Scotland. Pengelly, therefore, regarded the Meadfoot Beds as the equivalent of the Upper Old Red Sandstone of Scotland, and the succession above the Meadfoot Beds (which included nearly all the Devonian system of Sedgwick and Murchison) as of post-Upper Old Red Sandstone age. He summed up his conclusions as follows:

> "There are in Devon and Cornwall no representatives of the Lower and Middle Old Red Sandstone rocks of Scotland, but the lowest (Pteurodictyum) beds of the former are on the horizon of the Upper Division of the latter."

However, it must be noted that even if these identifications are correct (and it has been found impossible to trace the original specimens) it only establishes the age of the Meadfoot Beds, and would raise great complications regarding the South Devon stratigraphy since many subsequent workers (e.g. Middleton 1959; Taylor 1950) have clearly demonstrated the Middle Devonian age of the

South Devon limestones. In any case, the presence of these two fishes does not establish the age of the North Devon succession since no direct correlation has been proved.

Salter 1863. During the same meeting of the British Association, Salter presented a much more significant paper (1863a) in which he claimed to show that the Lower, Middle and Upper Devonian rocks were the equivalent of the Lower, Middle and Upper Old Red Sandstone respectively. He showed that there was an incoming of a marine fauna in the Upper Old Red Sandstone of the South of Pembrokeshire, and that this fauna was essentially similar to that occurring in the Upper Devonian rocks of North Devon (i.e. the Lower Pilton and Marwood Beds). This suggested correlation is discussed more fully in another paper later that year (Salter 1863b) and greater details of the faunal similarities are given.

By this time most writers on North Devon were content to accept the succession of Sedgwick and Murchison with only minor modifications, if any, and these usually involving a change of nomenclature rather than a change in stratigraphical classification. For example, a short paper by Hall to the Exeter Naturalists Society (1865) gave the following succession:

NORTH DEVONIAN	Pilton Beds Marwood Zone Morthoe Group Ilfracombe Group Martenhoe Beds Lynton Zone Foreland Group

The brackets (which are Hall's) suggest that he would place the Morthoe Beds (presumably including the Morte Slates) with the Upper Devonian, though there is no indication of where he would draw the line between Middle and Lower Devonian. The Marwood Zone is separated for the first time from the Pilton and Mortehoe Groups, and Hall followed de la Beche and Phillips in placing the Foreland Group below the Lynton Zone.

Hall (1867) published a small scale map of North Devon showing rather diagrammatically, but for the first time, the position and extent of the main divisions given above. So far as the Ilfracombe Group is concerned, he gave very little explanation for the position of the boundaries. The lower boundary in Wild Pear Bay is an obvious lithological one to take, as there is a rapid change from massive sandstones of the Hangman Series to calcareous shales. The upper boundary appears to be a very arbitrary one as it is taken within a succession of slates which show very little lithological variation throughout their thickness. Hall later attempted to justify this boundary on two grounds: (a) The Morte Slates, as a whole, are finer and more uniform in texture (b)"In the lower part, limestone bands occur, while the upper half is characterized by the absence of any limestone" (Hall 1879, p.190)

Jukes 1865. In the same year as Hall published his first succession of the North Devon strata (1865), a major attack was launched against what had now become the orthodox interpretation of the succession. After becoming familiar with the Lower Carboniferous

rocks of Southern Ireland. Jukes made a visit to North Devon and convinced himself "that the rocks of North Devon belong partly to the group called Carboniferous Slate of Ireland, and partly to the Old Red Sandstone" (Jukes 1866). Jukes explained the succession by postulating a great E-W fault, reaching the coast at Woolacombe and striking across North Devon somewhere near the villages of West Down, Bittadon, East Down and Challacombe. This, according to Jukes, caused a repetition of the succession and hence "the rocks of the north coast, the Lynton and the Ilfracombe Beds, will be placed on the same general horizon as those of Baggy Point and Barnstaple, and the classification of the rocks of Devonshire will assume the same simple type as those of Cork, viz:-

3. Coal Measures
2. Carboniferous Slate or Devonian Beds
1. Old Red Sandstone "

(Jukes 1865a p. 147)

Jukes gave three reasons for his hypothesis:

1. The vast thickness of rocks ("at least 25,000 ft") which must be assigned to the Devonian rocks if repetition is not admitted
2. The lithological similarity of the Lynton Beds with the Carboniferous Shales and the Pickwell Down Beds with the Old Red Sandstone of Ireland - to quote Juke's own words "the rocks about Lynton were precisely identical in lithological characters with the lower part of the Carboniferous Slate of Ireland" (Jukes 1865b) and "the non-fossiliferous grey slates which lie above the Lynton Beds are also precisely like the non-fossiliferous portion of the Carboniferous Slate of the county of Cork". (Jukes 1865b)

3. The fauna of the Lynton Beds and the Carboniferous Slate of Ireland was believed by Jukes to be essentially the same.

Jukes pointed out (1865) that nowhere is "the actual junction between the Old Red Sandstone (i. e. Pickwell Down Beds) and these apparently lower rocks (i. e. Morte Slates) to be seen". He recalled also that in places near Cork and Kerry it is possible to penetrate 10,000-12,000 feet down into the Old Red Sandstone but without any sign of the grey slates such as those at Ilfracombe or Lynton. He recognised, however, that "there is a good deal of difference in the assemblage of fossils that occur in different localities" (i. e. Lynton and Ilfracombe) but was willing to accept this merely as facies change. He continued (Jukes 1865)

> "There are, however, certain species which I believe prevail throughout the slates whether they contain inlying bands of limestone and peculiar sandstones or not. These species are the most common and abundant species everywhere and it is a fact of no little significance that most, if not all, of these species occur also in the Carboniferous Limestone."

Jukes does not list these "common species" but his remarks could well apply to long range species with little or no stratigraphical significance.

It was not until 1867, in a privately published paper, (Jukes 1867), that Jukes gave any field evidence for his supposed fault, and even then, his evidence is meagre. Near Wivelliscombe, "the beds are a good deal disturbed and crushed in the way that beds often are near a great dislocation." He goes on to say that there is marshy

ground with numerous springs along the strike in the same neighbourhood. De la Beche (1839) in fact recognised a small fault along this zone, but Jukes reckoned that it had a throw of about 4,000 feet to the North. Nowhere else can he give any positive evidence of faulting, and it is particularly significant that there is no sign of it in the coast section between Morte and Baggy Points.

In 1866 Jukes had read a paper before the Geological Society of London in which he re-iterated his idea that a concealed fault caused repetition of the strata in North Devon, but he also mentioned a second hypothesis - that there might be a great anticlinal structure which was causing the repetition. (This second suggestion was taken up many years later by Hicks, but the latter's interpretation is discussed fully below).

At the present time, with a more detailed knowledge of the fauna from at least some of the North Devon beds, it seems inconceivable that, for example, the Lynton and Morte Slates should be equated, but it must be remembered that it was not until 1869 that any fossils at all were found in the Morte Slates, and the Hangman Grits and Pickwell Down Beds have still only a very meagre fauna recorded from them. However, had Jukes investigated the limestones of the Ilfracombe Beds he could scarcely have failed to recognise in their fauna, in fact in their very presence, something quite different from his Irish Carboniferous Slates. Jukes himself admitted (1865) that he traversed the Ilfracombe Beds once only along the road from Barnstaple to Ilfracombe.

It is unfortunate that Jukes was so obsessed with the lithological similarities of the southern Ireland and North Devon succession that he was incapable of accepting any evidence which would suggest a contrary interpretation. He thought he had found palaeontological corroboration of his ideas when the fauna from the Pilton Beds was found to resemble that of the Lower Carboniferous of Ireland; he also recognised the Culm as the equivalent of the Coal Measures, but the limestones of the Ilfracombe Beds, which would have clearly demonstrated the error of his interpretation, were never investigated.

Etheridge 1867. So strongly, however, did Jukes express his convictions, that the Director of the Geological Survey felt it expedient to investigate the evidence for a great E-W fault causing repetition of the succession. Etheridge was sent, and in 1867 he published a paper strongly disputing Jukes's conclusions, primarily on palaeontological grounds, but also using physical and stratigraphical evidence. He entered into great palaeontological detail concerning the faunas from the various horizons in North Devon and compared them, in detail, with those from both South Devon and the continent; also he showed that the lithological sequence, in its broad essentials, is the same in North Devon and in South Devon, France, Belgium and Germany. This was especially so of the Middle Devonian in which there was an extensive development of limestone with a characteristic fauna throughout the whole North European area. Etheridge stated

"The middle group which holds so distinctive a place

> in the series in North and South Devon both by richness in special and peculiar genera and in number of species, is paralleled in every particular in the three continental areas"
>
> (Etheridge 1867)

He was also at great pains to show (as Lonsdale had shown 30 years before in South Devon), by means of numerous faunal lists and tables, that the Devonian of North Devon was a system quite independent of either the Silurian or the Carboniferous.

Etheridge was primarily concerned with the broad stratigraphical succession in North Devon; his map (Etheridge 1867) is very similar to the one published by Hall in the same year, though the boundaries on Etheridge's map appear to be drawn a little less diagrammatically. The map shows the following subdivisions:

	Carbonaceous
UPPER DEVONIAN	Pilton and Barnstaple Beds
	Braunton Beds
	Baggy and Marwood Slates
	Pickwell Down Sandstones
MIDDLE DEVONIAN	Grey unfossiliferous slates
	Calcareous slates - fossiliferous
	Hangman Grits
LOWER DEVONIAN	Lynton Slates
	Lynton Sandstones

Valpy 1867. Etheridge was the first to separate the whole North Devon Devonian into Lower, Middle, and Upper divisions, and most subsequent workers have been content to accept these

divisions (but see particularly Hicks (1890) and Evans (1922) below). Etheridge included detailed observations of some areas in his paper, but they are only included as evidence of his broad generalizations. He made use of the work of others where appropriate and, in particular, he quoted from the records and observations of Valpy for much of his detail concerning the Ilfracombe Beds. Valpy was an amateur geologist who lived in Ilfracombe. His one written contribution to geology was a small booklet - "Notes on the geology of Ilfracombe and neighbourhood" (anonymous= Valpy 1867), but this contains a wealth of detail which could only have been acquired by constant painstaking observation over a period of many years. His booklet contains the first detailed lithological succession within a part of the Ilfracombe Beds as exposed on Hagginton (or Haggington) Beach and in the cliffs above. He also records many fossils, unique in North Devon, from the limestone quarries which have now disappeared or have become so overgrown as to be completely inaccessible.

Etheridge made out a very strong, and in the present writer's opinion, conclusive, case against Jukes's interpretation, though the latter still found support for his ideas from various geologists throughout the latter part of the nineteenth century. Assessing the position in 1873, Woodward wrote

> "Whether we regard the Devonian Slates as the equivalent of the Old red Sandstone or of the lower carboniferous rocks, a great change in sedimentary conditions must have taken place, and the question is still perhaps to be decided whether part of the

> Devonian rocks are a modified extension of the old red sandstone ... a point which appears to take its stand merely on palaeontological evidence, or whether the whole fossiliferous Devonian slates and limestones be not of lower carboniferous age, the representative of the mountain limestone and the lower limestone shale and the carboniferous slate and limestone of Ireland ... this latter opinion finds the more support when we look ... to the variations which take place in the carboniferous limestone series when traced through the North of England into Scotland as well as through the South of Ireland".
>
> (Woodward 1873)

Champernowne 1878. Champernowne (1878) expressed the opinion that there was a repetition of beds in North Devon, though he favoured Jukes's alternative hypothesis that there was a great anticlinal structure with the Pickwell Down Sandstone forming the core, and the slates being repeated on either side. The Hangman Grits were equated with the Pickwell Down Beds and were thought to occur as the core of a second anticline. Champernowne was one of the few early geologists who was conscious of the complexity of the structure in North Devon; he recognised the multiplicity of the minor folds and this led him to suggest the major anticlinal structures mentioned above.

> "We often hear", Champernowne writes, "of the simplicity of North Devon. I confess I cannot see it. Faults may be rare and igneous rocks rarer still, but the instances of contortion with inversions on a small and medium scale are almost innumerable and lead one to suspect the existence of far grander ones."
>
> (Champernowne 1878)

Champernowne found no justification for separating the slates of the Ilfracombe Group (Hall 1865, Etheridge 1867) from those of the overlying Morte Slates -

> "I feel fully convinced that all the rocks from Combe Martin to Woolacombe constitute but one system, and any division of them into Ilfracombe Beds and Morte Slates must be purely artificial." (1878)

Further, he recognised that the limestone beds are constantly repeated due to overfolding and clearly considered the possibility that there may only be one limestone. Such a grasp of the structure had not been shown by any previous writer and even Evans (1922,1929) does not appear to have been aware of the constant repetition of beds that there is along the coastal section between Ilfracombe and Combe Martin.

Ussher 1879. Ussher agreed with Champernowne regarding the separation of the Ilfracombe Beds from the Morte Slates - "No persistent horizon can be drawn between the fossiliferous and unfossiliferous portions of the series" (Ussher 1879 p.17). However, he did not completely reject the separation of the Morte Slates from the Ilfracombe Beds since, ten years later, he wrote: "The lower beds are distinguished as a whole by the presence of grits and masses of limestone and by a great variety of colour and texture" (Ussher 1889 p.20). He drew the junction between the Middle and Upper Devonian at the base of the Pickwell Down Beds, but admitted that owing to "the gradual passage from the base of the Upper Devonian Beds into the Middle Devonian Slates... the boundaries between them are often arbitrary".

Ussher (1881) gave the following stratigraphical sequence, from which it is clear that he regarded the Morte Slates and the Ilfracombe Beds as a single lithological unit.

UPPER DEVONIAN	Pilton Beds - argillaceous slates Baggy Beds - Lingula Slates, Cucullaea Grits Pickwell Down Grits with slates
MIDDLE DEVONIAN	Slates, Shales, local Gritty Beds & Limestones (Mortehoe & Ilfracombe Series) Hangman Grits
LOWER DEVONIAN	Lynton Beds - Grits & Schists Foreland Grits

Eight years later, however, Ussher (1889) changed his opinion regarding the position of the Hangman Grits, and placed them in the Lower Devonian. No direct explanation was given for this change of opinion, but it seems clear from the correlation table that he was influenced by the fact that grits are developed at the top of the Lower Devonian in most other European localities, and that there is a sharp change to calcareous deposition at the beginning of the Middle Devonian in the same areas.

He commented on his changed opinion many years later (Ussher 1910) in these words,

> "Both Etheridge and Townsend Hall classed the Hangman Grits as the Middle Devonian and prior to 1888 the writer did the same. The prevalence of grits in the lower part of the Ilfracombe Series renders the line of junction between Middle and Lower Devonian somewhat vague and unsatisfactory."

Hicks 1890. In 1890, Hicks read the first of a series of papers in which he claimed that the simple succession of the rocks in North

Devon which had first been recognised by Sedgwick and Murchison, and which had been accepted by most subsequent writers, was an erroneous one. From the Morte Slates, Hicks had obtained a *Lingula* which he believed to be of Silurian age. This led him to postulate a great anticlinal structure with the Morte Slates in the core. His interpretation differed fundamentally from the alternative hypotheses put forward by Jukes (1866) and Champernowne (1878), who would have placed the Pickwell Down Sandstone in the anticlinal core, with the Morte Slates overlying and being of Lower Carboniferous age. Hicks's interpretation involved correlation of the

Ilfracombe Beds with the Hilton Beds
Combe Martin Beds with the Baggy Beds
Hangman Beds with the Pickwell Down Beds

and the Morte Slates being up-faulted as a horst block (see Hicks 1896b).

So great was the storm of criticism when Hicks presented his paper to the Geological Society (Hicks 1899), that he withdrew it before publication. The criticism was largely concentrated on the weakness of his palaeontological arguments (on structural and lithological grounds there is much to commend Hicks' hypothesis). Hicks continued to search the Morte Slates for fossils and his labours were rewarded by the discovery of some crushed brachiopods and lamellibranchs in the cliffs between Morthoe and Woolacombe, and in quarries near Ilfracombe (Hicks 1896a). These fossils are claimed to represent a horizon low down in the Silurian (Hicks 1896b).

The age of the Morte Slate fossils was disputed by Gregory (1897). He pointed out that four of them were new species and therefore of little weight in indicating a Silurian age, especially since genera such

as Spirifer and Lingula have a long range through the geological column. After a critical examination of the other fossils, Gregory felt that all of them could in fact be referred to Devonian genera. Hicks maked a spirited reply (Hicks 1897b) to Gregory's paper, concentrating his argument on the identification of Stricklandinia lirata from the Morte Slates. The preservation of all the fossils is so poor that it is impossible to identify them with any degree of certainty, so that the arguments on both sides are inevitably inconclusive.

A further paper published by Hicks in 1897 (Hicks 1897a) suggests that the Ilfracombe and Pilton Beds have several fossils in common, though none of these, according to Hicks, are to be found in the Morte Slates.

Hicks' interpretation failed to convince more than a handful of geologists and all subsequent writers have followed the 'orthodox' interpretation of the succession. The age of the Morte Slates and its position in the North Devon succession was put on a slightly surer foundation when Evans and Pocock (1912) described brachiopods from Barricane Beach (near Woolacombe) and considered them very close to, if not identical with, Sp.verneuili. The same authors compared a species of Rhynchonella, also from Barricane Beach, with Rh.(Camarotoechia) ferquenis from the lower Frasnian of Belgium.

Period 3. DETAILED STRATIGRAPHY WITHIN THE ILFRACOMBE BEDS

Evans 1919 ⇒ In 1919 Evans listed 24 species (the majority of them brachiopods) from the Ilfracombe Beds, and on the evidence of

these, referred the beds to the Frasnian stage (Evans 1919a). He also tentatively correlated the Morte Slates with the Schistes de Matagne (Evans 1919b). Later (1922) he gave a more detailed succession and comparison with the European stages.

		feet
FAMENNIAN	Morte Slates	1500
FRASNIAN	Woolscott Cleave Slates	250
	Slates with subordinate grits & limestones	1000
	David's Hole Beds - striped calcareous slate & limestones	250
GIVETIAN	Red Limestone Series	355
	Jenny Start Beds	30
	Slates & limestones of Oakestor Bay	135
	Newberry Beds	520
	Lester Series: Slates with grits & lenticular limestone	500
	Lester Series: Limestones, Grits & slates	550
	Wild Pear Beds - calcareous slates & lenticular limestones	400
	Little Hangman Beds	400
COUVINIAN	Rawn's Shales	200
	Trentishoe Grits	3000
	Lynton Beds	
	Foreland Grits	

This was the first detailed subdivision of the Ilfracombe Beds and it formed the basis for later work. The Morte Slates were placed in a separate stage, but the Ilfracombe Beds were divided between the Frasnian and the Givetian. Evans was uncertain where the boundary between Middle and Upper Devonian should be drawn and he suggested that it might be below the Jenny Start Limestone - i.e. all the main limestones would be placed in the Upper Devonian. This uncertainty

was still apparent in 1924 when he wrote "il est difficile de tracer une limite exacte entre le dévonien moyen et le dévonien supérieur." Evans' final contribution to the stratigraphy of North Devon was in 1929. His succession was essentially the same as in 1922 except that the 'Slates and Limestones of Cakestor Bay' and the 'Slates with subordinate grits' were omitted from the succession. More significant however, are his comments on the similarity of the fauna from Jenny Start and David's Hole, and with the latter he now linked the limestone at West Hagginton. This suggests that Evans was, at least tentatively, considering that some of the limestones might be equated with each other.

Since 1929, no further contributions have been made to the stratigraphy of the Ilfracombe Beds, except for a paper by myself (Holwill 1962) which is included as part of this thesis, and one by Webby (1964) in which he discussed the stratigraphical significance of the fauna from the Ilfracombe Beds of West Somerset. It is apparent from the foregoing review that many fundamental problems remain unsolved. Some of the more obvious ones are listed below and in the subsequent parts of this thesis an attempt will be made to resolve them.

(1) The age of the Ilfracombe Beds
(2) The number of separate limestones which are developed within the Ilfracombe Beds and their relative stratigraphical position
(3) The apparent absence of limestones to the east of Combe Martin
(4) The form of the limestone masses (lenticular or continuous)
(5) The true stratigraphical succession in North Devon.

PART II. STRATIGRAPHY AND STRUCTURE

A. INTRODUCTION

Shearman (1962) suggested a simple threefold division of the Ilfracombe Beds on the basic of lithology:-

Upper Ilfracombe Beds - dominantly arenaceous
Middle Ilfracombe Beds - slates, calcareous slates & limestones
Lower Ilfracombe Beds - dominantly arenaceous

This is a convenient division and although Shearman did not define the limits of these groups their validity is readily appreciated in the field. This thesis is largely concerned with the Middle Ilfracombe Beds and in particular with a description of the coral fauna from the limestones, but in mapping the coast section between Combe Martin and Ilfracombe (Beacon Point) it has been necessary to consider also the Lower Ilfracombe Beds. Strata assignable to the Upper division make a small outcrop in Hele Bay, but the main outcrop lies to the West of the area under review.

The Middle Ilfracombe Beds are considered to start with the Rillage Limestone and to end at the top of the David's Stone Limestone. Four mappable limestone horizons are recognised in this sequence:-

David's Stone Limestone
Combe Martin Beach Limestone
Jenny Start Limestone
Rillage Limestone

The succession between the three upper limestones has been discussed (Holwill 1962). Between the Rillage Limestone and the Jenny Start Limestone are slates with some very thin limestone and sandstone beds; this succession

is well-exposed at Rillage Point.

The sequence of strata within the Lower Ilfracombe Beds is best seen at Widmouth Head, though a continuous succession up to the Rillage Limestone is unfortunately not exposed. However, only a small part of the succession is cut out by the normal fault above Samson's Cave so that the succession at Widmouth can serve as the type succession for the Lower Ilfracombe Beds. This area is, therefore, described first, followed by the other areas in which Lower Ilfracombe Beds are seen (The Warren, Broadstrand, Hamator, and Golden Cove).

No further description is given of the Combe Martin-Jenny Start area as it is contained in the accompanying published paper (Holwill 1962), but a detailed description is given of the Middle Ilfracombe Beds outcropping West of Widmouth Head.

The geology is described in convenient geographical units from East to West, rather than in strict stratigraphical order, since the latter method would involve reference to numerous separated outcrops with consequent difficulty for a reader unfamiliar with the local details of the coastal section. Since, however, in general, younger rocks outcrop westwards along the coastline, the sequence of descriptions is largely in stratigraphical order.

B. THE LOWER ILFRACOMBE BEDS

(a) Widmouth Head

(1) The Succession

The essential features of the succession seen at Widmouth are as follows:-

11	34' 0"+	Arenaceous slates & sandstones
10		Thin limestone
9	8' 0"	Arenaceous slate
8	2' 0"	Greenish grey slate
7	90' 0"	Current bedded sandstones & arenaceous slate
6		Thin limestone
5	110' 0"	Massive sandstones with some slate. Quick-sand structures.
4		Thin limestone
3	54' 0"	Arenaceous slate & sandstones
2	2' 0"	Limestone
1	24' 0"+	Arenaceous slate - to low water mark

At the northern end of the headland, near low water mark, a limestone (bed 2) occurs in the dominantly arenaceous succession. It is of variable thickness ranging from 1' - 2' 6"; it is bluish grey when fresh and is largely formed of shelly debris but with much argillaceous material occurring as irregular elongated lenses. Such features suggest that the limestone accumulated as a shell bank and that it may not form a persistent horizon within the arenaceous beds. Unfortunately, no identifiable fossils have been obtained from the limestone and correlation with other limestones in the area is problematic. It is unlikely, however, that this limestone can be correlated with the Rillage Limestone partly because it lacks the characteristic features of the latter, but more particularly it occurs within an arenaceous succession with massive grits above, while the Rillage Limestone at its type locality and along Hagginton Beach always occurs at the top of an arenaceous succession, and is overlain by a dominantly slaty sequence.

The limestone (bed 2) is overlain by at least 200 feet of massive bedded sandstones and arenaceous slates. About 100 feet above the limestone the massive sandstones (bed 5), show the disturbed bedding structures which Selley et alia (1963) have attributed to quicksand action. Plate 1, fig 1-2

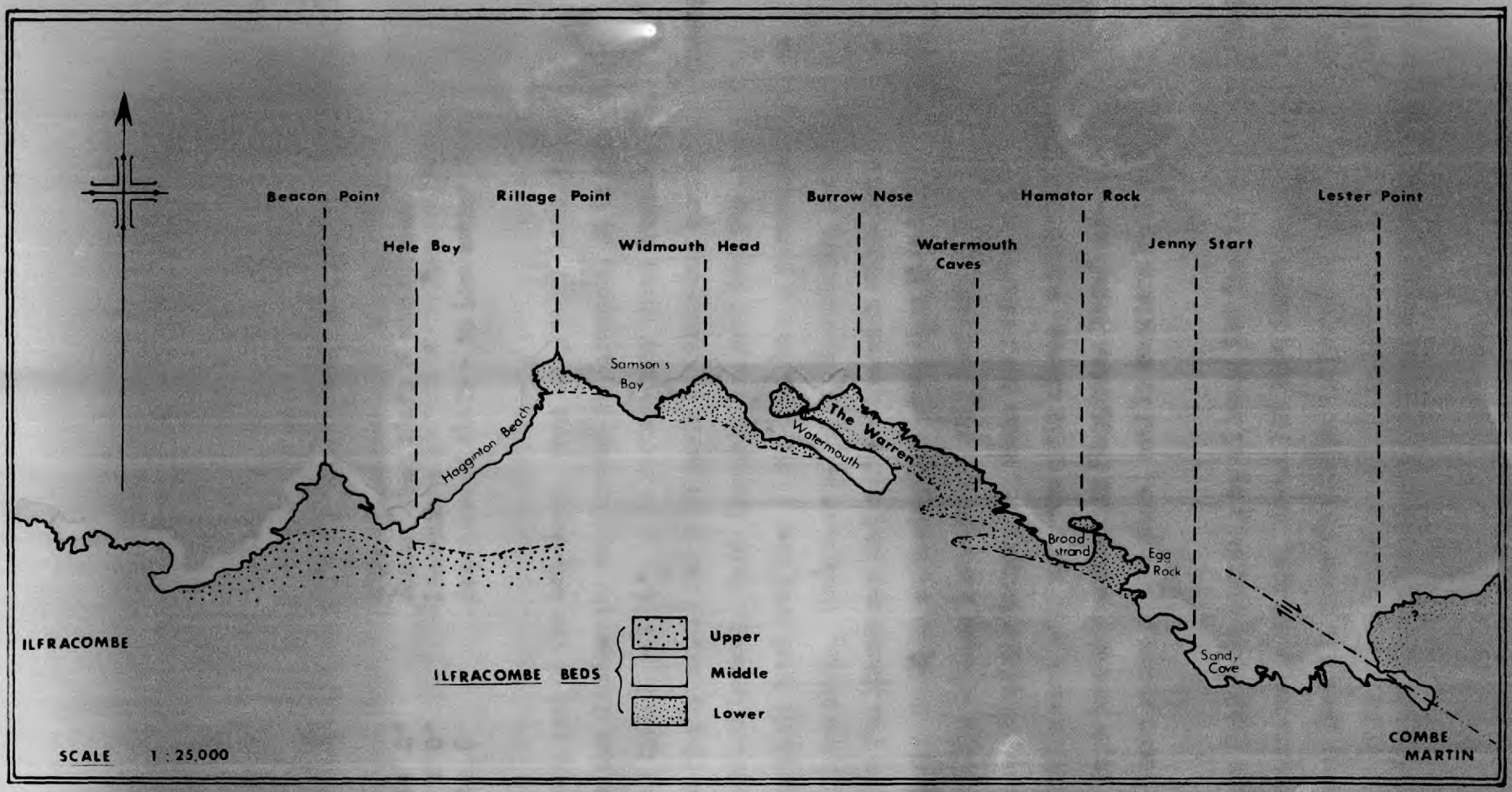


Fig. 2. Map showing the threefold division of the Ilfracombe Beds and important localities along the coast.

shows sections through these structures which vary in size from a few inches to about 2 feet in diameter; they are usually from 6 - 8 ins. high, and appear in section as basin-like structures in which the original(?) stratification is upturned and even overturned at the edges. The stratification within the structure is often much contorted.

These quicksand structures are confined to about 10 feet of sandstone at Widmouth Head and it is here that they are best developed, though they are also seen at Burrow Nose and are incipiently developed at other places. It seems possible that the sandstone sequence in which these structures occur may be used for correlation purposes. The validity of this can be demonstrated from Widmouth Head across to Sexton's Burrow and Burrow Nose and it has been used tentatively in the Hamator area for correlation of beds in the absence of more reliable criteria. The dangers of this correlation method are fully recognised and interpretations based on it may have to be modified in the light of further knowledge.

Two thin limestones (1"-1½") occur within the Widmouth Head succession (Beds 6 & 10). The lower one, seen on the prominent dip slope at the North-east corner of Samson's Bay, is probably the same horizon as the conglomeratic limestone which outcrops at Burrow Nose and the northern end of the Warren. (Both the limestone and the conglomeratic limestone lie at approximately the same distance above the quicksand structures)

To the South of Samson's Cove (i.e. above the Widmouth Head beds, but separated from them by a prominent fault - see fig.8) there occurs about 60 feet of arenaceous slate, greenish on wave smoothed surfaces, but a rusty brown when sub-aerially weathered, together with some sandstones and a very thin limestone near the base. Above these beds lies the Rillage Limestone which crops out near the bottom of the gully in the South-east corner of Samson's Bay and can be followed up the cliffs to where it passes over an anticline and is eventually cut off by the fault (figs 8.& R1). (Note: figure numbers prefixed by 'R' indicate that the figure will be found in the pocket at the back of the thesis)

The succession immediately above the Rillage Limestone is concealed beneath scree but there is a NW-SE fault passing into an E-W strike fault at this position. At the top of the cliff - that is, in the South-west part of Widmouth Headland - the Jenny Start Limestone is seen in a series of quarries from which a good coral fauna has been collected. (See table in Palaeontological section)

(ii) The Structure

The structure seen along the West side of Widmouth Head is shown in fig 8. The fault which runs down into Samson's Cove (the Samson's Cove Fault) dips South at 45° and strikes 257°. The dip of the beds below the fault varies from 30°-35° while above the fault the dip is about 40°; the direction of dip in both cases is due South.

The arenaceous succession North of the fault is not folded in any of the exposed parts on the West of the headland; immediately South of the fault there is an anticline overturned to the North so that the beds are inverted for a few feet. The anticline is well-marked by a thin wriggly limestone which passes over the hinge of the fold near beach level; the Rillage Limestone can also be detected on the inverted limb in the extreme top of the cliff.

The nature of the movement on the Samson's Cove Fault is not obvious; the dip is low and parallels the cleavage in the slaty beds, while immediately above the fault is the overturned anticline. These facts suggest that it should be a reverse or thrust fault resulting from compression, but there is a complete absence of any of the characteristic beds which lie above the Rillage Limestone (e.g. Jenny Start Limestone, Combe Martin Beach Limestone, David's Stone Limestone) from the sequence seen to the North of the fault. The fault is therefore interpreted as having a normal displacement, since the succession to the North is not affected by any other major tectonic structure. (It is possible that the initial fracture may have resulted from

compression, but subsequent release of pressure has permitted a down-faulting of the southern block; or there may have been two distinct periods of movement, one of compression and the other of tension. This interpretation is shown in the accompanying diagrams (fig. 3).)

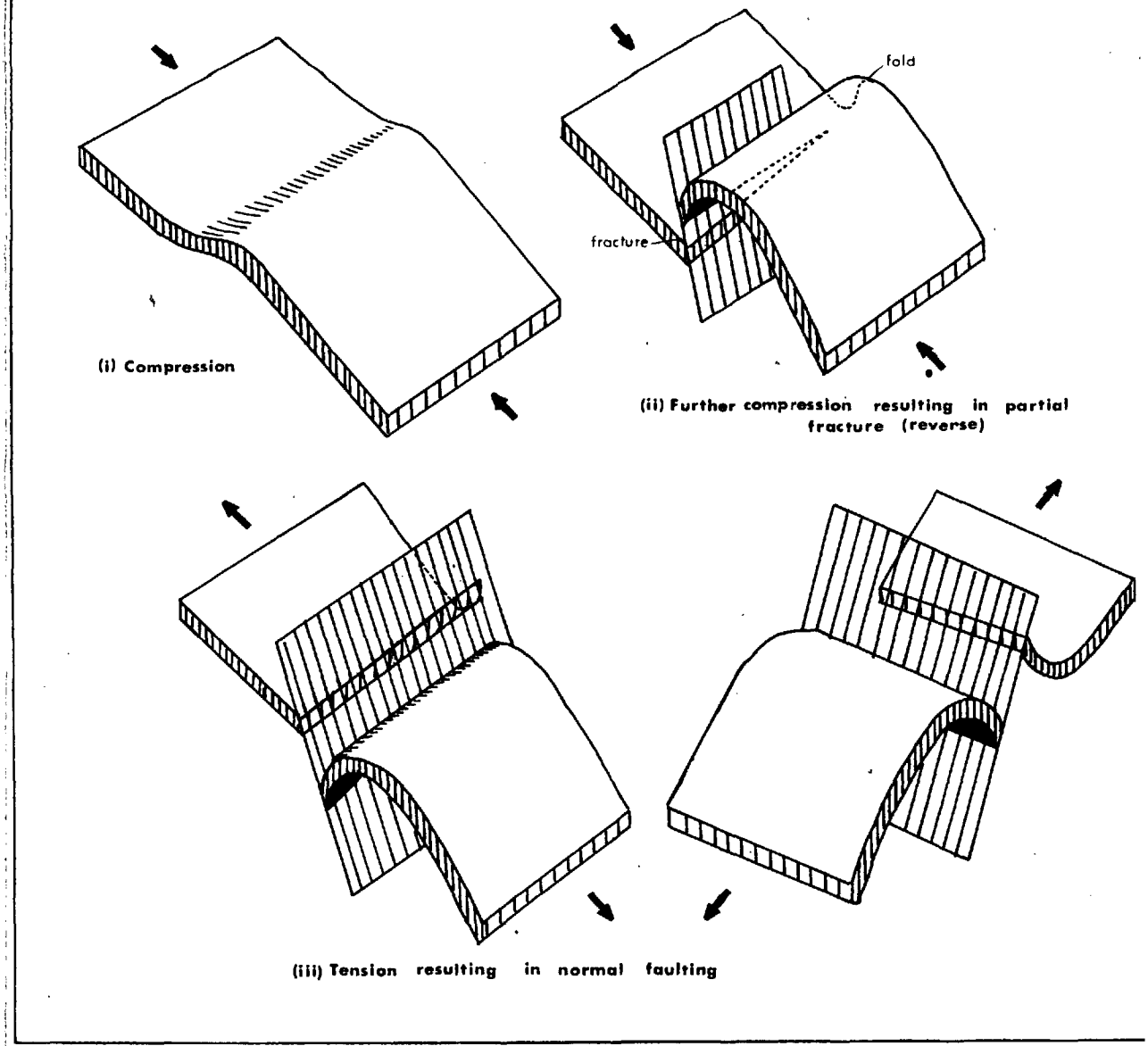


Fig. 3

That normal faults have in fact displaced the strata is shown by a normal fault with a throw of 1-2 feet, which occurs in the sandstones about 20 yards North of Samson's Cove (see also plate 10, fig.2).

The position at which the Samson's Cove fault emerges on the East side of the headland cannot be recognised with certainty. The most likely position is about 250 yards to the North of the outcrop of Rillage Limestone on Widmouth Beach, where there is a fracture zone marked by brecciation and quartz veining between an anticline and syncline (fig.7 and plate 2, fig.1). The strike of the fracture is 265° and this would carry it to about the position of Samson's Cove on the opposite side of the headland. If this is the correct interpretation, and it is confirmed by a feature seen running across the headland on aerial photographs, it means that the syncline seen in the East dies out against the fault before reaching the West side; i.e. when traced from West to East the fault diminishes in importance and passes into fold structures (this is also confirmed by the absence of any fracture in the corresponding position on the East side of Watermouth (fig 6)).

There are two objections to this suggestion:-

(a) The fracture on the East side of Widmouth Head is vertical while at Samson's Cove it dips 45°S

(b) Quartz veining is associated with the fracture in the East but not in the West

Neither of these objections is considered, however, fundamental enough to invalidate the suggested correlations and the sequence of events shown in fig.3 above.

Another fault in the South-east corner of Samson's Bay cuts off the Rillage Limestone abruptly about 20 feet above beach level. It is correlated with a fault 50 feet North of the Rillage Limestone on the East side of the headland and it is interpreted as another normal strike fault. (The Rillage Limestone is not found in the cliff to the South and must therefore be down-

faulted below beach level). This strike fault appears to be a continuation of a N.W.-S.E. fault which trends across Samson's Bay at 148° and which displaces the Rillage Limestone about 200 feet to the North on its South-west side. The line of this fault is marked by a prominent reddening of the beds for about 6 feet on either side, both across the beach and in the cliff. There is no evidence for the N.W.-S.E. fault continuing into the cliff along the trend of 148° and it must, therefore, either stop against the E - W fault or, as seems more probable, pass into it.

In the cliffs on the South side of Samson's Bay an anticlinal hinge can be clearly seen. This is stepped to the North as it is followed to the West by many small N.W.-S.E. faults; it is the same anticlinal structure seen in the natural arch at the West end of Samson's Bay (see plate 8).

The structure which follows this anticline to the South is seen in the deep N.-S. fault gully about the middle of Samson's Beach, where the Jenny Start Limestone is folded in the core of a syncline. The limestone is stepped successively to the South as it is traced towards the South-east corner of Samson's Beach; at the top of the cliff it is seen in a series of shallow quarries close to the cinder path used by the coastguards. Here the outcrop of limestone is about 100 feet thick, but this exceptional thickness is the result of the synclinal structure (see fig.8); this structure also accounts for its absence further to the East where the topography drops away sharply.

Widmouth Beach

The Rillage Limestone forms an outcrop some 12 feet long on the West side of Widmouth Beach; it dips due South at 30° and is approximately 1' 6" in thickness. It is not exposed continuously across the sandy beach, but it reappears on the East side along the same line of strike. It is then

shifted sinistrally 40 feet by a N.E.-S.W. fault; this is probably the same fault as passes between Sexton's Burrow and the main cliff of the Warren.

The limestone cannot be followed continuously once it has entered the cliffs on the East side of Widmouth Beach, but a series of exposures indicate that it is continuing along approximately the same line of strike except for minor faults (see fig.R1) until it passes out into Watermouth Harbour. It reappears again at the South-east corner of Watermouth, having been displaced about 100 feet by a postulated N.W.-S.E. fault through the harbour.

On Widmouth Beach, weathered surfaces of the limestone show small fossil fragments etched out; most of these are fragments of bryozoa but there is some evidence of tabulate corals. Two fragments of Thamnopora have been collected and a single specimen of Favosites. All the coral fragments are recrystallised; the Favosites is surrounded by a lamellar structure which may be algal. None of the corals is well enough preserved to make more than a doubtful generic determination.

(b) Watermouth, The Warren, Smallmouth and Broadstrand Beach

Introduction

The rocks exposed in the area belong to the Lower Ilfracombe Beds as defined above. The Warren is a narrow peninsula running N.W.-S.E.; it is about half a mile long, flanked on the West by the inlet of Watermouth and on the East by Combe Martin Bay. Smallmouth is a narrow inlet on the East side, while Broadstrand is a wide beach in the South-east which forms a convenient southern limit to the area under discussion.

The coastal section between Smallmouth and Broadstrand is difficult of

access; it is only possible to traverse the whole section at extremely low tides and even then it involves climbing up or down steep and slippery rock faces. The best means of approach is from Smallmouth through the natural tunnel and thence, at low spring tides, to wade through the shallow water and scramble up the steep rock face on the South side and so into the next inlet. (This inlet, which lies almost exactly half way between Smallmouth and Broadstrand Beach, will, for convenience, be referred to as 'Desolation Cove'.)

Progress further South beyond 'Desolation Cove' is impossible without the aid of ropes or some skill in rock climbing, for the buttress which forms the steep southern wall of the cove is never clear of water even at the equinoctial tides and in addition, a steep cleft with overhanging and wave-smoothed sides has to be crossed about halfway along this buttress. Beyong this point as far as Broadstrand Beach progress is easy at low water. There is a further cove just before Broadstrand and this will be referred to as 'Dead Sheep Cove'.

The geology of this area is not easy to interpret as reliable marker beds are lacking in a succession which consists almost entirely of arenaceous slates and sandstones. The Rillage Limestone is exposed near the South-east corner of Watermouth and this is clearly the continuation of the outcrop which strikes across Widmouth Beach. The limestone is drag-folded and dips normally to the South (185°) at 25°; it is about 1 foot thick and contains an abundance of shell fragments in its upper part together with the concentric algal structures which are noted elsewhere as typical of the Rillage Limestone. Ill-preserved bryozoa are also present and much vein quartz is associated with the limestone; a strike fault cuts off the limestone on the South-east side before it reaches beach level.

The Rillage Limestone is exposed again on the eastern side of the

Warren, though here it is involved in a syncline (fig.5). The apparent absence of this structure on the West side of the peninsula is partly the result of the fault mentioned in the previous paragraph which must displace the limestone below beach level and partly the result of lack of exposure since an artificial embankment has been built along the head of the harbour concealing the outcrops. However, on one occasion when storms had destroyed part of the embankment, it was confirmed that at least some of the beds were inverted, though the limestone itself was not exposed.

Northward from the outcrops of Rillage Limestone on the Warren, there is a normal downward succession of sandstones and arenaceous slates which is clearly the same succession as that seen on Widmouth Head; on the Warren, however, the succession of arenaceous slates immediately below the Rillage Limestone is more fully developed since none have been cut out by strike faults as on Widmouth Head. The folds seen on the East side of Widmouth Head can be traced across the Warren and the sandstones with quicksand structures are well seen on Burrow Nose and Sexton's Burrow.

About 30 feet above the zone of quicksand structures and almost at the top of the sandstone succession, occurs a conglomeratic band (the 'Burrow Nose Conglomerate'). This is well seen along the gully which separates Burrow Nose from the main cliff and also at the South-east corner of Burrow Nose just above a prominent dip surface, and again on the East side of the Warren, about 50 yards South of Burrow Nose. The conglomerate is essentially a very calcareous sandstone only 2 inches thick, and largely composed of angular grains of quartz cemented by calcite. In addition there are fragments of calcite (derived from crinoid ossicles and bivalve shells) and pebbles of quartz and fine grained sandstone. These pebbles weather out from the calcareous matrix and give it a nodular appearance; on freshly broken surfaces it is difficult to distinguish the pebbles, except under the microscope; they average 3-5mm in diameter but some are as

large as 30mm across; there is no evidence of an erosion surface below the conglomerate. The most distinctive feature of the conglomerate is the large fragments of whitish-brown calcite which occur in its upper part; these are best seen when a dip surface of the conglomerate has been laid bare as ~~on~~ on the East side of the Warren. These calcite fragments occur in distinctive forms (see fig.4) and are thought to represent the disarticulated valves of a large brachiopod - probably a form of Stringocephalus.

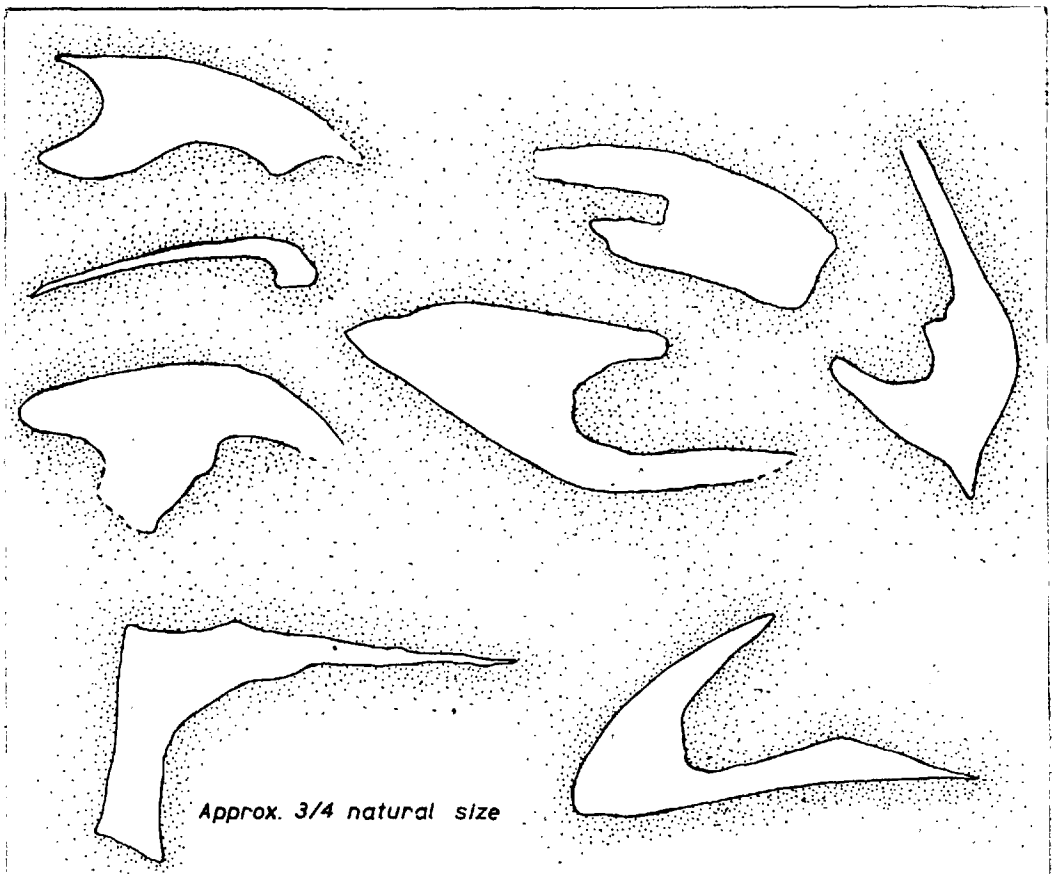


fig.4. Calcareous shapes seen in the Burrow Nose Conglomerate

Similar shapes are found in a thin conglomeratic bed in the vicinity of Egg Rock and again in the 'Stringocephalus Limestone' (Evans 1922) of Wild

Pear Beach (compare figs.4,14 and 15). The conglomerate at Egg Rock is tentatively correlated with the Burrow Nose Conglomerate, since the lithologies are so unusual and have not been found elsewhere in the succession; also the sedimentary sequence below the limestone is essentially similar. It is also considered likely that Evans's Stringocephalus Limestone lies at a similar, if not the same, horizon.

Followed West along the North face of the Warren the conglomerate thins to a mere inch or less, and it can only be traced as a result of its ochreous weathering when sub-aerially exposed. It has already been mentioned in an earlier section that the thin limestone seen near the North-west corner of Widmouth Head is probably the lateral equivalent of the Burrow Nose Conglomerate.

Apart from the evidence of brachiopods seen in the conglomerate, the only fossil found in the grit succession is Tentaculites sp. This fossil occurs in a band of calcareous grit, 1" thick, which is at the base of a current-bedded sandstone; the bed is exposed at the extreme North-west tip of the Warren where the path descends the cliff face to go across to Sexton's Burrow.

Between Smallmouth and Broadstrand Beach there are several outcrops of thin detrital limestones (figs.5 & R1), which have similar lithological characters - in smoothed hand specimens, sections of bivalve shells, all disarticulated, are frequently the most obvious feature. Thin sections show that bryozoa and crinoid ossicles also contribute a large part of the organic detritus, while concentric algal growths are found in varying abundance in each of the limestones. The thickness of the bands varies from 6 inches at Broadstrand and Desolation Cove, to just over 3 feet at Smallmouth. The question arises whether these are a series of discrete limestone bands or whether all, or some of them, are the same. A study of the field structures (fig.5) and of thin sections from each of the limestones

~~limestones~~ (see plate 3) does not permit a conclusive answer to the problem, but the balance of evidence suggests that the limestones all occur at a single stratigraphical horizon and are to be correlated with the Rillage Limestone.

A comparison of thin sections of the limestones seen at Desolation Cove and Broadstrand Beach (plate 3 g,h) leaves little doubt that they are the same limestone being repeated. The outcrop at Desolation Cove which forms a band 3-12 inches thick is inverted; when fresh the limestone is bluish-grey and hard but it weathers to an ochreous brown. Crinoid ossicles, bryozoa and broken and crushed brachiopods can be seen on weathered or smoothed surfaces; there is also an abundance of small rounded bodies, often bean shaped, with dark borders very similar to those seen in the Rillage Limestone on Hagginton Beach. Exactly comparable features are seen in the limestone at the foot of Broadstrand steps, though here the limestone contains galena.

Some doubt remains, however, as to whether the limestone at Smallmouth (the 'Smallmouth Limestone') is the same as the Rillage Limestone. It is thicker than the typical outcrop of Rillage Limestone; - the following is a section measured on the North side of Smallmouth:-

	Slates with occasional strong grit bands
	6" Limestone packed with crushed brachiopod shells
1'	0" Thin brachiopod limestones with grey slate partings
	6" Limestone packed with crushed brachiopod shells
2 -	3" Grey slate with limestone partings
	9" Limestone (brachiopod shells <u>not</u> conspicuous)
	3" Thin limestones and slates
	Coarse grit

At least 20 feet of current-bedded sandstones underlie this sequence; they are most massive just below the limestone and become more thinly bedded towards the base. They pass down into greenish-grey arenaceous slate of which about 8 feet can be seen in the core of the anticline at Smallmouth.

The upper massive sandstones have very thin (½ inch) partings of greenish shale. Such a series of sandstones passing down into slate are not seen elsewhere below the Rillage Limestone - the usual succession is slate or arenaceous slate with some sandstone bands. (Plate 2, fig.2, shows such a succession underlying the Rillage Limestone on Widmouth Beach.) However, there is a noticeable increase in the amount of sandstone from Samson's Bay to Widmouth and it is possible that the sandstones have developed almost to the exclusion of slates in the Smallmouth area.

There are, however, two further ways in which the 'Smallmouth Limestone' differs from the Rillage Limestone as it is seen on the East side of the Warren, 150 yards to the North of Smallmouth Beach. The brachiopod shells in the latter limestone exposure are of smaller average size than those found in the 'Smallmouth Limestone', and the concentric algal structures are very rare in the 'Smallmouth Limestone'. Such differences could be accounted for by local depositional changes, but even if these two limestones are not correlated, there can be no doubt that the limestones at 'Desolation Cove' and on Broadstrand Beach are the equivalents of the Rillage Limestone and that therefore the rocks exposed between the Warren and Broadstrand only show a very limited part of the succession, which is repeated at least three times as a result of folds and faults. This also explains why neither the Jenny Start Limestone nor the massive sandstones with the conglomerate and quicksand structures, are exposed along this coastal section.

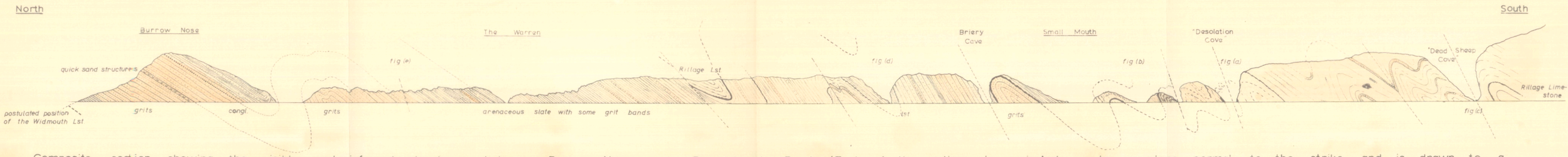
The interpretation shown in fig.5 suggests that many of the faults are normal strike faults. It is rarely possible to show conclusively which way any particular fault has moved, though some of them have a reverse displacement (fig.9c). However, that normal strike faults have also played a part in producing the present arrangement of strata can be shown conclusively in 'Desolation Cove'.

The stratigraphy and structure in 'Desolation Cove'

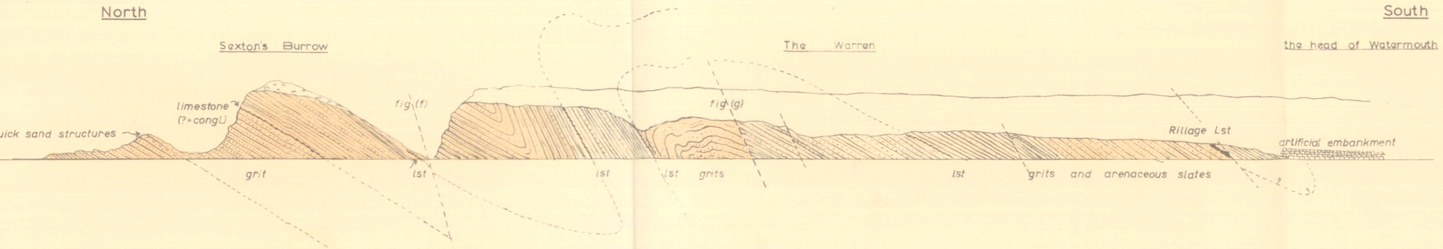
The limestone in 'Desolation Cove' is inverted, with a mean dip of 53° striking 266°, and the variations in its thickness noted above are largely the result of drag folds. Stratigraphically below the limestone is a series of slates with very thin sandstone bands followed by a stronger development of the sandstones in bands up to 8" thick, again separated by slates (sometimes arenaceous). Above the limestone are grey slates, sometimes with rusty weathering 'splinters' (these are slightly more competent bands which have been sliced up by the cleavage so that they appear like splinters of wood in the grey slate).

In the cliff face above the cave (caused by two subparallel strike faults which intersect a short distance inside) the limestone is seen displaced by a normal fault dipping at 37°-40° towards 180° - that is, subparallel to the strike of the beds - and this causes a repetition of the limestone (see fig 9), both in the cliff face and at beach level within the cave. The second strike fault trends 296° and dips slightly more steeply (40°-45°); it displaces the beds sinistrally by about 30 feet and must be later than the first fault, for this too is displaced. As a result, at one point within the cave, there is a fourfold outcrop of the limestone, each band being inverted.

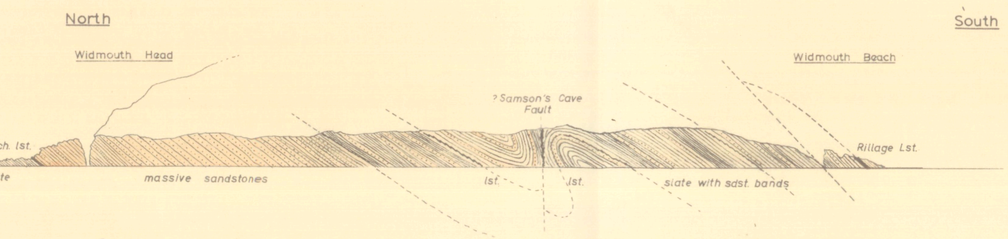
There is a further fault visible in 'Desolation Cove'; it is parallel to the first and can be seen in the cliff face just above the cave. It is impossible to ascertain the type of movement on this fault as the slates are crumpled and strongly cleaved without containing any distinctive horizon that can be identified on either side of the fault. However, this fault separates the inverted succession discussed above from the normal succession which is seen in the top of the cliff; it therefore appears to fault out an anticlinal hinge.



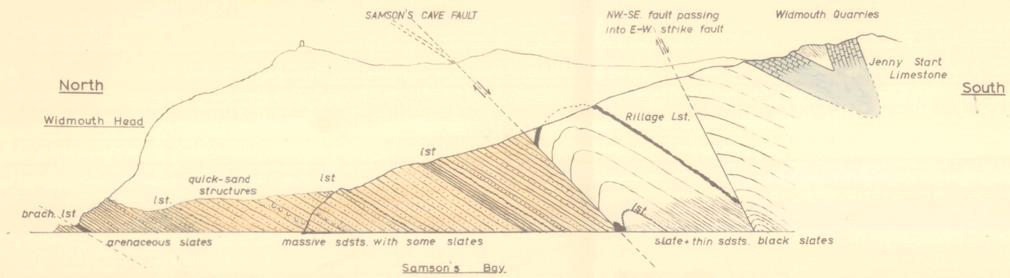
(fig 5) Composite section showing the visible and inferred structures between Burrow Nose and Broadstrand Beach. (Each of the sections is projected on to a plane normal to the strike and is drawn to a scale of 1 in. = 100 ft.)



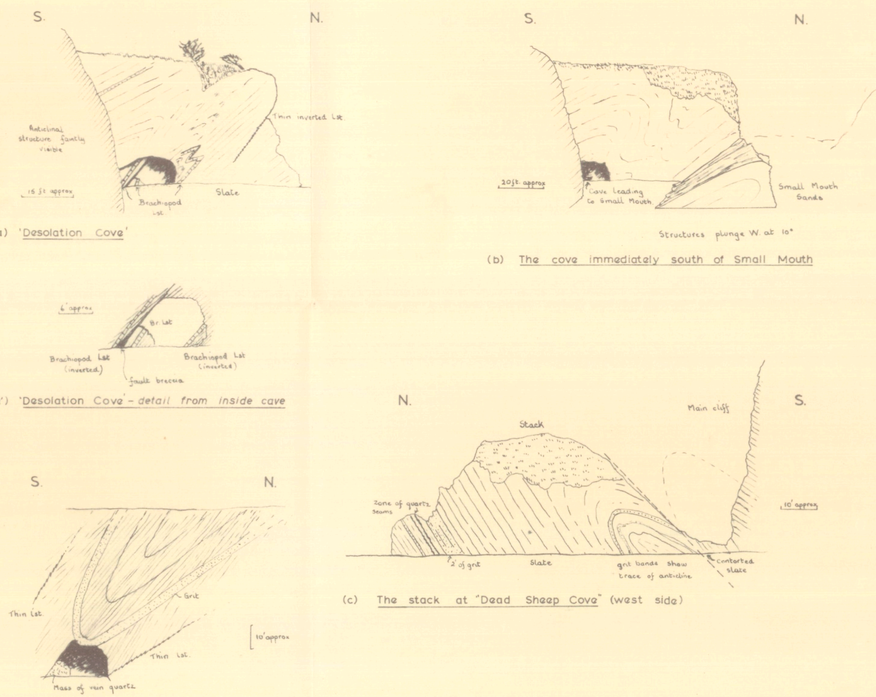
(fig 6) Section showing the structure along the west side of the Warren



(fig 7) Section showing the structure along the east side of Widmouth



(fig 8) Section showing the structure along the west side of Widmouth



(a) 'Desolation Cove'

(b) The cove immediately south of Small Mouth

(a') 'Desolation Cove' – detail from inside cave

(c) The stack at 'Dead Sheep Cove' (west side)

(d) The Warren – 100 yards north of Small Mouth

(e) The Warren – 70 yards S. of Burrow Nose

(f) Gully between The Warren & Sexton's Burrow

(g) The Warren - western side

(fig 9) Field sketches of structures seen at Watermouth and the Warren

The Brachiopod limestone has not yet been identified between 'Desolation Cove' and Broadstrand, but the section is very difficult to study in detail and it may well be present. What appear to be the sandy bands which underlie the limestone can be seen high up in the cliff at the South-west end of 'Desolation Cove', and loose blocks of the limestone, again associated with galena, are common in 'Dead Sheep Cove'.

(c) Hamator Rock to Oakestor Bay

Introduction

The section exposes the grits and slates of the Lower Ilfracombe Beds, but the precise correlation of the beds, which are folded and faulted extensively, must remain an open question though a possible interpretation is suggested.

There are two main reasons for this difficulty: the general absence of reliable marker horizons in the Lower Ilfracombe Beds has already been commented upon. An additional difficulty along this particular stretch of coast is the N.W.-S.E. faults which run parallel to the coast and frequently separate the exposures on the foreshore from those in the cliffs; exposures on the foreshore are usually seen in plan, while those in the cliff are seen in section. Theoretically it should be possible to correlate structures seen in the cliffs and those on the foreshore, even when lithologies cannot be exactly matched, but in practice, because of rapid variations in the form of a structure such correlations are always difficult and often impossible to effect with certainty.

The section is described from North to South under the following six divisions:-

(i) Hamator Rock
(ii) Turks Cove
(iii) Egg Rock
(iv) 'Raven's Nest' Cove
(v) Golden Cove
(vi) Oakestor Bay

(i) Hamator Rock

The succession of strata at Hamator Rock is conveniently divided into three units by prominent gullies cut out by the sea. From North to South these divisions are the Outer Stone, the Inner Stone, and Hamator Rock itself. Within the succession there is a limestone, a series of massive pinkish weathering sandstones, and slates - often arenaceous.

(a) The Outer Stone. The succession at this point is inverted and although the rocks are largely hidden by barnacles and seaweed, they include the youngest rocks in the Hamator area. The most distinctive bed is a brachiopod limestone, three feet thick, which can only be seen at lowest water during spring tides. It consists of hard limestone bands about 3" thick, separated by similar thicknesses of more slaty limestone. The brachiopods are concentrated in the uppermost band (i.e. that occurring furthest to the North since the beds are inverted), and the shells show a prefered orientation with convex sides uppermost. It is impossible to identify the shells as they are compressed, broken, and entirely re-crystallised. Not only is this limestone covered by seaweed and limpets, but the harder bands are extensively bored by living lamellibranchs. Petrological sections show that much of the rock is dolomitic and extensively veined by quartz; bryozoa are present also.

Below the limestone is a succession of massive sandstones passing down into arenaceous slates. These all dip 50° to the South, and are completely

covered by barnacles so that it is impossible to detect any small sedimentary structures which may be present. The arenaceous slates continue inverted as far as the gully separating the Inner from the Outer Stone; they then pass over the anticline which occurs along the North face of the Inner Stone (fig.11).

(b) The Inner Stone. The beds are essentially a repetition of those seen on the Outer Stone, though the sandstones which occur immediately South of the anticline mentioned above, appear less cleaved than their equivalents on the inverted limb. This fact is often noticed - the cleavage in arenaceous beds being more pronounced on the inverted limb. There is probably a small strike fault along the gully between the Inner and Outer Stones, for there is some evidence of movement in the gully and across the dip slope to the North. Its displacement, however, cannot be great for it has little effect on the succession.

On the southern dip face of the Inner Stone is seen a massive pinkish sandstone which is interpreted as the lowest band of the series of grits seen on the Outer Stone. These sandstones occur again in the core of the syncline on Hamator Rock itself and there must, therefore, be a reverse fault along the gully between Hamator and the Outer Stone (fig.11).

There is one bed on the Inner Stone which justifies special mention; it is a sandstone band about 6" thick which contains Thamnopora and branching bryozoa. These fossils all appear to be abraded though the average length of the fragments is 1"-1½"; they are usually recrystallised and weather out of the rock as ochreous concretions. In section, the rock is seen to be composed of angular quartz grains up to 1mm in diameter, calcite fragments, small grains of fine sandstone and occasional flakes of muscovite; the cement is calcitic.

(c) Hamator Rock. The same succession is again repeated as a result of the syncline on Hamator Rock. The brachiopod limestone is not seen, however, though it must lie only a few feet above the uppermost grit seen in the core of the syncline;(its postulated position is shown in the section - fig.11).

The syncline on Hamator is an impressive structure with the massive grits and sandstones which form the core being strongly quartz-veined and standing out in marked contrast with the darker slates (plate 5). The grits and sandstones have taken on a poor cleavage which fans out at an angle to the axial plane. On the lower limb of the fold, one of the sandstone bands has been cut out for a distance of about 8 feet as a result of bedding plane drag during the folding.

On the South side of Hamator Rock, almost at beach level, an anticline can be detected though it is not immediately obvious because it is seen only within slaty rocks which show little or no bedding. On the East side of the Rock, this anticline passes laterally into a thrust, the displacement of which is only small, though both thrust and anticline form a line of weakness exploited by the sea.

(ii) Turks Cove
(Marked on C.S. maps as "Turks Cave")

This division includes the cliff and foreshore outcrops between Hamator and Egg Rock, and as can be seen from the sections (figs.10 & 11) the rocks are strongly folded. The folds are most readily appreciated on the foreshore by observing the outcrops of the brachiopod limestone, which is the same one as that seen at the North edge of the Outer Stone. At the North end of Turks Cove the limestone dips South at 30°; it is normally disposed and immediately overlies a series of massive sandstones. To the North of this exposure there are about 10 feet of sand-

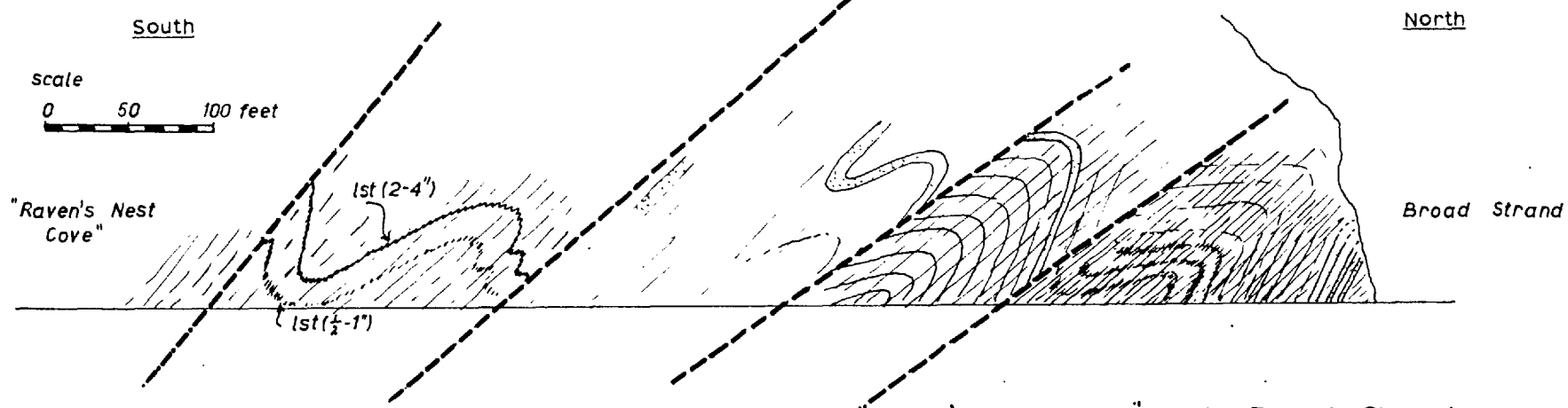


fig. 10 Composite sketch of the cliff section between "Raven's Nest Cove" and Broad Strand.

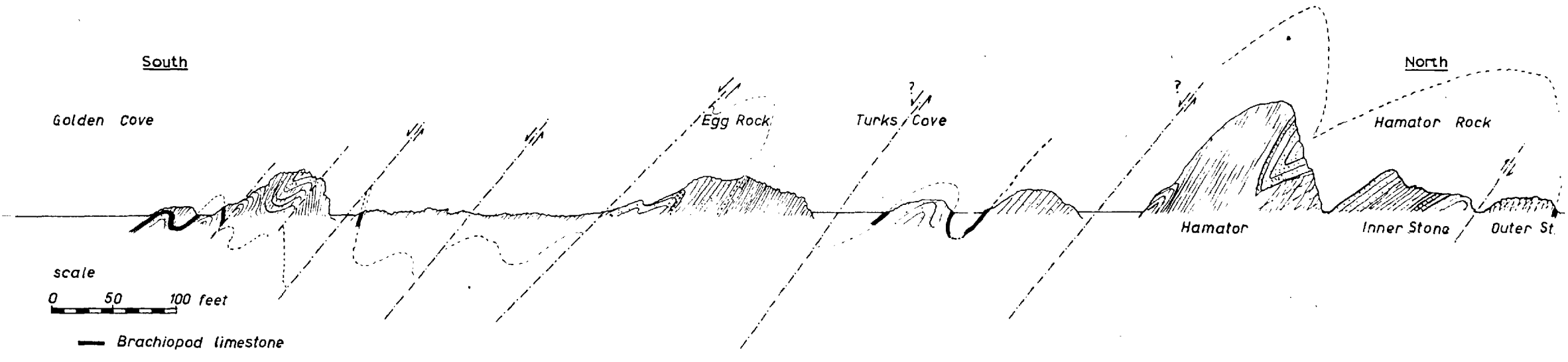


fig. 11 Composite section showing the outcrops along the foreshore between Golden Cove and Hamator Rock showing the probable structural interpretation

stones and then a sand-filled gully some 20 feet wide in which no rocks crop out. (It seems likely that this gully marks the line of an E - W normal strike fault). The limestone can be traced along its strike to the East until it becomes concealed beneath beach material; traced to the West, it is cut off by a N.W.-S.E. fault, and there are patches of limestone dragged around into the fault, suggesting dextral displacement. The Limestone is, however, absent on the West side of the fault unless it be represented by a veneer of limestone less than ½in. thick which is seen on the stack immediately to the West. This latter suggestion is discounted for three reasons -

(a) No massive grits occur beneath this thin limestone

(b) The main brachiopod limestone shows no tendency to attenuate as it approaches the fault

(c) The limestone lumps caught up in the fault lie to the North of the thin limestone veneer; this indicates that the continuation of the main brachiopod limestone must be further to the North.

The absence of the brachiopod limestone on the West side of the fault is explained either because its outcrop is concealed beneath the sandy gully, or because it is cut out by the E -W strike fault mentioned above. This interpretation is considered more likely and is shown on the following block diagram (see fig.12).

The brachiopod limestone outcrops at two other places in Turks Cove - at one, it is inverted, and at the other, it is dipping normally again, to the South; the syncline and anticline responsible for these outcrops is clearly seen within the massive sandstones which occur immediately below the limestone. The relatively simple folds in the limestones and grits cannot be equated with any of the structures seen immediately West of the N.W.-S.E. fault (figs.R1 & 12), and it seems probable

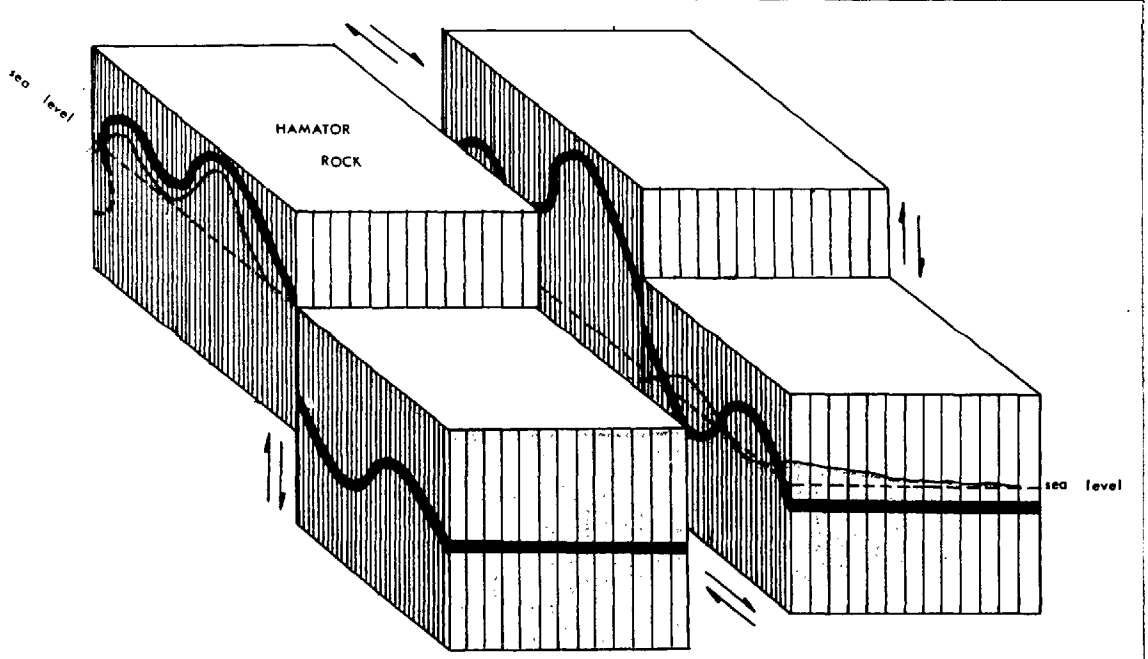


Fig.12 BLOCK DIAGRAM OF THE HAMATOR ROCK AREA SHOWING THE EFFECT OF NORMAL AND WRENCH FAULTING ON THE OUTCROPS OF THE BRACHIOPOD LIMESTONE

that the former are to be correlated with the simpler folds seen at Hamator or possibly even further to the North.

The structures seen in the stack to the West of the brachiopod limestone outcrops just discussed are shown in plate 6 (see also fig. R1). There are, in fact, only two synclines in the stack, and the appearance of three is occasioned by a small N.W.-S.E. fracture causing repetition. The hinge of one of the synclines forms part of the South face of the stack (plate 6, fig.1); it is a tight fold and pitches approximately W.(250°) at 10 . The beds in the stack are largely slates but with some sandstone bands (4"-6" thick) and the thin calcareous veneers mentioned above which sometimes show large worn fragments of shell (? brachiopods), ~~and~~ appear as conglomerates. There are, in fact, two of these calcareous bands, both about 1" thick, which can be found again in the smaller stack to the South.

Fig 10 shows the structure seen in the cliffs to the West of Turks Cove. A narrow gully along the line of a fault separates the cliff from the stacks discussed in the preceding paragraph. No precise correlations are possible across this gully, but as both the lithologies and the structural pattern are similar on either side, it is not thought to have a large displacement. The lithology in the cliff is essentially slaty but with some members in which there is an alternation of slate and thin sandstones. These sandstone bands are thickest (about 4"-6") at the base of the member, and tend to get progressively thinner towards the top. (This same feature has been noticed elsewhere - e.g. Broadstrand Beach, under Hillsborough, Golden Cove, Orthoceras Cove).

The complexity of the structures seen in the cliff and the adjacent stacks are thought to result from a piling up of strata on the steep or inverted limb of a major fold structure; this is illustrated in the following diagram (fig 13). It is noticeable that synclines are generally absent from this major inverted limb. It has already been suggested that these structures are broadly equivalent to the structures seen in the vicinity of 'Desolation Cove' (see preceding section on Watermouth, The Warren, etc.). The major N.W.-S.E. fault responsible for the displacement occurs about the centre of Broadstrand Beach (see map, fig R1).

(iii & iv) Egg Rock and Raven's Nest Cove

Egg Rock is shown on Ordnance Survey maps 100 yards South-east of Turks 'Cave'. The area now to be described includes the cove due West of Egg Rock ('Egg Rock Cove'), and the cove immediately to the South, for which I have coined the name 'Raven's Nest' Cove.

A large stack, mainly in massive sandstones occurs about the middle of Egg Rock Cove. Most of the succession here is inverted and the

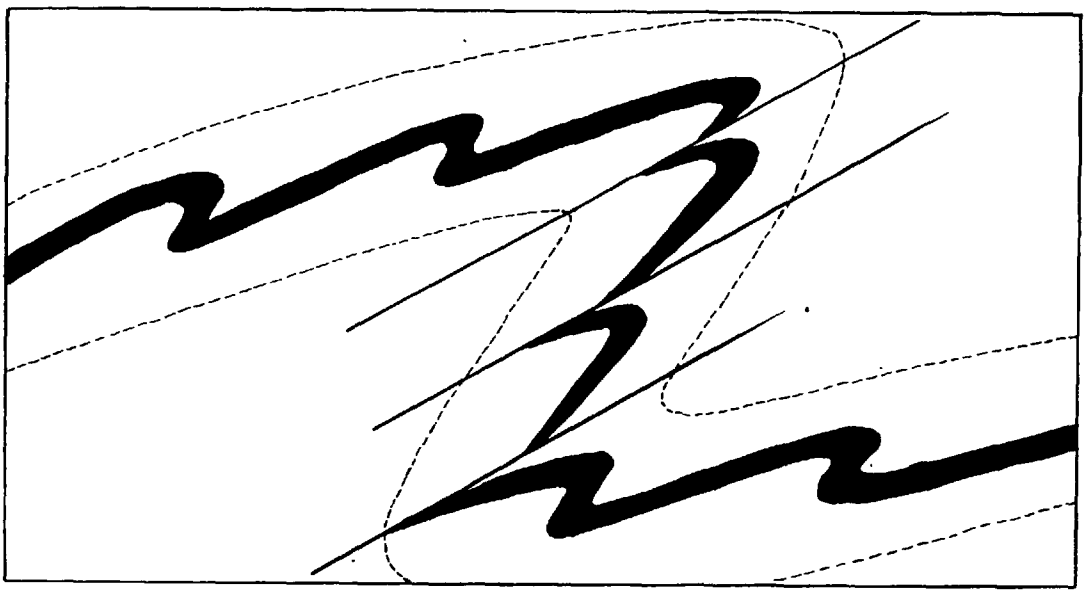


Fig. 13 Diagram showing the type of structures developed on the inverted limb of a major fold.

the sandstones pass up into dark brownish black slates at the northern end. The South part of the stack shows an anticlinal hinge cut off on the South (normal) limb by a strike fault, with a conglomeratic band only 1" thick prominently exposed on an inverted bedding surface. This band has many features in common with the conglomeratic band at Burrow Nose. In particular it shows sections of a large brachiopod (fig. 14) which are very similar to those seen at Burrow Nose (fig. 4), and which are thought to be a form of Stringocephalus. The sandstones themselves weather in the same way as those of Burrow Nose, giving a distinctly pinkish appearance.

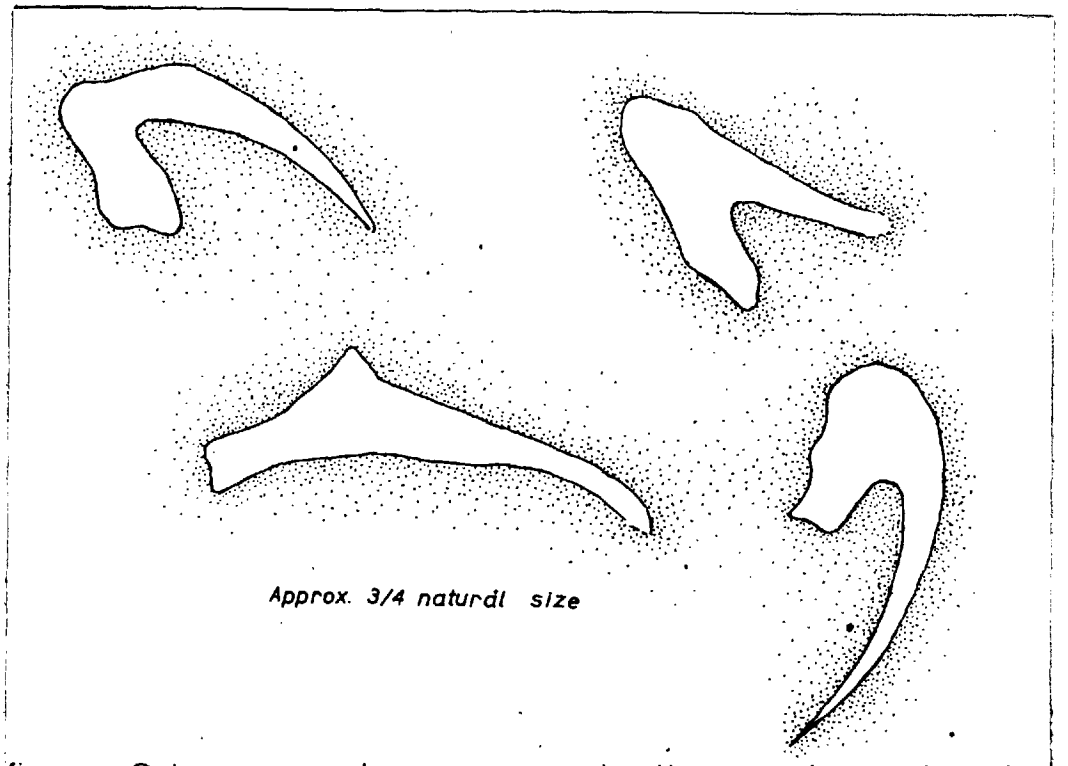


fig 14 Calcareous shapes seen in the conglomerate at Egg Rock.

The inverted sandstones dip South (165°) at 70° and the bands become less massive as they pass upwards (i.e. to the North); about 8 feet of massive sandstone is seen and then an alternation of black

slate and sandstone with the slate becoming increasingly important. About 60 feet of beds (mostly slate) is exposed above the sandstones. A calcareous band occurs near the upper limit of the sandstone bands, and this weathers an ochreous brown colour. It is prominent in the stack, but is only just visible when traced across a N.W.-S.E. fault into the cliff.

This N.W.-S.E. fault has a dextral displacement of about 25 feet, and the succession on either side of it can be correlated without difficulty in the Egg Rock vicinity; to the North and South of this area absolute correlation has not been possible because distinctive horizons are absent. The fault is believed to continue to the South-east and to pass East of the reef in which a brachiopod limestone is exposed opposite the entrance to Raven's Nest Cove (see sketch map fig 16)

The cliff at the back of 'Egg Rock Cove' is covered by scree so that the cliff section is broken at this point. Such screes of fallen slate frequently mask a line of faulting and the possibility of this is considered below.

Between 'Egg Rock Cove' and 'Raven's Nest Cove' folding is clearly visible in the cliffs, in particular a wriggly band of limestone, 3" thick, is seen passing over two anticlinal crests (fig.10). This limestone is characterised by an abundance of small black, slaty pellets together with unidentifiable organic detritus. About 6-8 feet below it is another limestone only ½-1" thick, and they are separated by striped slates. The West and South cliffs of Raven's Nest Cove expose only slate, while the dip face on the North exposes pinkish, flaggy grits. The West wall of the cove marks the line of a ~~reverse~~ dextral fault trending 170° and fragments of breccia are still seen adhering to the wall. Other faults trending in a similar direction are seen on the North and South sides of the cove, and one of these, as can be seen from the sketch map (fig 16), must pass into Egg Rock Cove, but is lost beneath fallen slate.

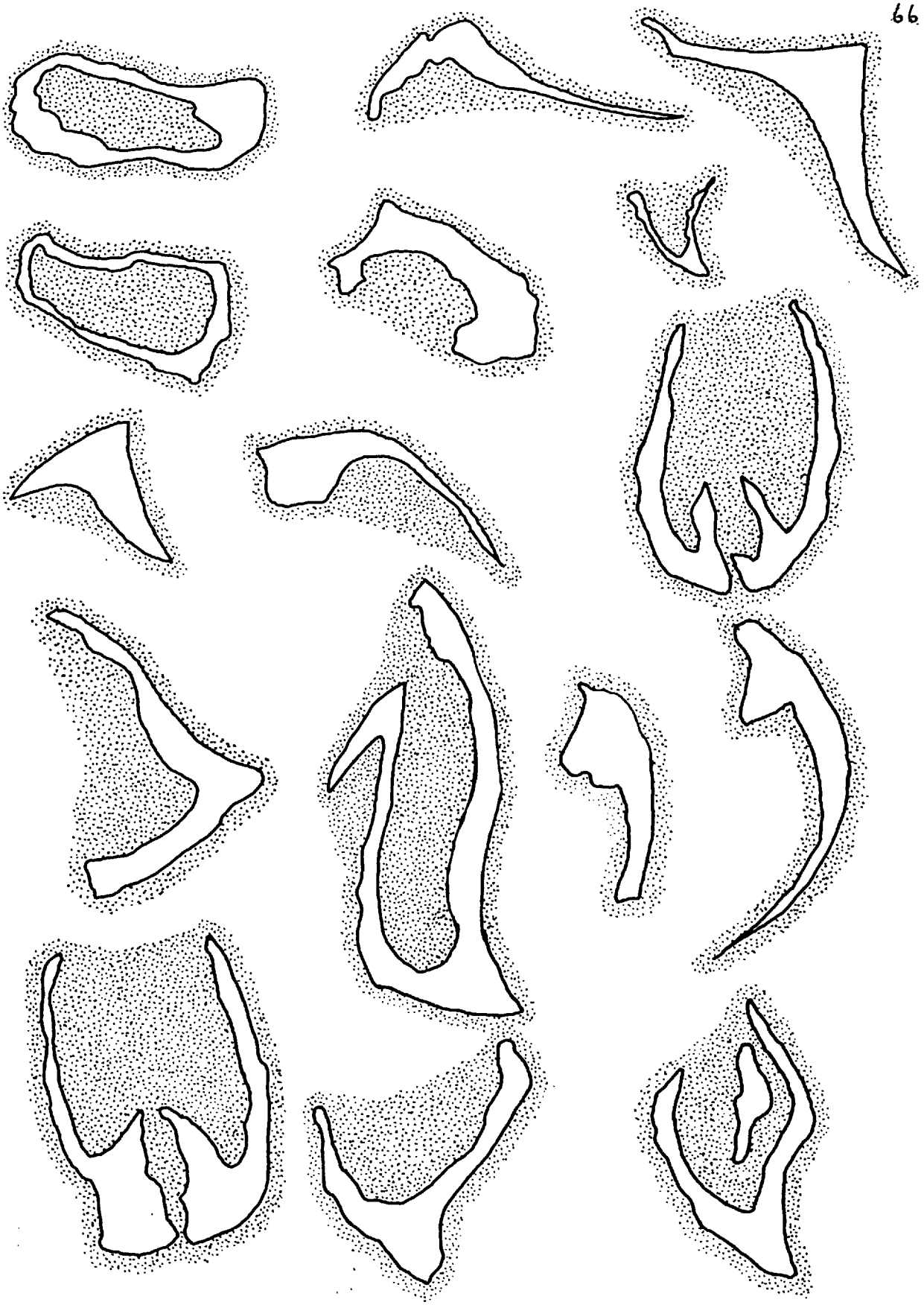


Fig.15 Sections of brachiopods (?Stringocephalus) - Wild Pear Beach.

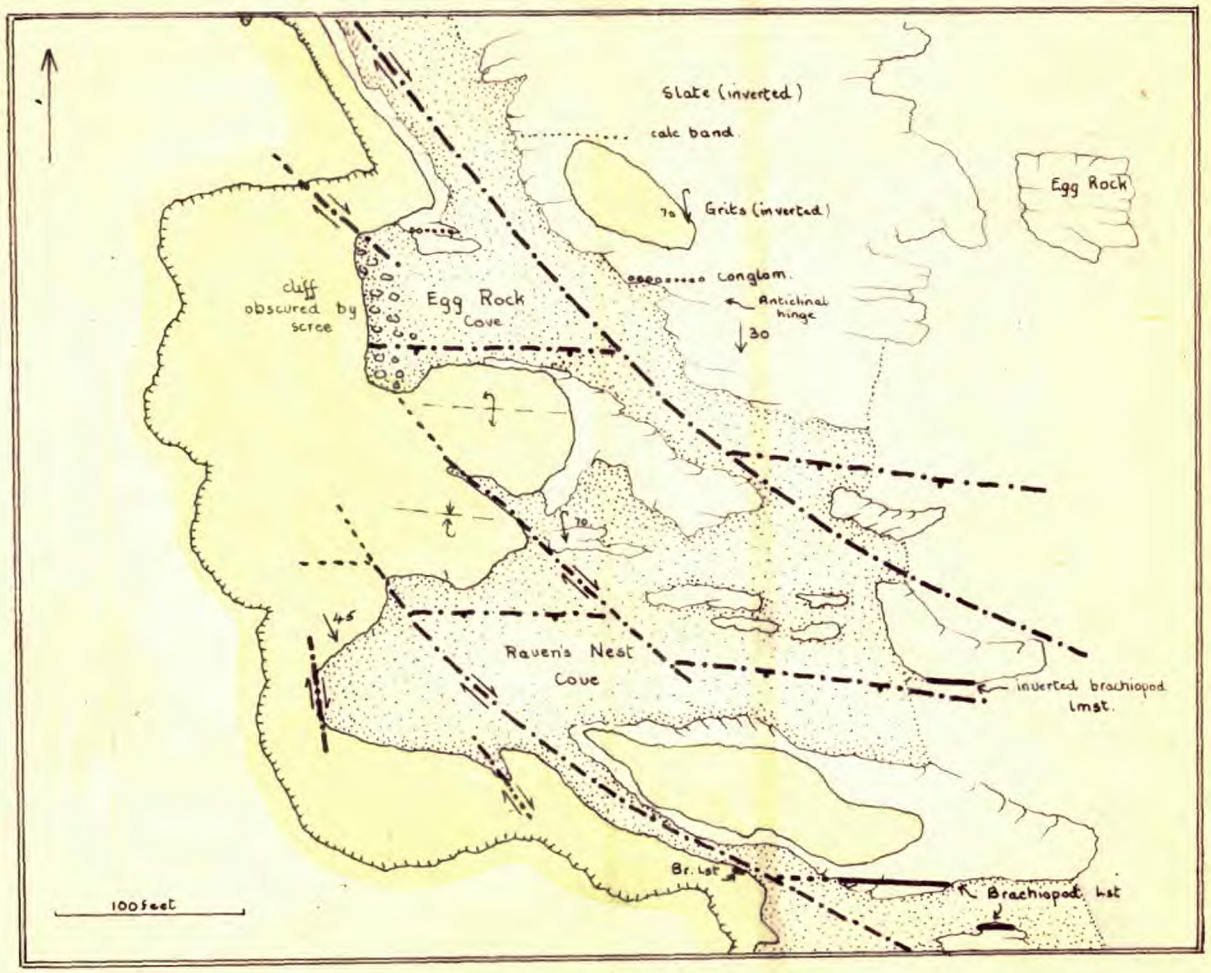


fig.16 Sketch map of Egg Rock and Raven's Nest Coves

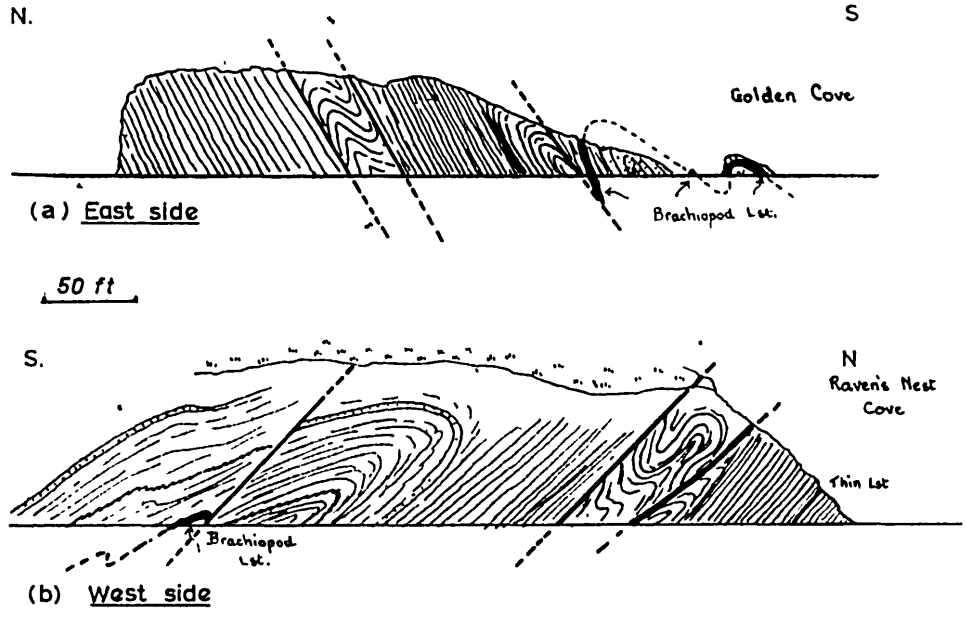
Strike faults must also exist at both Egg Rock and Raven's Nest Coves to account for the marked breaks in the continuity of the lithologies and fold structures. This can best be appreciated from the sections figs 10 and 11. Interpreting these breaks as normal strike faults provides the most logical reconciliation of the anomalies.

The brachiopod limestone which crops out near low water mark at

the entrance to Raven's Nest Cove is inverted. This is shown by the preferred orientation of convex shells in the upper layers and by the dip of 70°; (the dip on a normal limb is characteristically 30°-40° within the area covered by this thesis). The limestone is underlain (tectonically overlain) by sandstones, but only 1-2 feet are exposed before they are lost beneath the sandy foreshore. This sandy stretch is believed to mark the position of the second strike fault mentioned in the previous paragraph.

(v) Golden Cove

Leading South from Raven's Nest Cove into Golden Cove is a narrow gully eroded along a small N.W.-S.E. fault. The structures seen along this gully are shown in the following sections (fig.17, a & b) taken from field sketches.



(a) East side

(b) West side

fig.17 Sketches of the structures seen along the gully between Raven's Nest Cove and Golden Cove

Although individual beds cannot be correlated across the gully with certainty, the structures are broadly similar and this, combined with the observed displacement of a brachiopod limestone, indicates a dextral displacement of 10-15 feet.

The brachiopod limestone outcrops on a small reef at the North-west end of Golden Cove; it is folded into two anticlines (from the crest of one, the limestone has been eroded) and is last seen descending vertically into the beach at the South end of the gully (fig.17a). Only one small exposure of the limestone is seen in the main cliff and even this is sometimes concealed if the level of the beach shingle is high; this exposure is the crest of an anticline which is correlated with the more northerly of the two anticlines on the East side of the gully.

A plane of movement occurs immediately North of the limestone on both sides of the gully, and this is interpreted as a minor reverse fault which carries the main brachiopod limestone below beach level so that it is not seen again in the core of the anticline which follows to the North (fig.17b).

An inverted brachiopod limestone outcrops on the South-east side of Raven's Nest Cove as has been mentioned in an earlier section. That this is the same limestone as the one seen in Golden Cove is indicated by the following observations:-

(a) Lithologies are the same

(b) Both limestones are underlain by grits and overlain by brownish-black slate

(c) A thin conglomeratic band occurs at the top of both limestones.

Thus, unless the 15 feet of unexposed beach between the limestone and the gully conceals a normal limb of the limestone, a normal fault

must be present as shown on fig.11. (Although it is possible that the limestone has been eroded so that its outcrop is now buried beneath the shingle, it is much less likely that the underlying grits will have been so eroded so that all trace of the normal dipping limb has been lost. In any case, a normal fault seems necessary to explain the limestone outcropping at beach level, since the surface structures to the South suggest that it would otherwise be deep down below the surface).

Only one coral specimen has been obtained from the brachiopod limestone in Golden Cove; this is a small, globose form of Favosites.

The succession above the brachiopod limestone in Golden Cove consists of at least 50 feet of grey slates with a 1-1½ in. limestone about 8 feet above the main limestone, and two members of alternating sandstones and slates - the lower member about 8 feet thick with sandstone bands up to 6" thick, and a second member, 6 feet higher in the succession, which is only 4 feet thick; in both members the sandstone bands get progressively thinner as they are traced upwards. They are very similar to those recorded in the gully to the West of Tusks Cove.

To the South of this succession, exposures are concealed for some 50 yards by a mass of fallen limestone blocks and small slate fragments. The limestone blocks frequently show evidence of brecciation with very large crystals of calcite developed in cavities; galena, pyrite and chalcopyrite are associated. There can be little doubt that a fault occurs in the cliffs beneath the fallen blocks but the nature of the displacement is uncertain; it may well be a N.W.-S.E. fault trending parallel to the cliff - such faults can be detected at the South end of Golden Cove; the fact that the brecciation in the fallen blocks of limestone runs across the bedding would agree with this interpretation. It is considered that the major fault displacing the beds on Brandstand

Beach, emerges at this position - (see above section describing Turks Cove).

In the steep slope above the bench a massive limestone at least 6 feet thick can be seen in situ; it is difficult to measure the true thickness as at the point where the limestone is accessible it is involved in a tight anticline and syncline. The main mass of limestone is blue-grey when fresh and weathers to pock-marked surfaces; it is unfossiliferous except for crinoid ossicles and some broken fragments of bryozoa. In the upper more shaly bands, however, fossil fragments are more abundant though still almost exclusively crinoids and bryozoa. Large crinoid ossicles, $\frac{1}{2}$ in. or slightly more in diameter, are a noticeable feature. On worn surfaces, they often appear as rings of calcite and they may be slightly elliptical as the result of stresses. The fact that these ossicles so often appear as rings suggests that the articulating surfaces are deeply concave, at least on one side, and that they have a raised border.

Calicular plates of the crinoid Spinaxocrinus geometricus also occur. (Plate 7, fig. 1)

Although no corals have been found in the accessible outcrops of limestone in Golden Cove, nor yet in the large fallen blocks beneath this outcrop, they can be found in some of the boulders that litter the foreshore at the South end of Golden Cove; in particular, large blocks 1 foot and more across containing Endophyllum have been observed. Many of these blocks are only slightly abraded and have been derived

almost certainly from inaccessible outcrops of the same limestone which developed a local coral fauna. (Such rapid changes from uncoralliferous to richly coralliferous limestone can be seen elsewhere for example on Orthoceras Beach near Hagginton Steps - see below). The nearest known locality at which massive compound corals are developed is at Jenny Start, but the complete absence of blocks containing corals in the intervening cove of Oakestor Bay is clear evidence that they have not been brought along the coast.

The massive limestone in the cliffs of Golden Cove is correlated with the Jenny Start limestone even although locally it lacks the colonial corals which are typical of the limestone in its type locality; the limestone can, in fact, be traced almost continuously in the cliffs from Golden Cove into Oakestor Bay and thence to Jenny Start.

At the Southern extremity of Golden Cove is a steep gully up which it is possible to climb into Oakestor Bay. At the foot of this gully on the East side is a well-marked syncline trending 090° but showing no plunge. The gully itself is a fault line striking 135° and it shifts the axis of the syncline about 30 feet to the North on the west side, though it is impossible to identify the position of the syncline with certainty.

The section northward from this point consists of dark slates with two thin limestones (1" thick) and some arenaceous bands. No folds can be detected and apart from bedding plane movement indicated by the numerous quartz seams, there appears to be a normal succession. There is, however, only about 60 feet of strata exposed before the section is obscured by the landslip.

At the head of some of the gullies eroded out of the softer beds can be seen a zone of brecciation and movement trending 130°. It

may well be the same fault which gives rise to the fallen blocks of limestone and the associated brecciation.

VI (bis) Oakestor Bay

The bay is bounded on the South by the promontory of Jenny Start and on the North by a massive block of quartz-veined slates; it is completely filled at high water and is not accessible until the tide is more than half out.

The southern part of the Bay shows a normal descending succession down from the Jenny Start Limestone.

The lower part of the Jenny Start Limestone is seen at the top of the scarp face of Jenny Start, and it can be followed, apparently continuously, around the West side of Oakestor Bay, getting progressively higher in the cliff until it reaches the North-west corner. Here it is about 6-8 feet above the col by which it is possible to pass from Oakestor Bay into Golden Cove, and this is the only place (except Jenny Start itself) at which it is possible to examine the limestone in situ. It has a thickness of 6 feet and this it appears to maintain until it reaches Jenny Start where the total thickness of the limestone beds is about 30 feet. The reason for this contrast in thickness is thought to be the thick coralliferous development at Jenny Start, while corals are locally absent further North.

Fallen blocks from the limestone show the typical pock-marked appearance, while the upper more slaty bands contain an abundance of crinoid ossicles - some of them of the large type which were noted in Golden Cove. Plates of Sphaerocrinus geometricus are also found. No massive colonial corals have been found either in situ or in the blocks which have fallen to the beach; nor yet are they found amongst the larger stones which may be moved by the tides - the significance

of this has already been commented on in the discussion on Golden Cove.

Below the limestone is a succession of slates with occasional arenaceous bands, some of which are lenticular. These slates are at least 100 feet thick though they are not exposed continuously across the beach. In the centre of the cove are dark, wave-smoothed slates which contain several seams of quartz and a thin (1") limestone. These all dip normally to the South at about 30°.

In the North-west part of the bay is a small cave, on the South side of which an anticline occurs in the slate. The trace of the bedding in the slate is very faint, but the anticlinal structure is confirmed by the inversion of the bedding to the North. The slates which form the North side of the bay are riddled by quartz veining and infilled tension gashes. This is interpreted as bedding plane movement in the synclinal fold which is best seen at the southern end of Golden Cove, though it is possible that the fold passes laterally into a fracture - as is seen, for example, at Widmouth, Hamator and Sandy Cove. The slates on the North side of the cove frequently contain thin calcareous films, in some of which it is possible to detect crushed and distorted ?brachiopod valves. Nothing identifiable has yet been obtained from these calcareous films which are no more than $\frac{1}{16}$ in. thick.

The following sketch map and section show the essential features of the structure in Oakestor Bay and Golden Cove (fig 18). (See following page.)

Correlation between the areas exposing Lower Ilfracombe Beds

It has been pointed out above that there is good correlation between the succession at Widmouth and that seen on the Warren - bulk lithologies can be matched and the structures are comparable. Above the Widmouth Head succession is found the Jenny Start Limestone (see fig. 8) occurring

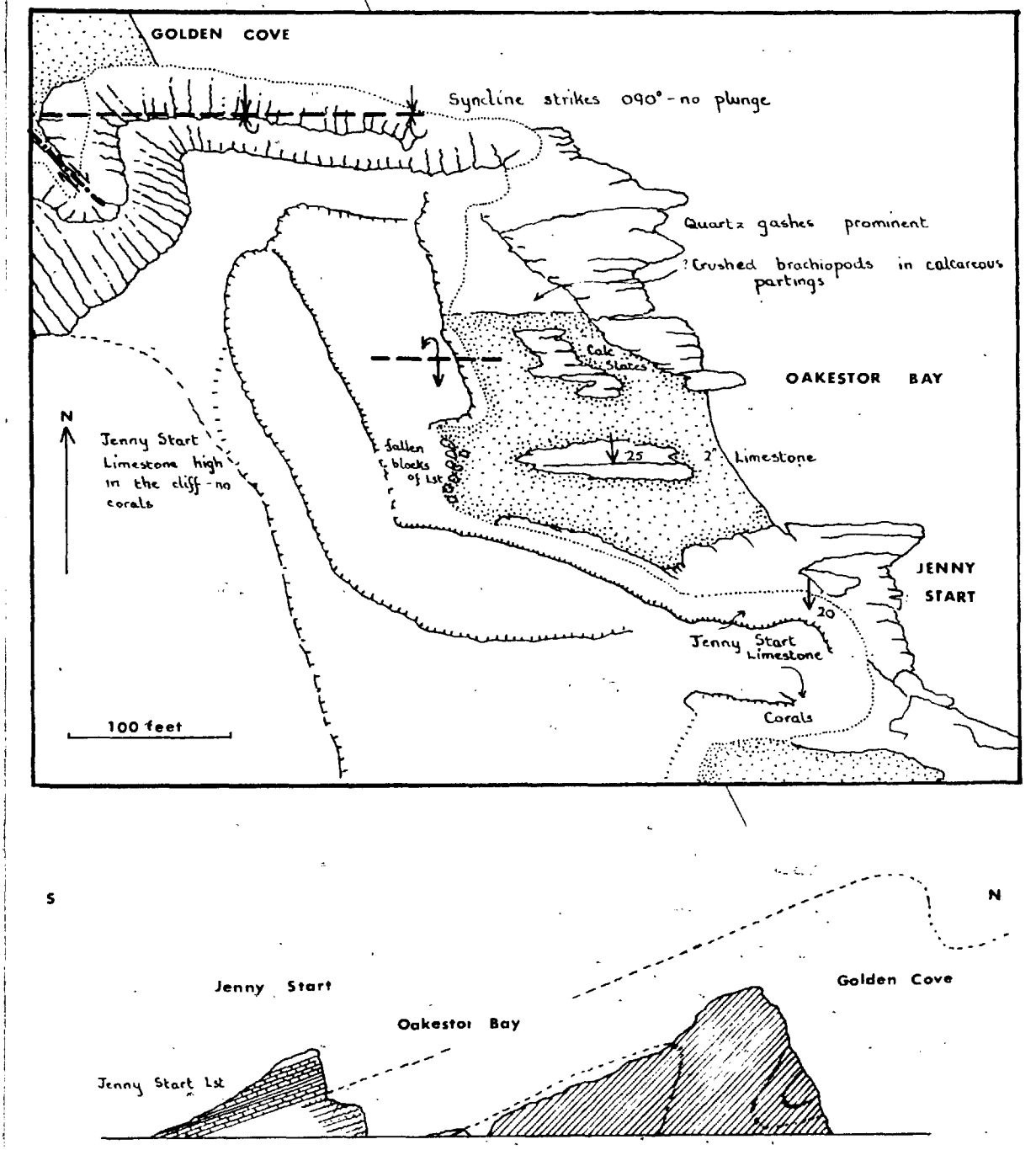


Fig. 18 Sketch map and section of the Oakestor Bay area.

in a synclinal core. This structure is equated with the syncline seen 130 yards to the North of Briery Cove on the East side of the Warren - this follows from the correlation of the Rillage Limestone between Samson's Bay and the Warren. The Jenny Start Limestone is absent from the Warren and to the South as far as Broadstrand because of (i) the westerly plunge of the structures and (ii) the down-throw of the N.W.-S.E. faults on their western side combine to bring older strata to the surface as the rocks are traced to the East. An additional reason is the higher topography of Widmouth Head as compared with the Warren - for, although the beds are highly folded and faulted, the net effect of the tectonics is to simulate a horizontal series of beds; for the same reason, the Rillage Limestone is found at beach level at no less than seven separate localities between the Warren and Broadstrand (fig.5).

Between Smallmouth and Broadstrand there is a marked tendency for the synclines to be faulted out (see fig.5). This is in contrast to the structures seen further North along the Warren where the synclines, and indeed the anticlines also, are typically unbroken. A similar contrast in the behaviour of the folds is seen between Hamator and Golden Cove (see figs.10 & 11).

This change in structure is considered significant enough to be of use in making a broad correlation across Broadstrand Beach where an important N.W.-S.E. fault prevents any immediate correlation of individual beds. Thus the anticlines and synclines of Smallmouth are correlated in a general way with the anticlines and synclines seen on Hamator Rock. This suggests a displacement on the N.W.-S.E. fault of about 350 feet (the major fault runs up into the gully about midway along Broadstrand Beach, and it probably emerges again at Golden Cove, though the actual position is concealed by scree.)

C. MIDDLE ILFRACOMBE BEDS

a. Hagginton Beach and Rillage

The Strata

The complete series of limestones within the Middle Ilfracombe Beds is exposed along this section, though owing to tectonic complications, the succession is not immediately obvious. The following table shows the main elements in the succession:-

	50'	The David's Stone Limestone
	34'	Slate
	4'	Sandstone with thin slate bands
MIDDLE	60'	Slate
	3'	Combe Martin Beach Limestone
ILFRACOMBE	38'	Slate associated with arenaceous bands
	55'	Calcareous slate and thin limestones
BEDS	20'	(Variable) Jenny Start Limestone
	75'	Slate, often calcareous & with thin limestones
	1'	Rillage Limestone (='Curtain Rock')
	40'+	Arenaceous beds with some prominent grit bands

(All the thicknesses in the above table are approximations; exact measurement is impossible on account of the tectonic complications, and in any case, the thickness of individual units is not constant from locality to locality).

The oldest rocks exposed along the Hele-Samson's Bay section outcrop at Rillage Point. They consist of sandstones and arenaceous slates - the former are often current-bedded and one massive band shows balled-up structures. These structures which may be up to three feet in diameter, are attributed to slumping. Current-bedding, and cleavage/bedding relationships indicate that these beds are normally disposed, and dip 40° in the direction 178°. The upper part of these beds is seen again in the core of an anticline on the foreshore near West Hagginton Beach (fig.21). This arenaceous succession is placed

in the Lower Ilfracombe Beds and correlated with the beds seen on Widmouth Head, on the basis of similar gross lithology and the same position relative to the Rillage Limestone.

The Rillage Limestone

At Rillage (fig. 28) this limestone shows a beautiful series of drag folds which somewhat resemble the drapings of a heavy curtain, and it has been appropriately termed 'Curtain Rock' (Valpy 1867) (see plate 7 fig. 2). It is 1' - 1'3" thick on 'Curtain Rock' and is made up of two bands of pale greyish limestone separated by 3" of slate. The lower band is 4" - 6" thick and consists of small crinoid ossicles (about 2mm diameter), together with broken fossil fragments of approximately similar size. Larger shaly pellets (1"-2") and strings of blackish shale also occur. In the upper limestone band brachiopods are very abundant together with crinoid ossicles and occasional fenestellids. Orthoceratids (plate 9) are also present and small concentrically layered bodies are common (plate 3); the latter may be 2-3mm in diameter, and the layers are developed around a nucleus of detrital calcite or sometimes a quartz grain; they are often distorted as a result of pressures within the rock and also may be flattened on one side, where the layers are thin or altogether absent. These structures are clearly not normal ooliths since they lack the radiating structure and they are here interpreted as algal growths, though no diagnostic structural detail is recognisable. (The bands do, however, seem to be made up of a series of rods tangentially arranged such as seen in the genus Girvanella).

The limestone itself is very compact and contains a small quantity of pyrite - the latter being responsible for its rusty appearance on sub-aerially weathered surfaces. There are also occasional detrital grains of quartz, but these make up less than 1% of the whole rock. The limestone is partially dolomitized and some of the crinoid ossicles have an outer

rim of dolomite, while the core remains unaltered calcite. There has also been resorption and recrystallization as a result of pressures, and the boundary between adjacent calcite crystals is strongly marked by a black deposit - presumably impurities in the crystalline calcite which were left behind when resorption took place.

Tension gashes infilled by an intergrowth of quartz and calcite are a prominent feature of 'Curtain Rock'. They are closely spaced (about 6" apart) and trend 158°. This is at right angles to the crests of the drag folds since the latter plunge to the West. The gashes dip very steeply to the East (Evans 1922b). The significance of these has been discussed by Wilson (1961).

The Rillage Limestone is correlated with a limestone, about 7" thick, which forms a prominent band running across the foreshore in the first cove to the East from the steps leading to Hagginton Beach. For convenience of reference, this cove is termed 'Orthoceras Beach' (fig. 27) on account of the occurrence of orthoceratids in the limestone at this point.

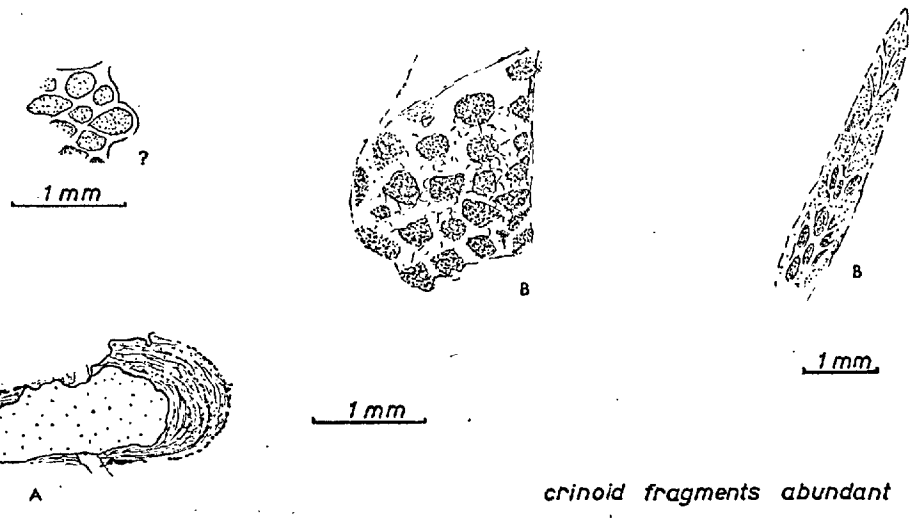
The thickness of the limestone varies between 3" and 9". Sections of brachiopod shells are very abundant on the upper smoothed surface, and, although they occur throughout the limestone, they are concentrated in the upper part. The shells are recrystallised, often incomplete, and crushed, so that it has not been possible to identify them. Fragments of fenestellids and other bryozoa are also abundant, and these show up best on sub-aerially weathered surfaces where they are etched out in relief.

Orthoceratids are not common but they were found in the limestone near to the cliff on 'Orthoceras Beach' and also in the cove immediately to the East. In the latter locality several specimens were found in boulders of the limestone which had fallen from the cliffs.

Concentrically banded bodies similar to those described from

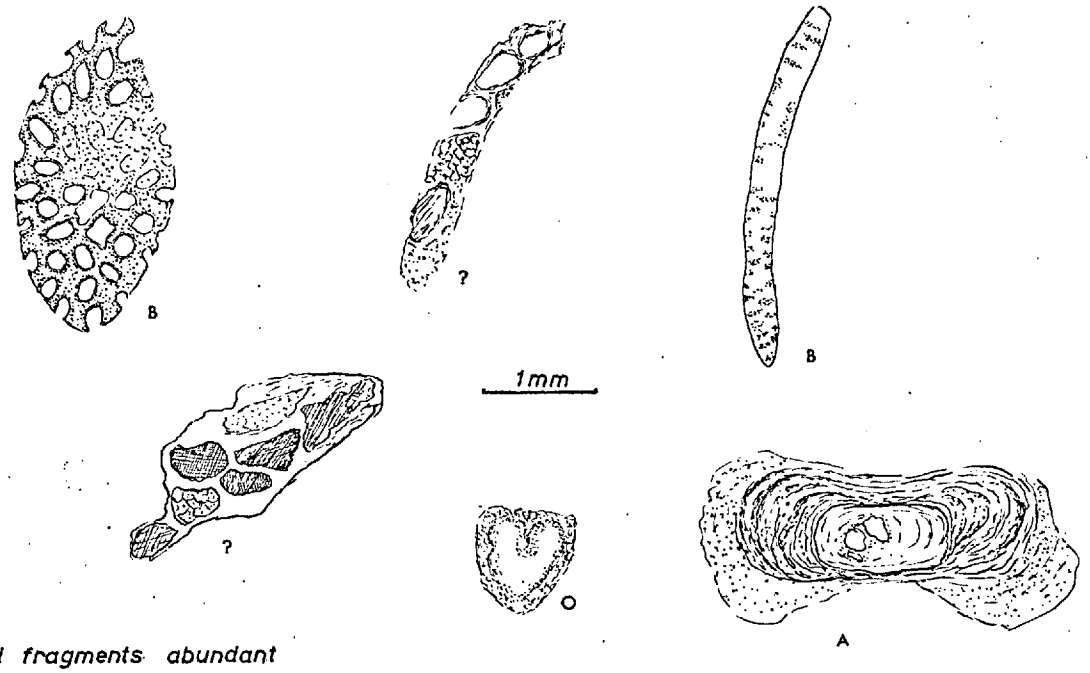
SMALLMOUTH slide 9.6

fig.19



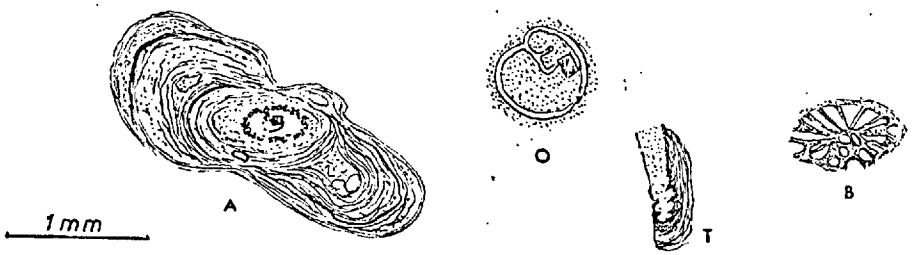
crinoid fragments abundant

WATERMOUTH slide 9.3

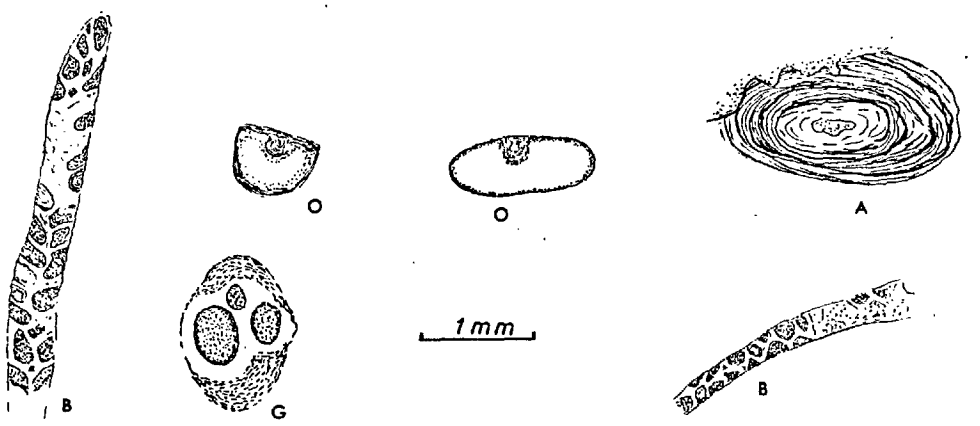


crinoid fragments abundant

RILLAGE slide. 19.1

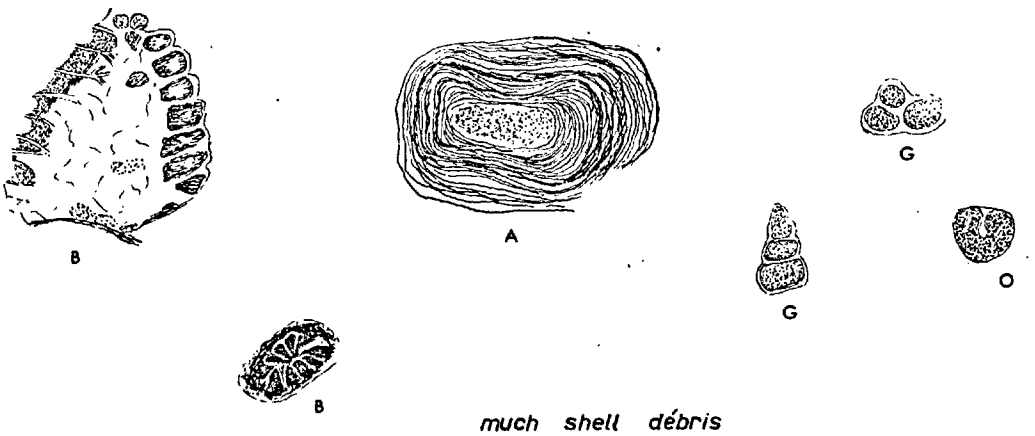


DESOLATION COVE slide 9.23



abundant crinoid and shell fragments

S. of SMALLMOUTH slide 9.21



much shell débris

Fig. 19-20 ORGANIC FRAGMENTS FROM THE RILLAGE LIMESTONE AS SEEN IN SECTION

A= *Algae* B= *Bryozoa* T= *Tentaculites* G=*Gasteropod*
O=*? Ostracods*

'Curtain Rock' are again common. They range from 2-15 mm in diameter, but the vast majority are of the smaller size. The fact that occasional larger specimens do occur is additional evidence suggesting an organic origin for the bodies. They tend to occur concentrated in pockets, together with crinoid ossicles and black bean-like objects about 1 mm long. Although the exterior surface of these latter objects is black, the interior is filled with white calcite. Many of them show a lobe projecting into the interior (plate 10 fig. 1) and it is thought likely that they are ostracods. Micro-organisms from the Rillage Limestone, as seen in section, are further illustrated in figures 19 & 20.

Small black flecks and streaks are common in the limestone and there are occasional bony fish fragments (plate 9 fig.2). No piece of diagnostic significance has been found. The limestone has not yielded conodonts, although samples have been dissolved in acid.

When fresh, the limestone is pale grey, but it weathers to a rusty brown on account of the abundance of pyrite which is disseminated throughout the limestone. Quartzo-calcitic veins and tension gashes are abundant within the limestone but do not characterize the beds above and below. About 16 feet above the main limestone is another about 1" or less thick.

The correlation of the limestone on Orthoceras Beach with the Rillage Limestone is based on four main factors:- (1) The faunal content of the limestones is similar, especially with regard to the concentrically layered bodies and the orthoceratids, (2) Both limestones occur at approximately the same distance below the Jenny Start Limestone and are associated with a thin limestone about 10 feet above (3) The limestones have a similar lithology (4) Both limestones are underlain by a similar succession of arenaceous beds.

The Rillage Limestone can be followed about 150 yards to the East

from its outcrop on 'Orthoceras Beach' though N.W.-S.E. faults step it back high into the cliffs. The inverted limb of the limestone, which is seen close to low tide mark on 'Orthoceras Beach', can be traced as far as 'Tufa Cove' (a small indentation in the cliffs characterized by large boulders of fallen tufa) at which point the inverted limb is also faulted high up into the cliff so that it can no longer be followed.

Traced to the West from its outcrop on 'Orthoceras Beach', the Rillage Limestone becomes faulted out to sea by N.W.-S.E. faults and no further outcrops occur to the West (see fig.27).

The Rillage Limestone can also be followed eastwards from its outcrop on 'Curtain Rock' and it outcrops on the foreshore of Samson's Beach. It is much dolomitized and strongly stained with haematite in the neighbourhood of the N.W.-S.E. fault which strikes across Samson's Beach and shifts the limestone back into the cliff in the South-east corner (fig 28). Its outcrop eastwards from there has already been discussed in the preceding sections on Widmouth and The Warren.

Between the Rillage Limestone and Jenny Start Limestone are about 75' of slate, often black in appearance and sometimes calcareous, with thin (1" or less) bands of detrital limestone occasionally developing. Outcrops of the Jenny Start Limestone occur at two localities between Hele and Samson's Cove. The first of these localities is at the foot of the path leading down to West Haggington Beach, and the second is in the vicinity of Rillage Point. At both localities the limestone has been tightly folded and is affected by minor fractures in addition to the main faults discussed below.

The Jenny Start Limestone

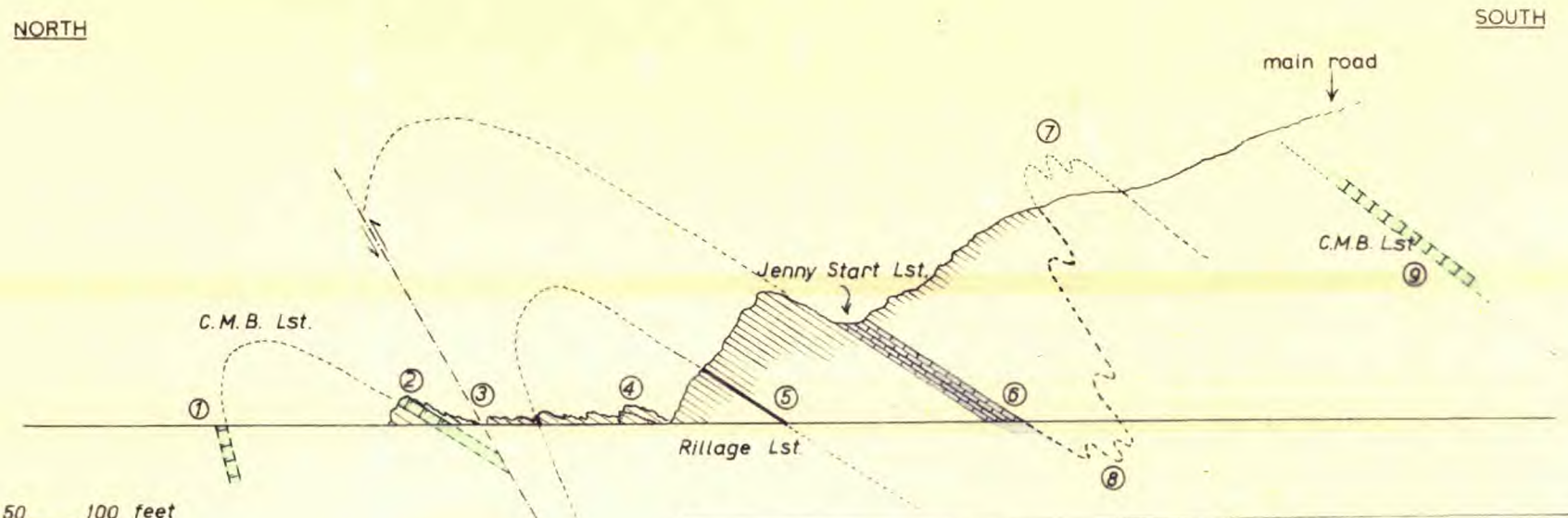
(a) At Haggington Beach

The clearest picture of the Jenny Start Limestone in this locality is obtained on 'Orthoceras Beach' (see figs 27 & 28); here the limestone

dips South at about 35° and is normally disposed, while at the foot of Hagginton Steps it is much buckled and fractured as the result of passing over a tight anticline (see figs. 21 & 22). At the West end of the foreshore on Orthoceras Beach the Jenny Start Limestone contains an abundance of corals with colonies of Disphyllum up to 2 feet across (Plate 12). Less than 20 yards to the East, where the limestone crops out at the foot of the cliff, corals (except for Thamnopora) are absent, and the limestone succession (including interbedded slate) is some 4 feet thinner. There are two possible interpretations of these facts: (1) the bands containing the massive corals have been cut out by tectonic disturbance in the eastern outcrop (there is an abundance of quartz, associated with lumps of dolomite up to 1' 6" thick, at the base of the limestone, which clearly suggests movement); (2) the massive colonial corals are only developed in local patches so that in places they may be completely absent from the succession.

Although movement has almost certainly taken place at the base of the the limestone the second interpretation is considered the more likely since the higher zone at which corals occur in the western outcrop lacks corals in the eastern outcrop, and there is no evidence of movement at this horizon. Secondly, at Oakestor Bay (and other localities) the Jenny Start Limestone can be traced from where it contains an abundance of massive corals to where corals are completely absent. Also, when the lowest band of limestone in the cliff exposure is traced to the West across the beach, massive corals begin to make their appearance.

It is noticeable that the massive colonial corals (e.g. Disphyllum and Endophyllum) occur at the top of a limestone bed (not within it) and are inferred by the argillaceous material now in the form of slate. This suggests that these particular colonial forms flourished in somewhat



1 Inverted limb can be followed across the beach and into the cliff at the E. end of Hagginton Beach.
2 Normal limb crops out on the fore-shore about the middle of Hagginton Beach.
3 Fault is marked by crumpled slate both in the cliff and across the fore-shore.
4 Anticline seen at the west end of Hagginton Beach.
5 Prominent dip slope on the N.E. side of "Orthoceras Beach."
6 Cliff on the S. side of "Orthoceras Beach."
7 Anticline seen W. of the steps leading to Hagginton Beach.
8 Syncline seen N.E. of the steps leading to Hagginton Beach.
9 The C.M.B. Limestone is seen dipping normally in the "Sewerage gully."

fig.21 Composite section to show the main structures of the Hagginton Beach area.

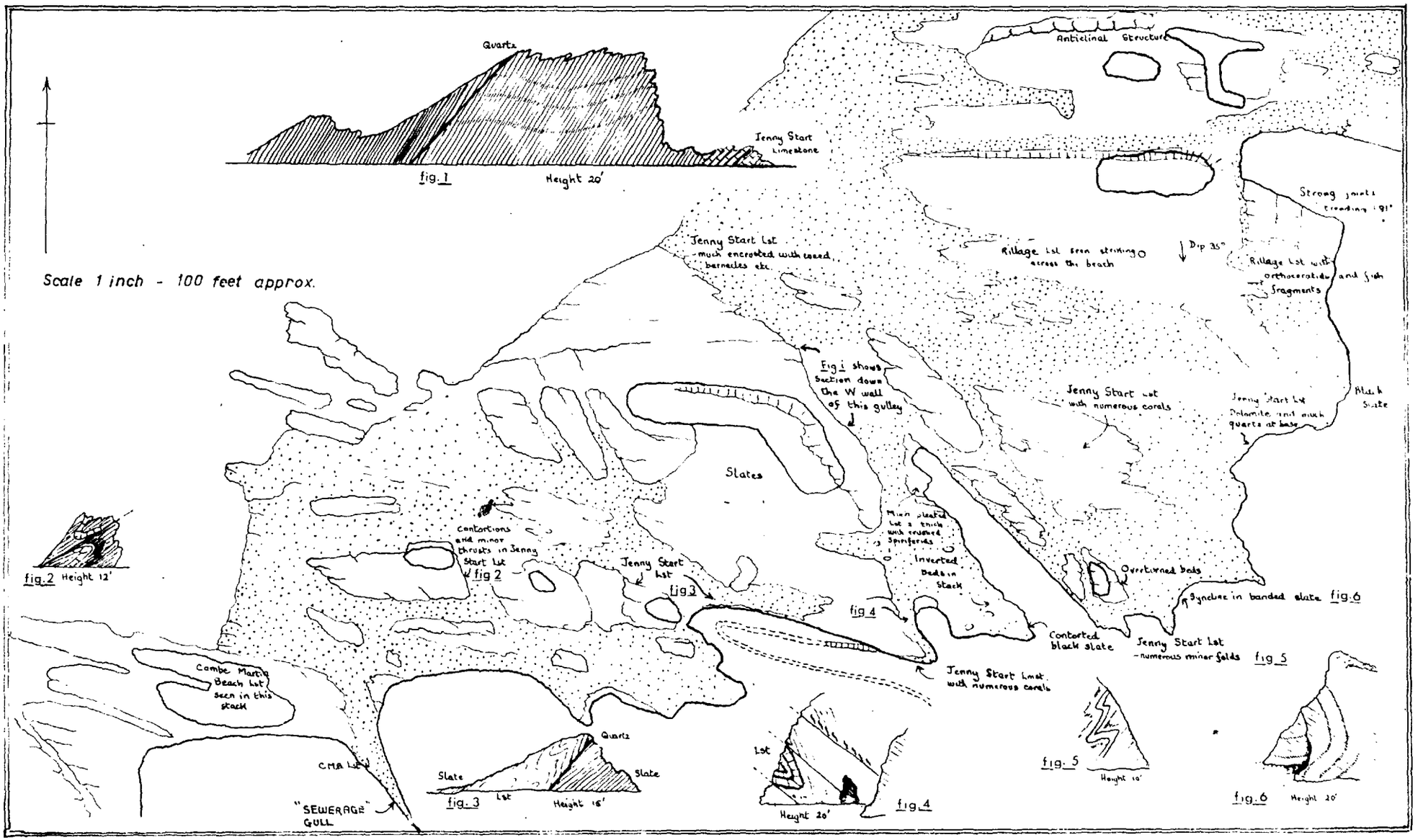


fig 22 Field sketch-map of the area at the foot of Hagginton Steps

muddy water, though when the argillaceous deposition became excessive, they were unable to survive.

(b) At Rillage

As a result of folding (see fig.23) there are numerous separate outcrops of the Jenny Start Limestone in the vicinity of Rillage Point. These are numbered on the accompanying sketch map (fig.28) for easy reference.

1. The eastern end of Haggerston Beach

About 4 feet of calcareous beds are exposed at the foot of the cliff. These beds have been down faulted from the top of the cliff to the North, and the present outcrop is a wedge of limestone caught up between two normal faults (see fig.23). The upper two feet of the limestone consist of slaty limestone in which fossils are moderately abundant; these can readily be seen on the abraded dip slope. Specimens of Thamnopora are common and may sometimes form ramifying colonies up to 12" across; recrystallization is most noticeable in the neighbourhood of these corals. Rugosa are not common at this locality. Brachiopods are frequently seen in cross-section occuring together in clusters. Other elements of the fauna which have been collected are (?) Cystids, Capulus (sp).

The lower part of the exposure consists of flaggy limestone without fossils other than crinoids. This can be seen to pass laterally into massive dolomite lumps (plate 11, fig.2), some 3-4 feet long and up to 2 feet high. The origin of these lumps is problematical but the following observations are of importance in considering the time at which the dolomitization took place:-

(a) The more slaty bands above and below the lumps appear to have been bent, but they do not thin over the dolomitic areas. This must be the result of differential compaction as the volume of the limestone would be reduced on conversion to dolomite.

(b) The dolomite passes laterally into limestone bands and although the contact is sharp, it is possible to trace individual limestone bands into the dolomitic mass; the slate bands do not pass into the dolomite. This suggests that the dolomite is secondary, resulting from an alteration in the limestone.

(c) More quartz veining is associated with the dolomite than with either the limestone or the slate - this may be the effect of reduced volume causing tension.

(d) At Rillage (locality 2) massive lumps of dolomite suddenly make their appearance as the limestone is traced along its strike. The corals also became dolomitised in the same sudden way.

It seems to the writer that the most likely explanation of the observed facts is that dolomitization took place at an early stage in the history of the limestone, but probably after the overlying argillaceous beds had been deposited. Subsequent compaction and tectonic movement would be sufficient to account for the bending of the shale around the more competent dolomitic mass, and would also suggest a reason for the associated quartz, since the dolomite would offer more physical resistance to fracture and the resulting strains might well cause quartz to be deposited in the cracks and fissures.

The cause of the dolomitization is not known. The normal limestone can be found passing quite suddenly into the massive dolomitic lumps in several localities. Most impressive are the great reefs of dolomite on the West side of Rillage Point (locality 2), and it can be seen to a lesser degree at Orthoceras Beach and on the West side of Hillsborough (at the latter locality it is associated with the David's Stone Limestone). It is the lowest bed of the limestone which is most often affected and there is always a large amount of associated quartz veining which suggests that the dolomitization may be associated with a plane of movement.

2. The West side of Rillage Point

The old quarryman's path leads directly down to this locality and the limestone is seen striking due E-W from the foot of the path. Two N.W.-S.E. gullies cut through the limestone reef as it runs across the foreshore and these are the result of minor fractures which have been widened both naturally and artificially. The limestone forms an outcrop about 9 feet wide at beach level, but this gives a false idea of the thickness of the limestone which is involved in a tight synclinal structure at this locality (see section, fig 23). It is extremely difficult to see any evidence of the synclinal structure within the limestone itself since the cleavage tends to obliterate all trace of original bedding. Two factors confirm the synclinal structure however: (i) the syncline can be clearly seen on the East side of Rillage and the structure can be traced through a series of quarries across the intervening headland, (ii) the beds are inverted to the South of the limestone and normally disposed to the North of it.

The limestone seen at beach level consists of flaggy limestone with some calcareous slate, though much of the limestone has become so broken that it is difficult to separate the two types of rock. Cracks and cleavage surfaces in the limestone are frequently tinged with red, and this is attributed to iron staining; such staining is often noticeable in the vicinity of faults (e.g. in Samson's Cove and South of Jenny Start). No fossils, apart from traces of fenestellids in the calcareous slate, are found at beach level but there is a zone about 15 feet above beach level, in the core of the syncline, in which massive compound and solitary corals occur in profusion. The best place to see this band is in the reef between the main cliff and the most westerly reef. It can be seen also in the latter reef but here the massive colonies are all completely recrystallized and nothing but the form of the colonies remains to indicate their abundance in the rock. At the same locality

massive lumps of dolomitised limestone some 12 feet or more across, are developed at the hinge of the fold; the beach is strewn with boulders of the same rock.

3. The East side of Rillage (Samson's Beach)

The synclinal structure mentioned in the previous section is clearly seen on the East side of Rillage Headland and the base of the limestone passes around the axis of the syncline, a few feet above beach level. The limestone has been quarried here in the past and the main exposure is now to be seen in the vertical cliff face. A thin veneer of the limestone is still preserved on the platform at the base of the cliff, and in this can be seen traces of the original bedding strongly plicated as it passes round the hinge of the main synclinal structure (plate 11, fig 1).

The limestone has the typical flaggy appearance, already remarked upon, as a result of being cleaved. There are few traces of fossils other than crinoids, though one large nodule seen in the vertical cliff section was possibly a colony of Disphyllum; (it was not practicable to collect a sample for sectioning).

There are approximately 90 feet of strata between the Rillage Limestone and the Jenny Start Limestone at this point. It will be noted that the thickness of strata between these limestones is comparable with that between the same two limestones on 'Orthoceras Beach'. Even more important, as a factor in correlating between the respective limestone beds, the essential elements of the succession are similar.

4. The Quarries on the cliff above Rillage Point

It has already been remarked upon that the synclinal structure seen on the East side of Rillage can be traced across the headland, and is seen again on the West side. A double line of quarries marks the outcrop of the two limbs of the syncline across the top of the cliff. On the West side, however, an additional quarry was formerly worked between the

fig.23

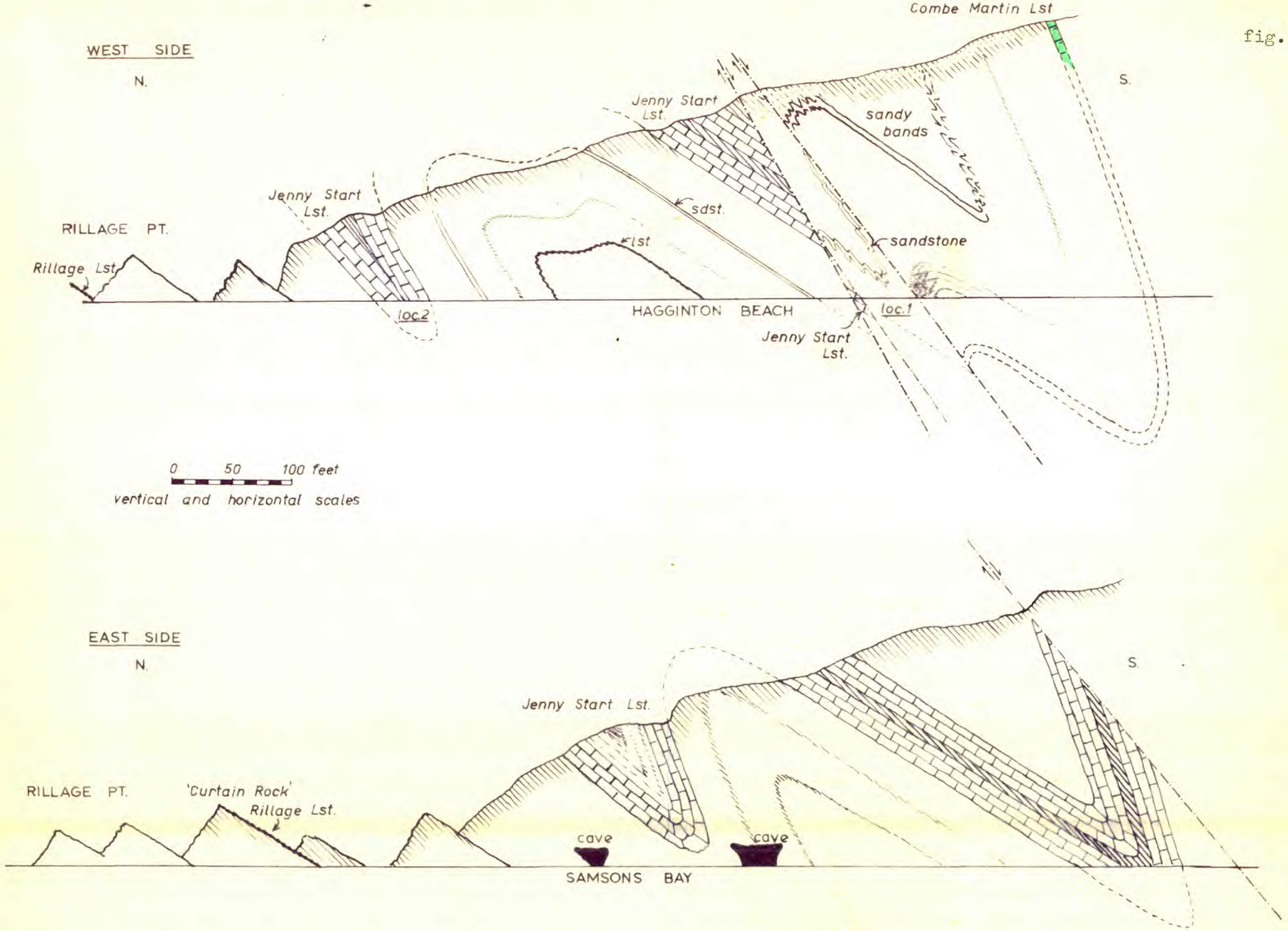


Fig.23 DIAGRAMMATIC SECTIONS COMPARING THE STRUCTURES ON EITHER SIDE OF RILLAGE HEADLAND (*Note:* the lower section has been reversed to facilitate comparison)

other two (this feature can be seen on the 25" map). It is in this middle quarry that the limestone is richly fossiliferous (chiefly corals and bryozoa). The explanation of these facts is readily appreciated: the Jenny Start Limestone both here and elsewhere, consists of two bands of massive limestone which formerly were economic to quarry; between the two is a slaty limestone in which corals frequently become prolific; the thickness of these three units within the Jenny Start Limestone is variable, but they can usually be distinguished; the syncline on the East side of Rillage exposes only the lower division of the massive limestone, but as a result of the plunge to the West, the coraliferous division is preserved only in the centre and West side of the headland, while the upper massive horizon is preserved only on the extreme West side. The middle quarries are the result of the exploitation of this upper band.

The quarries on the East side of the headland (along the strike of the syncline) are unfossiliferous, except for crinoids and rare brachiopods. Where the middle division of the limestone is preserved in the West, fossils become abundant. Thamnopora and Alveolites develop colonies which may be 3 feet and more in length; members of the Disphyllidae are also abundant.

About 50 yards to the North of the quarries discussed above, another line of quarries can be seen trending across the headland. These are now grassed over and there are no exposures of solid rock except in the extreme East. The form of these abandoned quarries suggests that two parallel bands of limestone were worked and that the intervening more slaty horizon was sometimes left untouched. This can be appreciated both in the field and from an inspection of the 25" map. It is apparent that the Jenny Start Limestone has passed over an anticline and is now dipping South into the cliffs on a normal limb (fig 23b). This normal

limb can be seen reaching beach level in Samson's Cove (South of the exposures discussed in Section 3), but on the West side of the headland the limestone is cut off by a normal fault down-throwing to the South (see fig 23a), and its full thickness can only be seen in the top of the cliff; a small wedge of the limestone is caught up between two splinters of the fault; this is exposed at beach level and has been described already (Section 1).

5. Samson's Beach

The Jenny Start Limestone occurs here in the core of yet another syncline, and forms an exposure some 30 feet high at the base of the cliff. The normal limb of this syncline is the continuation of the band which was quarried at the top of the headland and which was discussed in the preceding paragraph. The synclinal structure is readily appreciated by viewing the dip section in the fault gully to the East of the main outcrop; the fold can also be seen in the strike section along the cliff face, where one surface of the limestone forms a natural trough as it passes around the axis of the syncline. At the same horizon massive compound corals are abundant and one colony of Endophyllum measured over 4 feet in diameter. Occasional brachiopods can be collected also from this locality.

The inverted limb of the limestone is seen also in the fault gully to the East but it does not extend across the headland as it is cut off by the normal fault. This fault is not exactly parallel to the strike of the beds but trends slightly North of West; the result is that on the East side of Rillage (Samson's Beach), the inverted limb of the limestone is cut out above beach level, while on the West side the fault cuts through the normal limb at the top of the cliff (compare fig 23a and 23b).

The Lithology of the Jenny Start Limestone at Samson's Cove

Throughout its outcrop between Combe Martin and Ilfracombe, the Jenny Start Limestone is locally oolitic, but frequently, as for example on Newberry Beach, the ooliths have become so streaked out as not to be immediately recognisable (see Holwill 1962, Plate 13 A). At Samson's Beach some of the ooliths are not deformed and their nature is readily recognised even in hand specimens. Thin sections, however, show what appear to be two distinct types of oolith which have reacted to pressure in different ways.

Fig 24d shows ooliths which have not been distorted but which have been modified in shape as the result of resorption. Two or more ooliths have been compressed together and at the point of tangent where pressure was greatest, resorption has taken place and has continued along the whole line of contact; impurities (? iron pyrites) which were present in the original oolith are concentrated along this line and now show as a strong opaque suture appearing slightly brassy in reflected light.

Fig 24e shows ooliths which are streaked out to several times their original width with no obvious evidence that resorption has modified them in any way.

These two types of oolith can be observed within the compass of a single thin section though they are never randomly intermixed. In slide 2 (D-E) there is a gradual transition between those which are undistorted, through ones which are mildly distorted, into those which are streaked out as fig 24e. Slide 2 also shows distorted and undistorted ooliths though here the transition is abrupt -but not so sharp as to justify the conclusion that a pebble of one type has become interred in an oolitic sediment which reacted differently to later pressures. There is

however, evidence of current action and penecontemporaneous erosion so that it is possible the two types of oolith have been brought together as a result of movement along the sea floor.

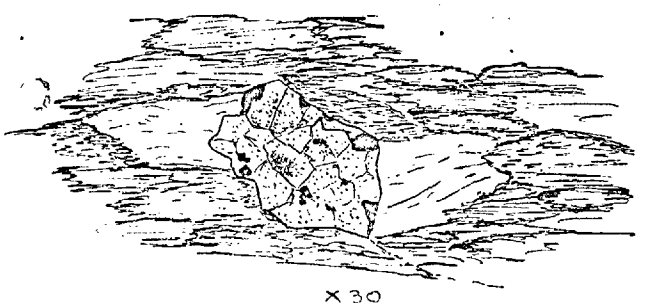
The possibility that one set of ooliths was deformed before the introduction of undeformed ones is discounted, and it is therefore necessary to find a means whereby similar pressures should affect the two types of ooliths in quite different ways.

Chapman (1893) examined the oolites in Samson's Cove and, although he recognised the distorted and undistorted varieties, he does not appear to have found them in such intimate association as has been seen by the present writer for he concluded that the altered and sheared oolites represented the parts of folds which had suffered most stress. He also commented that the ooliths ('granules') were found to be formed of microcrystalline secondary quartz which had almost entirely replaced the original grain. This latter observation has not been confirmed by the present study and all the ooliths studied show a double refraction indicative of a carbonate, certainly not of quartz.

The beds between the Jenny Start Limestone and the Combe Martin Beach Limestone consist of slates, somewhat calcareous in the lower parts with occasional thin limestone bands, and rather more arenaceous towards the centre of the succession; the upper part is dominantly grey slate. The only locality in the present area, at which this sequence of beds can be seen, is between the steps of Haggington Beach and the gully some 100 yards to the West into which a main sewer empties (for convenience of refetence this gully is named 'The Sewerage Gully'!) The succession appears to be slightly thicker than on Newberry Beach (the only other place where this sequence of beds is fully seen) but there is close enough agreement in the main elements of the succession to preclude any suggestion that part of the succession has been faulted

Slide 3

A

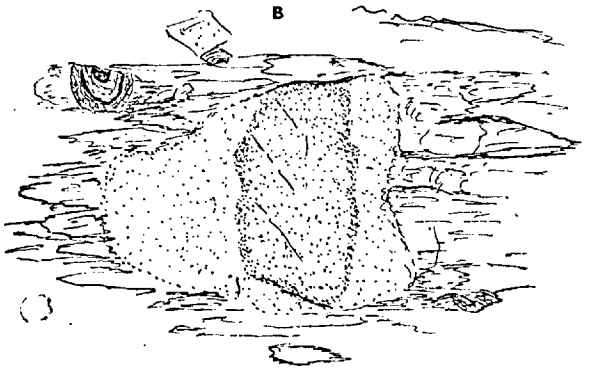


× 30

Dolomite Augen with tension shadow of Quartz × 30

Slide 3

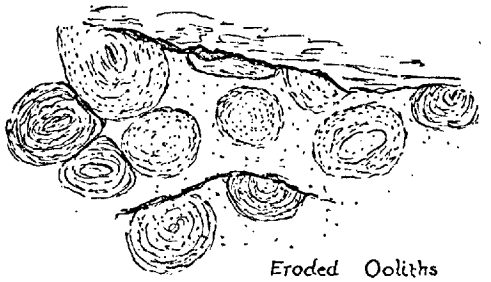
B



Calcite Augen and shadow × 30

Slide 3

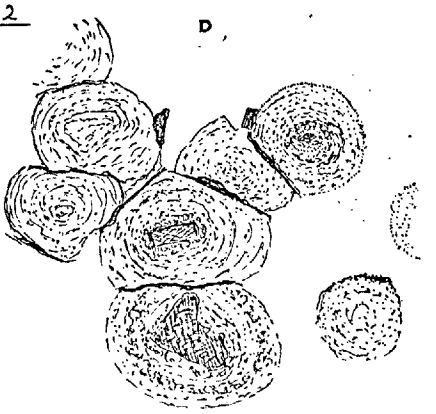
C



Eroded Ooliths

Slide 2

D



Welded ooliths × 30

Slide 2

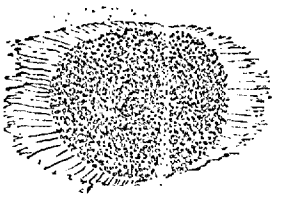
E



Deformed ooliths × 30

Slide A2

F



Oolith with fibrous calcite outgrowth

Fig. 24 **OOLITIC LIMESTONE - SAMSON'S COVE, NEAR ILFRACOMBE, NORTH DEVON**

out at Newberry.

The Combe Martin Beach Limestone

This is the most distinctive of all the limestones in the Ilfracombe Beds and it was fully described by Hickwill (1962). Numerous exposures of it occur between West Haggington Beach and Hillage, but only at the former locality can it be seen with a reasonably complete series of beds above and below it. Elsewhere, tectonic complications prevent the full succession of associated beds being seen. The outcrops in the Haggington area are shown in fig 27.

Although the Combe Martin Beach Limestone at Haggington has the same characteristics as in the type locality on Combe Martin Beach, there are two features about it which justify special mention. (1) Solitary corals (chiefly Petraiadophyllum and Syringaxon) are much more abundant at the East end of Haggington Beach than at Combe Martin; the corals, though still fragmentary, tend to be less distorted and less recrystallised. Collecting is never easy from any of the rocks as fossils do not weather out from the matrix, but a large collection of individuals has been made from Haggington Beach and, with the aid of polished sections, it has been possible to make detailed studies of some species.

(2) The upper layers of the Combe Martin Limestone typically contain an abundance of brachiopods, but it is only on Haggington Beach that it has been found possible to obtain relatively undistorted casts and moulds. No systematic work has been attempted on these brachiopods though a form close to Cyrtospirifer verneuili is very common; this and other species from the Combe Martin Beach Limestone, are illustrated in plate 13.

At the extreme Eastern end of Haggington Beach, the Combe Martin

Beach Limestone is seen inverted in the foot of the cliffs; the thickness is very variable (4'-6') as a result of drag folding. The inverted limb can be followed in the lower part of the cliff, climbing higher as the bed is traced to the Northeast; it is then stepped South by a N.W.-S.E. fault, and a small exposure can be found high up in the cliff to the W.N.W. of the coastguard houses.

The same inverted limb of the Combe Martin Beach Limestone can be traced across the foreshore trending W.N.W., and being stepped by a series of N.W.-S.E. faults until it is eventually lost out to sea (fig 27). In places much breccia has developed along the line of these faults and it forms prominent reefs projecting through the sandy beach. However, a short distance further West along the foreshore, the Combe Martin Beach Limestone is found outcropping on a normal limb; this is the result of movement along a powerful N.W.-S.E. fault which shifts the normal limb of the limestone from high up in the cliffs (where it is inaccessible but can be recognised with the aid of binoculars) down onto the beach. This normal limb can now be followed to the West across the foreshore and again it is stepped to the North by a series of N.W.-S.E faults, until this too is lost out to sea.

The Combe Martin Beach Limestone crops out again in the cliffs on either side of the 'Sewerage Gully' and from here it can be traced to the West in a reef which projects out into the Northeast corner of Hele Bay. The limestone is again on a normal limb but it is separated from the previously described outcrops across Hagginton Beach by a powerful strike fault which causes not only repetition of the Combe Martin Beach Limestone, but of the whole succession between this and the Rillage Limestone. The fault can be seen in the cliff near 'Tufa Cove', where the slates are severely buckled (plate 14), and it can be traced

West across Haggiton Beach, being stepped by the N.W.-S.E. faults.

The succession between the Combe Martin Beach Limestone and the David's Stone Limestone is seen on the Northeast side of Hele Bay and it is about 110 feet thick. The succession is dominantly slate but about 70 feet from the base there are about 8 feet of more arenaceous beds.

The David's Stone Limestone

This limestone can be seen on the East side of Hele Bay and it is the only beach outcrop of this limestone within the area, except at David's Stone (see Holwill 1962). There are about 54 feet of calcareous strata grouped within the David's Stone Limestone, but most of this is either calcareous slate or thin limestone interbedded with slates. The thickest development of limestone occurs near the base and it is this massive band some 3 feet thick which has been most extensively quarried; in fact its position is marked over most of the foreshore by a sandy gully in which there are no outcrops of solid rock. A band of slaty limestone at the top of the massive limestone shows evidence of partly preserved fossils and the following have been recognised : Fenestella sp., Thamnopora sp., Zaphrentoides sp.

Many of the thin limestones are oolitic and show evidence of current bedding; most of them weather with a pock-marked surface (see pl.13 Holwill 1962) and individual beds of limestone are rarely more than 6"-9" thick; they are interbedded with calcareous slate which is usually only two or three inches thick.

There is evidence of movement along some of the bedding planes and quartz is developed parallel to the bedding at various horizons; slickensides can also be seen in some places. Despite these evidences of movement, it is considered unlikely that there is any major displacement between the various beds as the limestone sequence is essentially the

same as that developed both on the West side of Hele Bay and near Beacon Point.

The limestone cannot be followed up the cliff owing to a scree of superficial material and vegetation. However, there can be little doubt that it is the same limestone which was once quarried in the neighbourhood of the present Golf Club House. The limestone can be followed for a short distance to the West across the beach, but it becomes lost beneath sand before reaching the N.W.-S.E. fault which must must cut across Hele Bay, and which displaces the limestone to the North; the same limb of the David's Stone Limestone is seen in the reefs off the North end of Ellisborough.

A few feet above the David's Stone Limestone on Hele Beach are two bands of limestone separated by 6"-8" of slate. These are detrital limestones and similar to many other detrital limestones which have been noted as occurring at various points in the succession. These two bands are rather more prominent than the average and the lower limestone contains abraded fragments of black, bony material. Although a dozen or more of these bone fragments have been collected, ranging from ¼"-3" in length, they have all proved unidentifiable. Dr I. White, who has inspected the fragments, considered it possible that one piece was a Pteraspis. This would suggest a Lower Devonian age for the limestone. However, the evidence for this suggestion is so meagre, and it is not confirmed by either structural or other palaeontological evidence, that it must be disregarded until such time as more conclusive evidence comes to hand.

About 150 feet of slate are exposed above the David's Stone Limestone on Hele Beach. The lower parts of this are calcareous, but arenaceous slate becomes increasingly important as the succession is traced upwards.

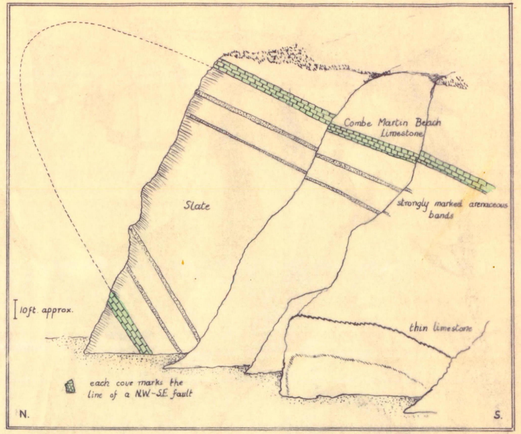


fig.25 Field sketch showing the structure to be seen in the cliff at the east end of HAGGINTON BEACH.

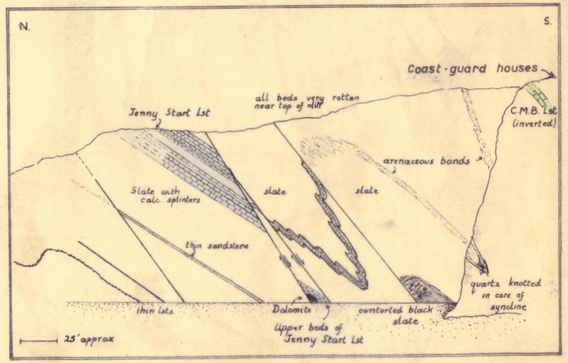
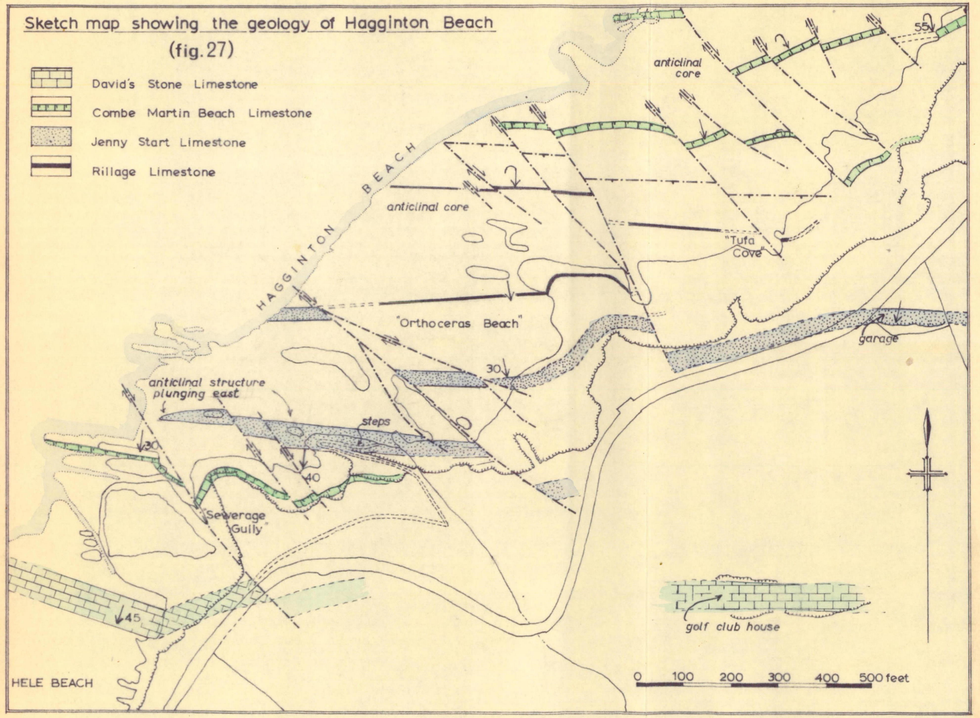
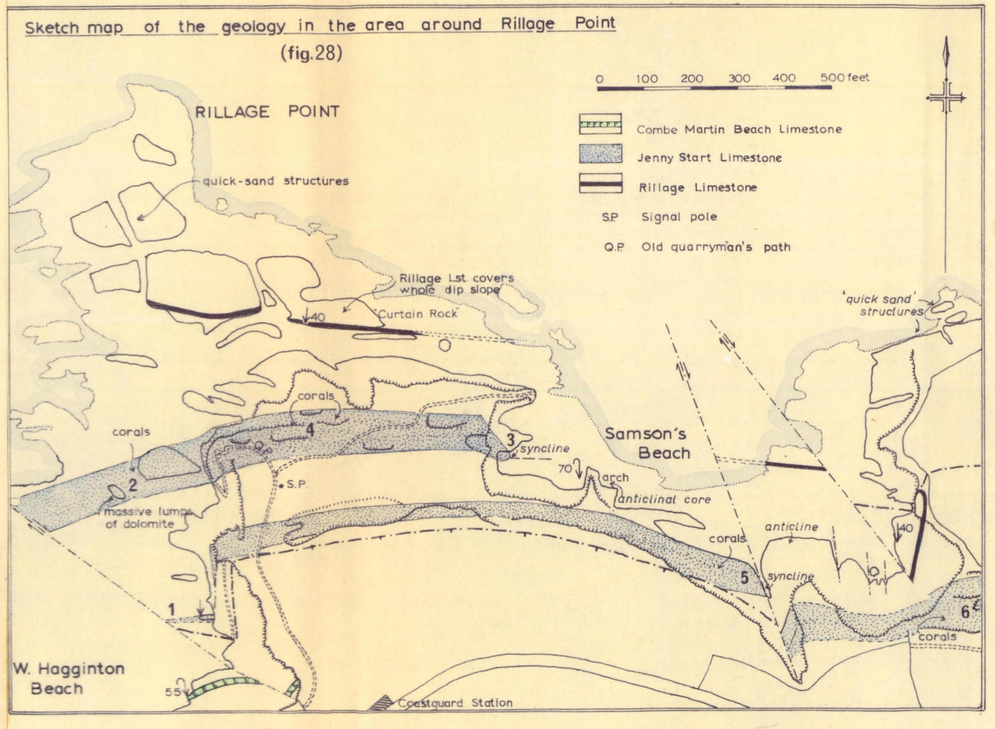


fig.26 Structure discernible in the cliffs to the N.W. of the Coastguard houses on West Hagginton Beach.





Hillsborough and Beacon Point

Two limestones are exposed within the area - the David's Stone Limestone and the Combe Martin Beach Limestone. The latter can only be seen at lowest spring tides as it crops out on the most seaward reefs at Beacon Point. There are three separate outcrops of the Combe Martin Beach Limestone; each band is about 4 feet thick, and they are separated by slates. All the outcrops are concealed by seaweed or encrusted with barnacles, and the limestone is extensively bored by small lamellibranchs. However, there is no doubt about the identity of the limestone for fresh broken surfaces show the characteristic features of the Combe Martin Beach Limestone - in particular its platish appearance and associated green shale. Thin sections also show the typical abundance of bryozoa.

Valpy (1367) recorded "two or three bands of hard white siliceous rock full of brachiopods" from Beacon Point, and from these bands he obtained "Spirifer disjuncta" (=Cyrtospirifer verneuili) and "Stophomena rhomboidalis"(=Leptaena rhomboidalis). These have not been collected from Beacon Point by the present writer, but they are comparable to the forms illustrated in Plate 13 from the Combe Martin Beach Limestone of Baggintom Beach. This additional evidence puts the identity of the limestone at Beacon Point beyond doubt.

The reason for the repetition of the limestone at Beacon Point cannot be stated with certainty as the weathered state of the limestone and slates make it impossible to detect whether there is any inversion of the beds. There is a suggestion of anticlining between the two more southerly outcrops of the limestone and if so, it is likely that a syncline

is present between the middle and most northerly outcrop. Such a pattern of folds would fit tolerably well with the structures seen to the North of Haggington Steps in the Jenny Start Limestone.

The strike of the rocks at Beacon Point is 97°, and to the East across Hele Bay the Combe Martin Beach Limestone is continued by the outcrop seen in the neighbourhood of the 'Sewerage Gully'. It is displaced 200 feet to the South by the faults running almost N-S across Hele Bay.

Between the Combe Martin Beach Limestone and David's Stone Limestone is a succession of slates with arenaceous bands becoming increasingly important near the top. Details can be seen in figure 28. The thickness of these beds separating the limestones is about 90 feet.

The David's Stone Limestone occurs in three distinct bands, each of which can be traced across the headland of Hillsborough. Two of these bands (the most southerly and the most northerly) dip normally to the South at 30-35°. The intermediate band shows various anomalies and is broken up by low angle strike faults; this band is interpreted as the overturned limb of an anticline (to the South) and syncline (to the North) (see section fig 29).

(a) The northern outcrop of David's Stone Limestone at Beacon Point

This outcrop of limestone is seen on the South side of the reef marked as 'Fishing Rock' on Ordnance Survey maps, and it can be traced to the West across the headland until it is lost out to sea. The total thickness of the limestone is about 22 feet; it is intercalated with calcareous slate and and cleaved sub-parallel to the bedding, giving it a flaggy appearance.

Immediately above the dip slope of the Fishing Rock there occurs about 4 feet of massive limestone and it is this band which has been largely quarried out across the headland. The dip slope itself is still covered by a veneer of slaty limestone with occasional nodules up to

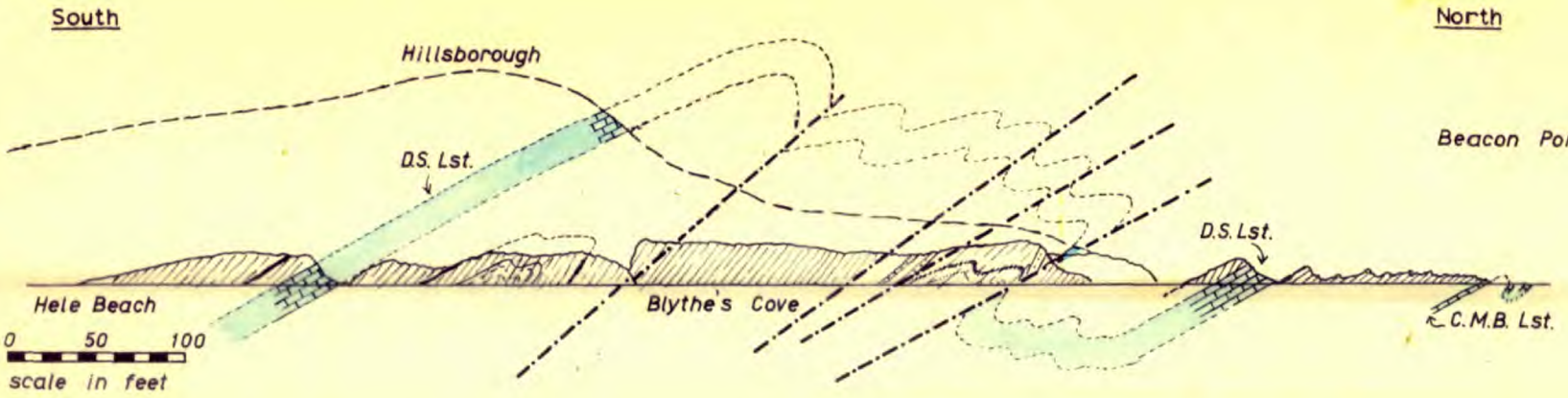


Fig. 29 SECTION ALONG THE EAST SIDE OF HILLSBOROUGH SHOWING THE OBSERVED GEOLOGY AND PROBABLE STRUCTURAL INTERPRETATION

(Section projected on to a plane normal to the strike)



Plate 15 THE EASTERN SIDE OF HILLSBOROUGH LOOKING ACROSS HELE BAY.

3 in. long, which are formed by a concentration of coarse organic detritus - largely derived from calcid stems, but with some ill-preserved brachiopods. Small coiled gastropods have also been found at this horizon.

Fossils are not common in the massive limestone, but about eight feet from the base of the limestone there is a more arenaceous band from which weather out poorly-preserved bryozoa (mostly Fenestellids), Thamnopora, moulds of brachiopods, moulds of gastropods, and rare solitary corals. This clearly is the equivalent of the middle fossil band seen at David's Stone (Holwill 1963). Thamnopora and fenestellids have also been found in the bouldered limestones at the top of the David's Stone Limestone at Beacon Point.

(b) The intermediate outcrop of David's Stone Limestone (the northern end of Hillsborough)

On the East side of Hillsborough, just N'wth of Blythe's Cove, the limestone is seen forming a wedge about 4 feet or more in thickness, near the foot of the cliff (fig 31). Immediately to the South of this outcrop, sandstone beds dip South at 70° and are inverted. Figs 30 and 31 show the structures a little further to the South (but still on the North side of Blythe's Cove).

As the wedge of limestone is traced across Hillsborough to the West, its outcrop becomes wider and at one point it has been quarried. The limestone is well-exposed again in the long N.W.-S.E. trending gully below the flagstaff. Fig 33 and fig 34 show the structures seen on the East and West sides of the gully respectively. Exact correlation of the structures seen in this gully and near Blythe's Cove is not possible, but the observed evidence is compatible with the interpretation outlined above which regards this intermediate band of the David's Stone Limestone as being inverted, whilst at the same time it is folded and

sliced by reverse faulting parallel to the strike (see fig 29). The folding is very difficult to see in the limestone, as axial plane cleavage gives the impression of a regular dip to the South. It is only when there are colour differences within the limestone that it is possible to appreciate the numerous plications into which it has been thrown. Fig 35 and plate 16 show the folds and faults which can be seen in the limestone on the West side of Beacon Point. Fossils other than fragments of crinoid ossicles are rare and only one specimen of Thamnopora has been found.

Fig 32 shows the structure which is seen in the slaty beds to the North of the last mentioned outcrop of limestone. This suggests a low mean dip in the beds and would accord with the suggestion that a synclinal axis occurs at about this position.

(c) The southern band of David's Stone Limestone at Hillsborough

This is seen in the gully 20 yards South of the slipway on the West side of Hele Beach, and it can be traced over the headland through a series of quarries until it descends to sea level again at the South end of Broadstrand Beach.

Near Hele the limestone and interbedded calcareous slates have a total thickness of 34 feet 6 ins. At the base is 11 feet (estimated - since this band has been largely quarried out) from which the coral Syringaxon has been obtained. On top of this is a more argillaceous limestone about 1 foot thick in which tabulate corals are reasonably abundant, though usually much distorted.

This argillaceous limestone is clearly the equivalent of the similar fossiliferous band seen at the top of the lower massive limestone at David's Stone. Above it, as also at David's Stone, are some 10 feet of calcareous slates before the development of an upper sequence of flaggy limestone. At Hele this upper series of flaggy limestones often show

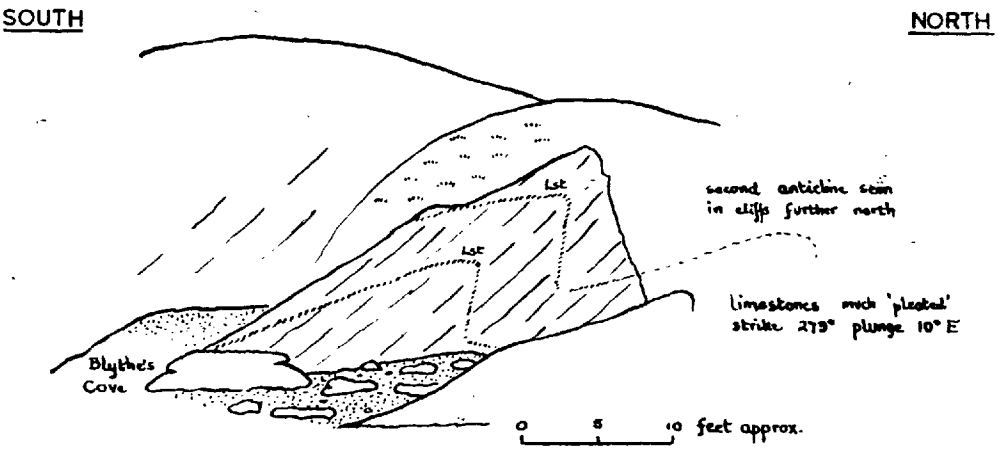


Fig. 30 FIELD SKETCH OF THE CLIFF IMMEDIATELY NORTH OF BLYTHE'S COVE, HILLSBOROUGH

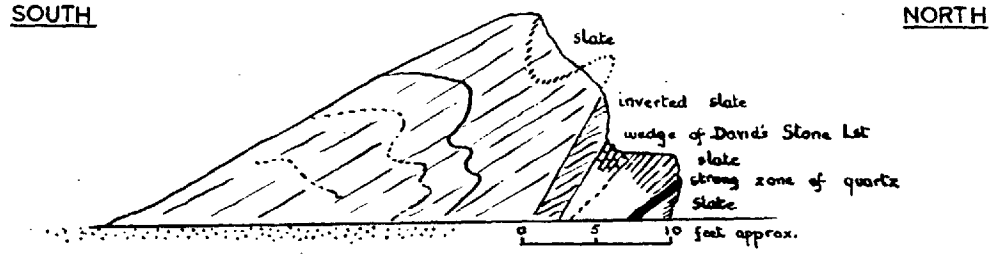


Fig. 31 FIELD SKETCH OF THE STACK IMMEDIATELY E.N.E. OF THE PREVIOUS SKETCH (fig. 30)

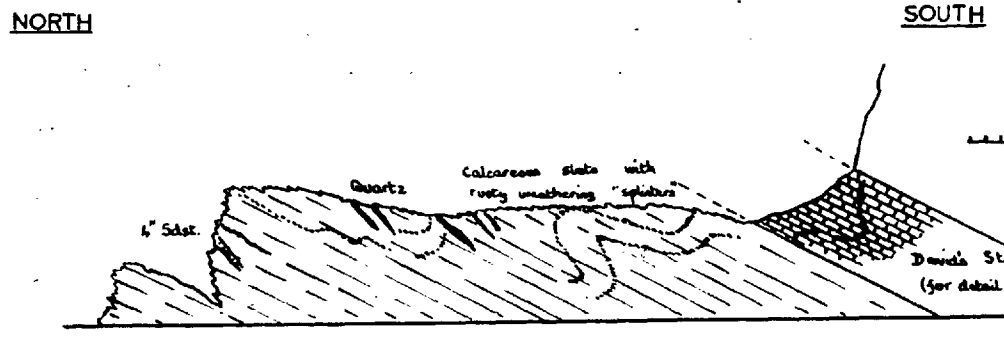


Fig. 32 FIELD SKETCH OF THE REEFS ON THE FORE-SHORE IMMEDIATELY N. OF THE FLAG-STAFF GULLY

small scale current bedding.

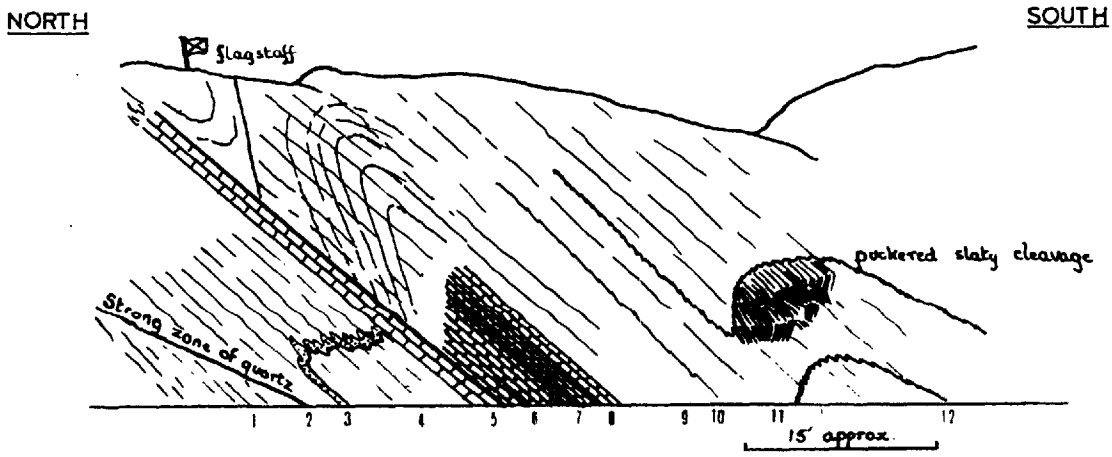
At the top of the limestone sequence are two bands of detrital limestone each about 1 foot thick. They are drag folded and separated by about 3' 6" of slates and thin slaty limestones. Unidentified bony fragments have been found in the upper of these two limestone bands; there are also traces of solitary rugose corals, but the specimens so far seen are too poorly preserved to be identified.

The detailed succession of calcareous beds has all the same elements as in the type locality at David's Stone. The overall thickness is similar though the 'twin bands' of limestone at the top of the sequence are markedly thicker. The lithological sequence at Hele is also very similar to that seen at Beacon Point and, although fossils are absent at the latter locality, it would be unreasonable not to correlate them.

Again, on Broadstrand Beach, the same sequence of limestone beds can be observed. There are minor differences chiefly the result of calcareous slates passing into slaty limestones, or vice versa. One interesting difference is the greater number of fossils occurring in the limestones at Broadstrand Beach.

The beach at Broadstrand is strewn with large limestone boulders which must have fallen from the cliff above; these are full of corals, stromatoporoids and bryozoa. Plate 17a shows one such boulder, and they suggest a reef-like development within the limestone at this point. Unfortunately the actual locality from which the boulders are derived is inaccessible.

Massive lumps of dolomite which occur about the middle of the limestone succession on Broadstrand Beach are similar to those observed near Rillage. The lumps are associated with a strong development of quartz, which is suggestive of a zone of fracture, but the limestone shows no marked anomalies beyond a local thickening as a result of



1) greenish-black slate
2) slate
3) grit
4) black slate
5) limestone – much quartz near the base.
6) flaggy limestone
7) flaggy limestone
8) slate and 1st – thin alternating bands
9) slate – dark and calcareous
10) limestone 1–2 ins. thick
11) slate with calcareous splinters
12) limestone about 1 in. thick

Fig. 33 FIELD SKETCH SHOWING THE STRUCTURE ALONG THE EASTERN WALL OF THE FLAG-STAFF GULLY

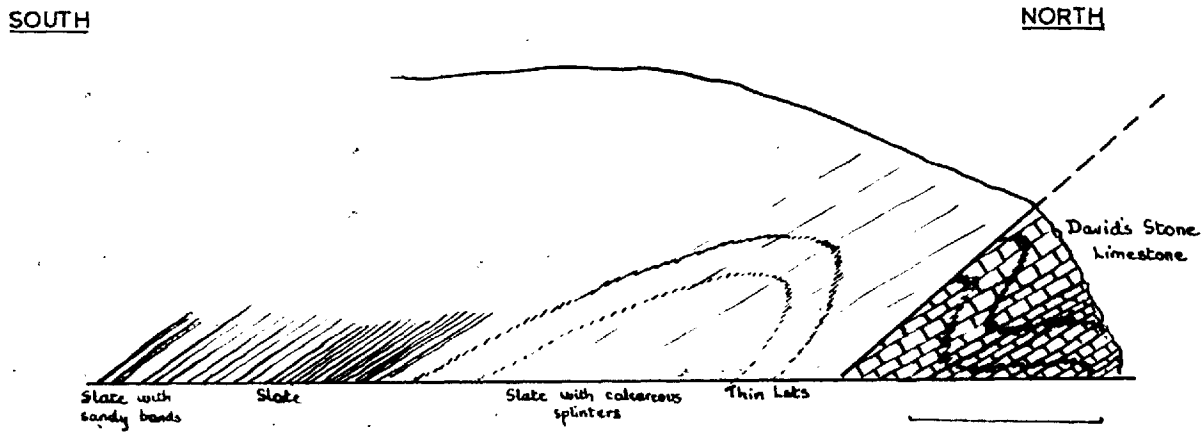


Fig. 34 FIELD SKETCH SHOWING THE STRUCTURE ALONG THE WESTERN WALL OF THE FLAG-STAFF GULLY

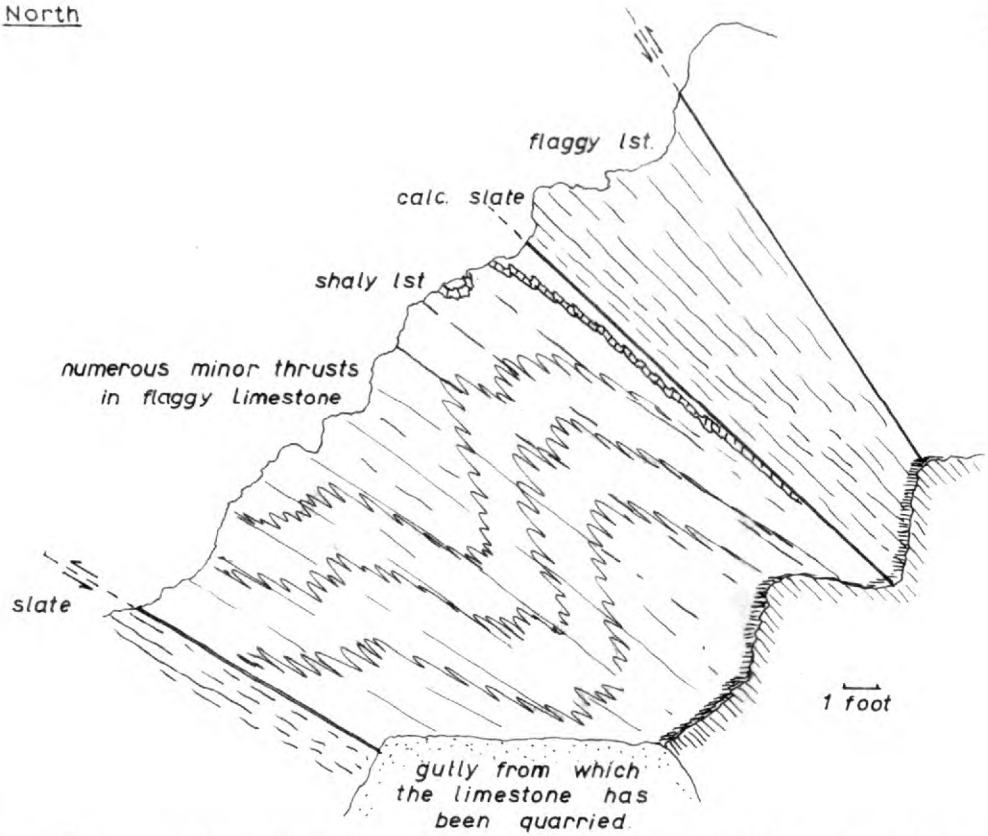


fig. 35 Field sketch showing folds in the David's Stone Limestone near Beacon Point



plate 16 Folded David's Stone Limestone near Beacon Point.

the dolomite, and if there is a zone of fracture, the displacement involved is likely to be very small.

D. CONCLUSIONS

The stratigraphical conclusions are summarized on the chart (fig. R2) which shows successions measured at localities between Combe Martin and Ilfracombe, and their correlation with each other. The columns show a generalized succession, since on the scale of 1 mm = 1 ft. it is not possible to show details of beds less than 1 ft. thick. The very thin detrital limestones, often no more than 1" thick, are shown as solid black lines and marked 'lst.'. The measurements, though carefully made, are not claimed as absolutely accurate: all beds are strongly cleaved and frequently folded, and in the absence of well-marked bedding it is impossible to be certain that the measurements were at right-angles to the stratification. In any case the frequent occurrence of quartz seams parallel to the bedding is indicative of bedding plane movement which may cause duplication or omission of small parts of the succession. Despite these limitations, it is considered that the table gives an accurate overall picture of correlations and represents, approximately, the true thicknesses involved.

The correlations are based on palaeontology, gross lithology, and local marker bands, all of which have been discussed in the preceding parts of this thesis. The dominantly arenaceous nature of the lower parts, and the calcareous succession in the middle parts, is emphasised by the colouring. The upper arenaceous division is not shown on the chart (except partially in the Hele Bay succession) as its main outcrop is to the West of the area mapped.

ie. the Lower Ilfracombe Beds

The lower arenaceous beds are tentatively correlated with the Hangman Beds (i.e. it is considered that they lie below the level of the Stringocephalus Limestone of Wild Pear Beach (Evans 1922)). This is based on the following evidence:-

1) The occurrence of Stringocephalus-like fragments in the topmost arenaceous beds of Widmouth and the Warren.
2) The abundant massive grits, seen at Widmouth, do not appear again between Combe Martin Bay and Wild Pear Beach and the succession exposed along this stretch is largely slates and calcareous slates (=Wild Pear and Lester Series).
3) The similarity of the Lester Series with the beds at Oakestor and Golden Cove (a similarity commented upon by Evans, 1929) which lie above the Widmouth Succession.
4) The similarity of sedimentary structures in the Widmouth succession and those seen in the Hangman Grits near the Little Hangman.

None of these factors is conclusive in itself, but the weight of evidence seems to be in favour of the correlation suggested.

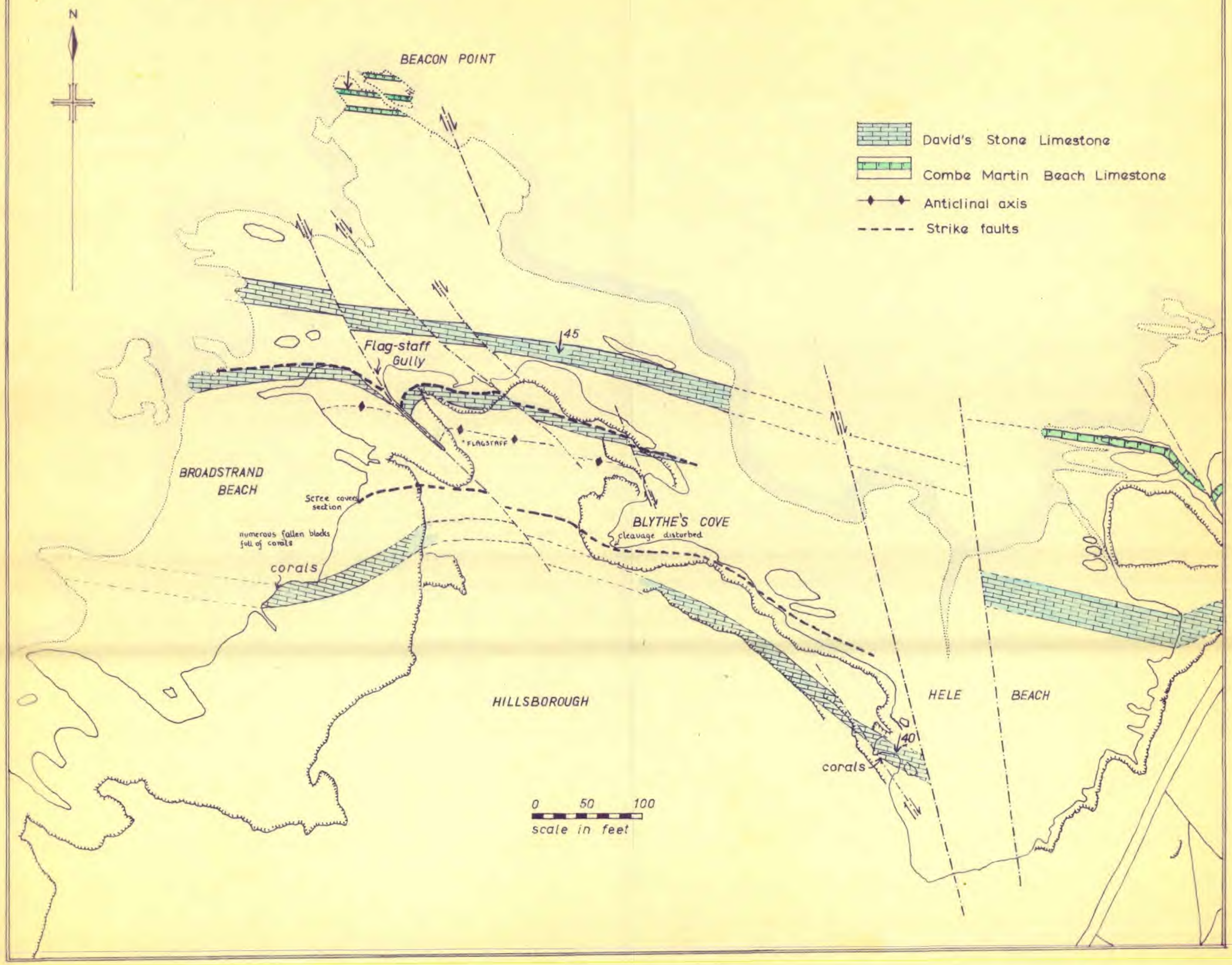
It is obvious from the chart that there are lateral variations both in lithology and in thickness of the individual units. In particular there appears to be a thickening of the succession to the East (cf. the succession at Hele Bay and at Newberry). However, the area covered by these observations is of limited extent and it would be unwise to draw major palaeogeographical conclusions. The transition from the arenaceous beds (partly litoral and partly continental in facies) at the base, into the limestones and slates of the middle part, must indicate a marine transgression into the North Devon area at this time, though sedimentation was never far from the litoral zone - this is inferred from the numerous very thin layers of limestone ($\frac{1}{2}$-2" thick) which consist largely of comminuted fossil fragments, mostly crinoid debris.

It seems likely that much of the deposition took place in a tidal mud-flat environment, and it was rarely possible for corals to establish themselves except when the water deepened slightly or possibly became less muddy. After the deposition of the David's Stone Limestone, there was a temporary retreat of the sea resulting in the arenaceous succession of the upper part of the Ilfracombe Beds, but a further deepening is indicated by the deposition of the Morte Slates. This interpretation is in close agreement with Webby's (1964) inferences from the successions in the Brendon and Quantock Hills.

The age of the Ilfracombe Beds has been discussed in one of the accompanying papers (Holwill 1962). The suggestions made then have been confirmed by a detailed investigation of the fauna, i.e. that the Jenny Start Limestone is Upper Givetian, and the David's Stone Limestone is Frasnian. No further evidence has been found to confirm the Couvinian/Lower Givetian age of the Hangman Grits, nor has it been possible to put a precise boundary between Middle and Upper Devonian Beds.

It has been clearly demonstrated that there are two important limestone developments within the Ilfracombe Beds and that these are not lenticular, though it would seem that they pass laterally into calcareous shales to the East of Combe Martin. The Jenny Start Limestone is thought to lie at the same horizon as the Roadwater Limestone of the Brendon Hills - this correlation is based on a close affinity of faunas; the lack of continuity of this limestone across North Devon and Somerset is suggested both by Webby's work and by the lack of limestone outcrops between Combe Martin and the Brendon Hills.

Fig. 36 THE GEOLOGY OF THE AREA AT BEACON POINT AND HILLSBOROUGH



PART III PALAEONTOLOGY

Introduction

Systematic palaeontological work on the Ilfracombe Beds of North Devon has been severely hampered both by the state of preservation of the fossils and by their relative sporadic occurrence. Most workers in the area have recorded fossils but only a few have attempted to give comprehensive lists and these have not included descriptions and illustrations of the fauna. It has thus been difficult and in some cases, impossible, to examine critically the recorded fauna, for many of the specimens to which the names were applied have been lost. Even where it has been possible to find original specimens, these are frequently part of beach pebbles (e.g. the Hall collection in the Barnstaple Athenaeum) and therefore not accurately located. With one exception, all the corals described and illustrated below, have been collected *in situ* by myself.

In this thesis only the coral fauna of the Ilfracombe Beds is described in detail. This is for two reasons: (i) corals are the most abundant element in the fauna; (ii) it is often possible to make use of mere fragments of whole corallites for systematic study, and it is rare that more than broken and distorted fragments can be obtained even with the most patient collecting.

To a large extent, the corals described substantiate previous records but many additional species and genera are added to those already known. Some genera have not been substantiated in this present study nor have I been able to find traces of them in museum collections. All the specimens labelled *Petraia* from the Ilfracombe

SPECIES	First recorded by:-	SUBSTANTIATED	REMARKS
A. RUGOSA			
Amplexus tortuosus Phillips	Valpy 1867		
Astraea helianthoides Goldfuss	Sedgwick and Murchison 1840		see Cyathophyllum helianthoides
A. hennahii Lonsdale	Sedgwick and Murchison 1840		probably Phillipsastraea hennahii; this species has not been identified, but the genus is common
Calceola sandalina (Linne)	Davidson 1864-7		
Cyathophyllum aequiseptatum Edwards and Haime	Edwards and Haime 1853	✓	Type specimen entirely recrystallized
C. boloniense (de Blainville)	Murchison 1872	✓	= Hexagonaria boloniense
C. caespitosum Goldfuss	Sedgwick and Murchison 1840	✓	= Thamnophyllum caespitosum
C. damnoniense (Lonsdale)	Phillips 1840	?	a fragment, probably referable to Mesophyllum damnoniense has been found
C. hallii Edwards and Haime	Etheridge 1867	?	= Heliophyllum hallii. Some forms of Cylindrophyllum are similar
C. helianthoides Goldfuss	Evans 1919	✓	a specimen in the Hall Collection has been referred to this species; its locality is uncertain as it occurs in a beach pebble; it is a species of Mesophyllum
C. obtortum Lonsdale	Hall 1867	?	this species is close to Stringophyllum turbinatum sp. nov.
C. quadrigeminum (Goldfuss)	Sedgwick and Murchison 1840		a species of Hexagonaria close to H. boloniense
Cystiphyllum vesiculosum (Goldfuss)	Evans 1919		very close to Cystiphylloides corneolum.(See systematic section)
Endophyllum bowerbanki Edwards and Haime	Evans 1928	✓	see qualifying note in systematic section
Hallia pengelliyi Edwards and Haime	Etheridge 1867		very close to some forms of Stringophyllum described below
Heliophyllum halliii(Edwards and Haime)	Etheridge 1867		see Cyathophyllum hallii above
H. helianthoides (Goldfuss)	Evans 1919		see Cyathophyllum helianthoides above
Petraia celtica Lonsdale	Valpy collection		specimen in the British Museum (Nat.Hist.) - it is a species of Syringaxon
P. bina M'Coy	Valpy 1867	?	the name Petraia has almost certainly been applied to all small solitary corals irrespective of their internal structure; all that have been studied in this present work belong to the family Laccophyllidae
P. pleuriradialis	Valpy 1867		
P. sp.	Valpy 1867		
P. sp.	Evans 1929		
Strombodes vermicularis Lonsdale	Phillips 1841		=Cyathophyllum obtortum - see comment above
B. TABULATA			
Favosites cervicornis (de Blainville)	Etheridge 1867	✓	=Thamnopora cervicornis
F. fibrosa Edwards and Haime	Phillips 1841		
F. polymorpha (Goldfuss)	Phillips 1841	✓	=Thamnopora polymorpha
Helioiites porosus Goldfuss	Etheridge 1867		
Alveolites suborbicularis Lamarck	Etheridge 1867	✓	
Favosites dubia Edwards and Haime	Etheridge 1867	✓	=Thamnopora dubia
Michelinia antiqua (M'Coy)	Valpy 1867	?	=?Pleurodictyum sp. recorded in Evans 1929. A single specimen of Pleurodictyum from the British Museum is figured below; it cannot be identified specifically
Syringopora sp.	Valpy 1867		
Cladochonus sp.	Valpy 1867	?	probably a synonym of Aulopora figured below

Beds in the collections are in fact species of Syringaxon, Metriophyllum or Barrandeophyllum.

A list of all corals recorded from the Ilfracombe Beds of North Devon, together with the author who first recorded them is shown on the accompanying sheet. (Page 115.)

It is significant that this fauna, with two exceptions, was recorded before 1870 and the vast majority of the corals are identified with species figured by Edwards and Haime (1853). Since this time, study of internal structures with the aid of thin sections has resulted in a finer subdivision of coral taxa; this is considered the main reason why there is not greater agreement between the fauna recorded in the literature and that described below.

51 species (20 of them new) are described in the following section, and they have been referred to 23 genera. The proportion of new species is high, but most of them belong to the Rugosa and in particular to the Metriophyllidae (10 new species). No species of Syringaxon and only one of Barrandeophyllum have been recorded from Devonian rocks nearer than Bohemia, and there is little in common between the rich reef faunas of South Devon and those from the Ilfracombe Beds. The modern revision of the Belgium tabulate corals by Lecompte has greatly facilitated my own study and, in fact, only two new species of tabulate coral have been found.

Below is a complete list of the coral fauna. It is noteworthy that very few genera and only two species are common to both the Jenny Start Limestone (Givetian) and the David's Stone Limestone (Frasnian). This is particularly significant when distinguishing between the two limestones in the field since their general appearance and thickness is almost identical.

	RILLAGE LST.	JENNY START LST.	COMBE MARTIN BEACH LST.	DAVID'S STONE LST.
Acanthophyllum (Acanthophyllum) zonatum sp. nov.		X		
Alveolites suborbicularis Lamarck		X	X	X
A. suborbicularis Lamarck forma gemmans		X		
A. multiperforata Lecompte		X		
A. sibiricus Lecompte		X		
Amplexiphyllum spinum sp. nov.			X	
Aulopora tubaeformis Goldfuss				X
Banffia confluens (Stewart)				X
Banffiphyllum intervallum sp. nov.			X	
B. newberriense sp. nov.			X	
B. cf. symmetricum (Frech)				X
Billingsastraea cf. devonense Edwards and Haime		X		
Chaetetes lonsdalei Etheridge and Foord				X
C. multitabulatus sp. nov.				X
C. cf. rotundus Lecompte				X
Coenites escharoides (Steininger)		X		
C. caudatus Lecompte				X
C. sp.		X		
Cylindrophyllum cf. elongatum Simpson		X		
C. inaequalis sp. nov.		X		
C. stonehousense Taylor		X		
Cystiphylloides corneolum (Wedekind and Vollbrecht)		X		
Disphyllum goldfussi (Geinitz)		X		
D. hagginsonense sp. nov.		X		
Endophyllum abditum Edwards and Haime		X		

	RILLAGE LST.	JENNY START LST.	COMBE MARTIN BEACH LST.	DAVID'S STONE LST.
Entelophyllum samsoni sp. nov.		X		
Hexagonaria boloniensis (de Blainville)		X		
Meniscophyllum crescentum sp. nov.			X	
Mesophyllum (Hemicosmophyllum) irregularum sp.nov.		X		
Metriophyllum lituum Holwill			X	
Phillipsastraea cripta sp. nov.				X
P. sola sp. nov.		X		
Pleurodictyum sp.			X	
Stringophyllum carinatum sp. nov.		X		
S. turbinatum sp. nov.		X		
Syringaxon forte sp. nov.				X
S. geniculata sp. nov.			X	
S. grandis sp. nov.				X
S. grossa sp. nov.		X		
S. latiseptata sp. nov.			X	
S. parva sp. nov.			X	
S. rota sp. nov.			X	
S. cf. smithi Pfantl				X
Thamnophyllum caespitosum (Goldfuss)		X		
T. sp.		X		
Thamnopora boloniensis (Gosselet)		X		
T. cervicornis (de Blainville)	X		X	
T. cronigera (d'Orbigny)		X		
T. dubia (de Blainville)		X		?

	RILLAGE LST.	JENNY START LST.	COMBE MARTIN BEACH LST.	DAVID'S STONE LST.
T. dubia (de Blainville)		X		?
T. irregularis Lecompte		X		
T. polymorpha (Goldfuss)				X
T. tumefacta Lecompte				X

Techniques

Some of the techniques used are described in the paper (Holwill 1964) which is submitted as part of this thesis. In the field it was rarely possible to collect complete corals; most were dug out from wave-smoothed surfaces of hard limestone by patient work with a hammer and chisel. Because of the distorted and fragmented nature of most of the material, special care was needed when sectioning them and this work was done by the writer using a diamond dental cutting wheel, and a home-made apparatus (Plate 15). The great advantage of this apparatus over any marketed commercially was that the revolving saw, adjustable to any angle, could be moved through the stationary specimen (instead of vice versa).

Recrystallization of the skeletal material of the coral made the use of peels a poor substitute for sections, and polished surfaces were often found preferable to thin sections since they give a greater depth of vision into the skeletal structure.

SYSTEMATIC DESCRIPTIONS

Order RUGOSA

Sub-order STREPTELASMATINA

Super-family ZAPHRENTICAE

Family ARACHNOPHYLLIDAE Dybowski 1873

Sub-family ARACHNOPHYLLINAE Dybowski 1873

Genus Entelophyllum Wedekind 1927

For generic description see Hill 1940c

Entelophyllum samsoni sp. nov.

Plate 35, figs. 1,2; Text figs. 37,38

~~Plate 36, fig. 1~~

Holotype: 11.2 from the Jenny Start Limestone of Samson's Bay, near Ilfracombe, North Devon.

Paratype: 14.94 from Jenny Start Limestone of Rillage Point.

Diagnosis: Entelophyllum in which both major and minor septa are thickened at the inner edge of the dissepimentarium and again at the periphery where the wedge-like dilation of the septa results in a peripheral stereozone. Epitheca is thin. Major septa barely reach the axis and have slightly rhopalcid ends. Carinae are developed particularly near the peripheral ends of the septa. Tabularium wide with large horizontal tabulae.

Description: The corallum has a trochoid form and tapers from a diameter of 24 mm. to one of 15 mm. in a length of 34 mm. There are twenty-six septa of each order at a diameter of 24 mm; all the septa are dilated at the periphery and the wedge-like thickening causes the septa to be laterally in contact, thus forming a narrow stereozone. The major septa do not reach the axis but are usually flexed at their axial ends and are slightly rhopaloid; they are strongly thickened at the inner margins of the dissepimentarium but are not contiguous with the minor septa. The minor septa are irregular in length but the majority extend just beyond the inner margin of the dissepimentarium and the axial ends are frequently sharply bent so that they join the adjacent major septum (fig. 37). The minor septa also show slight thickening at the inner margins of the dissepimentarium. Near the periphery, both orders of the septa are thin, irregularly bent and carinate. There is an outer set of very globose dissepiments and an inner group which are more elongated (i.e. less globose) and steeply inclined; there are occasional lateral dissepiments. The tabulae are downturned at their axial edges and have a slight median depression; they are closely spaced but occur in groups; the majority extend the whole way across the tabularium. The tabularium occupies just over one third the diameter of the corallite; (in earlier growth stages the tabularium occupies a greater proportion of the total diameter).



Fig. 37 Freehand drawing (based on the holotype) showing the form of the septa in E. samsoni

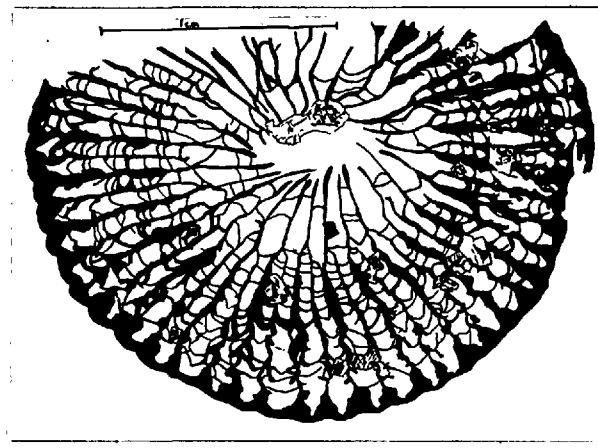


Fig. 38 E. samsoni. Transverse section of the holotype (from a photograph) Crystals of dolomite have developed, partially destroying the original structure of the corallite.

Discussion: Entelophyllum has hitherto been recorded only from Silurian rocks - mainly Upper Wenlock and Ludlow. It is thus with some caution that I have placed the North Devon specimens in this genus; however, they possess all the characteristic features of the genus and so I consider that its range must be extended at least into the Middle Devonian. Pocta (1902) has, in fact, recorded a species from Siluro-Devonian transition beds in Bohemia.

E. samsoni differs from other species of the genus mainly because of its strongly dilated septa which in transverse section are suggestive of Acanthophyllum; the zig-zag septa, the strong carinae, and above all, the broad horizontal tabulae, clearly separate it from this latter genus. Hill (1940c) has made an interesting observation on the septal dilation in Entelophyllum; she found that the same species shows much greater dilation in shaly beds than in limestone beds;

the North Devon species occurs in a shaly limestone and the dilated septa may possibly be an ecological adaption.

Most forms of Entelophyllum are fasiculate but Hill (1940c) records a solitary variety from the Yass-Bowning District of New South Wales; this occurs stratigraphically higher than the fasiculate ones though both are in Upper Silurian rocks. Only broken fragments of of E. samsoni have been recovered but all suggest that it was a solitary form.

Family LACCOPHYLLIDAE Grabau 1928

Syringaxonidae Hill 1939a

Amplexocarininae Soshkina 1941

Family description: Small solitary rugose corals with the axial ends of the major septa uniting together to form an aulos, or 'stereotheca' (Grabau 1928). Minor septa may be present. Tabulae consist of two series: those within the aulos which are horizontal and usually complete, and those which occur between the aulos and outer wall; the latter slope outwards and downwards. True dissepiments are absent. The aulos may be formed by thickening of the inner ends of the septa (as in Syringaxon siluriensis) or by deflection of the axial ends of the septa (as in S. depressa).

Included genera from the Ilfracombe Beds (Middle and Upper Devonian) of North Devon:

Syringaxon Lindström 1882

Barrandeophyllum Počta 1902

Range: Silurian - Permian.

Genus SYRINGAXON Lindström

Syringaxon Lindström 1882, p.20

Laccophyllum Simpson 1900

Alleynia Počta 1902

Syringaxon Butler 1935

Type species: (by monotypy) Cyathaxonia siluriensis McCoy 1850, p.281, and 1851, p.36.

Horizon and locality of type species: Silurian (Upper Ludlow), Underberrow, Kendal, Westmoreland.

Generic description: (Butler 1935) "Small simple conical or cylindrical Rugose corals in which the axial ends of the major septa are dilated and laterally contiguous forming an inner wall or aulos. The tabulae, which are few in number and irregularly spaced, are divided by the aulos into an inner and outer series; the inner tabulae are flat or slightly depressed; the outer tabulae vary in form, but generally slope upwards from the epitheca to the aulos. Dissepiments are absent. Stereome is usually abundant and cements the axial ends of the minor septa to the sides of the major septa."

Remarks: When Lindström (1882) erected this genus he gave no diagnosis or description and it remained imperfectly known until Butler (1935) published his description. The genus is very closely allied to Barrandeophyllum and some authors (e.g. Grabau 1928, Pranti 1938) have suggested that Syringaxon was the direct ancestor of Barrandeophyllum, but that during the Devonian they existed side by side representing diverging types of the same stock.

The precise distinction between Syringaxon and Barrandeophyllum is difficult to establish from the existing literature. Butler's (1935) description of Syringaxon differs in only two respects from that of Barrandeophyllum given by Pocta (1902); in the latter genus, stereoplasm is said to be thin or completely absent, and dissepiments may or may not be present. Grabau (1928), however, is unable to regard the presence or absence of stereoplasm as of generic value; instead, he differentiates the two genera by the fact that in Barrandeophyllum the aulos widens more rapidly and is usually imperfectly formed - being

either elliptical or broken at one or more points. Prantl (1938) and Stumm (1949) concur with this view.

Hill (1939a, 1956a) emphasises the importance of stereoplasmic thickening in Syringaxon, in contrast to Barrandeophyllum, in which there is little or no thickening. She also mentions (1956a) that in Barrandeophyllum the septa and aulos are thin and that the aulos is commonly imperfect.

It is obvious that the two genera are morphologically very similar, and if, as suggested by Grabau and Prantl, Barrandeophyllum represents an off-shoot from Syringaxon it is to be expected that initially there must have been a complete gradation of morphology between the two genera. In general, however, the two forms appear sufficiently distinct to be separated. In the following descriptions, all forms with complete aulos and noticeable stereoplasmic thickening are referred to Syringaxon, and those with more slender (and usually more numerous) septa, incomplete aulos, and little or no stereoplasmic thickening, to Barrandeophyllum.

In the type species (of Syringaxon) the aulos is formed entirely by the dilation of the axial ends of the septa, and this mode of formation for the aulos is implicit in Butler's generic description. However, Prantl (1938) included within the genus forms in which the aulos was formed by a deflection of the axial ends of the septa in addition to their dilation - 'In S. memorabilis ... and also in S. depressa the aulos is formed by some slight thickening and by the bending of the axial ends of the major septa.' (Prantl 1938, p.19)

The aulos ratio: It is desirable to have some value for the size of the aulos and it has been found convenient in the following descriptions to express the size as a ratio of the whole diameter.

i.e. $\frac{\text{Diameter of aulos}}{\text{Diameter of coral}}$ = Aulos ratio

In making these measurements the diameter of the aulos is taken as the inside diameter, while the diameter of the coral is the maximum diameter at the same level. If the coral has been distorted so as to become elliptical in transverse section, the mean of the maximum and minimum diameters has been taken, though theoretically, provided the aulos diameter and total diameter are measured along the same line, the ratio will be constant.

The question arises as to the validity of this ratio as a specific characteristic. Unfortunately no perfect specimens have been obtained from North Devon, nor are the broken fragments abundant enough to make the statistical study which would be necessary to decide what percentage variation in the aulos ratio is of specific significance. Observations on the larger fragments suggest that the ratio is constant in the mature corallites of any one species; in earlier ontogenetic stages it may be more variable. In the following descriptions the aulos ratio is used as a descriptive measurement and it does not necessarily imply a specific characteristic.

Sclerenchyme v. stereome or stereoplasm: In the glossary of morphological terms compiled by Moore, Hill and Wells (Hill 1956) the implication is that stereome is the deposit of calcareous tissue resulting in the thickening of some part of the coral; sclerenchyme is also used in the same sense but it may also refer to the normal unthickened calcareous tissue of corals. The former term is applied by the authors to the Scleractinia and the latter to the Rugosa. However, Smith and Lang (1930) used 'stereome' to describe thickening in certain Rugose corals. 'Stereoplasma' was used by

Lindström (1876, p. 30) to describe what he erroneously regarded as secondary dilated tissue in the primary septa. In subsequent descriptions, the term 'stereoplasm' is used in the sense intended by Lindström - to describe secondarily deposited calcite which results in the thickening of some part of the coral skeleton.

Nicholson and Etheridge (1880) noted that the parts of a coral in which stereoplasm had been most thickly deposited were the parts which tended to become weathered most rapidly so that they frequently found only moulds of those parts which had been thickened. A similar thing is noticeable in the North Devon rocks, only here it seems that the thickened tissues are recrystallised much more readily and what once was a septum thickened by stereoplasm is now only a thin septum surrounded by recrystallised material.

Syringaxon foste sp. nov.

Plate 30, figs. 3, 4

Holotype: 6.2 from the David's Stone Limestone at David's Stone near Combe Martin, North Devon.

Diagnosis: Small solitary corals with a diameter of about 4-5 mm. 16-18 septa are developed at this diameter, and the aulos is formed by the sharp bending of their axial ends. The outer wall is thick.

Description: The holotype is a broken fragment about 3 mm. long. It has an aulos ratio of about 0.3. In the transverse polished section some of the tabulae are seen; these suggest that the tabulae are regularly spaced. Specimen 6.8 from the same bed shows a juvenile form with only fourteen septa and a much thickened aulos.

Remarks: S. forte is similar to S. geniculata in having a thick outer wall and strong septa, but it has fewer septa, a smaller aulos and is much smaller in overall size.

Syringaxon geniculata sp. nov.

Plate 30, figs. 1,2,7
Plate 31, fig. 3
Plate 32, fig. 5

Holotype: Specimen 5.6

Horizon and locality: The Combe Martin Beach Limestone (Lower Frasnian), The Parlour, Combe Martin.

Diagnosis: Solitary corals with a maximum diameter of about 10 mm. 20 septa are developed at this diameter. An aulos is formed partly by thickening of the septa but principally as the result of a sharp geniculate deflection of the septa at their axial ends. The aulos ratio is about 0.5. Tabulae are of two types: those within the aulos are complete or commonly extend at least two-thirds of the way across the aulos; the tabulae are thin and about 0.5 mm. apart. The tabulae outside the aulos are more widely spaced and slope downwards and outwards. The outer wall is thick and the calyx is deep and steep sided.

Description: The recovered part was 12 mm. long; it had a circular cross-section with a diameter of 8 mm. The diameter remains constant over this length so that the form of the adult corallite is presumed to be cylindrical. The calyx, seen in section, is 4 mm. deep with steep sides (Plate 30, fig 2). The outer wall is thick, averaging over 1 mm. The aulos occupies about half the diameter of the lumen and is regularly circular; it is formed in part by the sharp flexure at the axial ends of the septa as well as by slight septal thickening.

The aulos may occasionally be broken when one septum does not completely abut against its neighbour. A suggestion of a phyllotheca (Grabau 1920) is seen in plate 30, fig.7, but this is the effect of the section cutting through part of a central tabula.

20 septa are present in the holotype, all of which reach the aulos; they are thin and slightly flexed; they thicken just before reaching the outer wall and also at the aulos. Slight bulges in the peripheral wall between the septa suggest the possibility of incipient minor septa. The septa may have a slight swelling where they meet the outer series of tabulae. The tabulae within the aulos are sometimes complete, in which case they are horizontal or slightly depressed at the centre; the majority, however, extend about two-thirds of the way across the aulos and are slightly convex upwards. About 8-10 tabulae occur in the space of 5 mm. and they are approximately equidistant.

The tabulae occurring between the aulos and the outer wall are inclined downwards towards the periphery; they are usually straight but may be slightly depressed towards the proximal end; these peri-axial tabulae are very thin and barely discernible in transverse sections; there are sometimes additional vertical plates close to the aulos wall.

Between successive tabulae, the diameter of the aulos increases slightly, but returns to approximately the original diameter before continuing between the next pair of tabulae; this gives the wall of the aulos a very irregular appearance when seen in longitudinal section, even although the mean diameter remains constant (see Plate 30, fig.1).

Discussion: This is the most common species of Syringaxon in the Combe Martin Beach Limestone; it resembles S. bohemica bohemica Prantl but the North Devon species has more septa, and appears to

be lacking a minor series (though see remarks above); the tabulae are also more regular in S. geniculata. The aulos is formed in a similar way to that of S. memorabilis Prantl, but this latter species has fewer septa and more closely packed tabulae.

Syringaxon grandis sp. nov.

Plate 31, figs 1,7

Holotype: Specimen 15.7

Horizon and locality: The David's Stone Limestone (Frasnian), Hele, near Ilfracombe.

Diagnosis: Turbinate solitary corals; diameter reaching 15 mm. at the distal end; at this diameter there are 24 septa which are straight or only slightly flexed; they are radially arranged and their axial ends are much thickened so that neighbouring septa are in contact, thus forming an aulos; the peripheral ends of the septa are slightly thickened before reaching the thick outer wall. The aulos is complete and regular; aulos ratio about 2.5. The tabulae within the aulos are usually complete and horizontal but occasional ones bifurcate; about 10 tabulae occur in 5 mm., but they are irregularly spaced. The outer tabulae slope downwards and outwards at about 45° to the aulos wall; they are more widely spaced than those within the aulos. Additional small globose plates occur between these outer tabulae close to the aulos wall.

Description: No complete specimens have been obtained; the holotype is a fragment about 5 mm. long and embedded in an argillaceous limestone. Paratype specimens show the turbinate form of the coral

and suggest that the full length of the mature corallite would be 20-30 mm. The outer wall is 1.5 mm. thick and there is no evidence of minor septa. The bifurcation of the central tabulae takes place about two-thirds of the way across the aulos with the result that the split portions are no longer horizontal but are flexed up or down. The axial ends of the septa are not deflected but are thickened at their axial ends to form a stereotheca as in the type species.

Discussion: S. grandis is similar to S. major (Pocta). Both have 24 major septa and are of similar size and form. However, S. major has minor septa developed together with dissepiments. No sections are given with Pocta's (1902) original description so that it is not possible to see whether the dissepiments he mentions are comparable with the small globose plates which occur around the aulos in S. grandis. S. major is a Silurian genus and it seems advisable to treat the North Devon form as a separate species until more precise comparisons can be made with S. major .

S. grandis differs from S. latiseptа in having fewer and thinner septa, by the absence of incipient minor septa and by having a larger aulos ratio.

Syringaxon grossa sp. nov.

Plate 32, figs 3,4,7

Holotype: 14.104

Horizon and locality: Jenny Start Limestone (Givetian) of Rillage Headland, near Ilfracombe, North Devon.

Diagnosis: Syringaxon in which the aulos is formed by the axial

thickening of the septa. The tabulae within the aulos are stout and are concave downwards; those between the aulos and the outer wall are slender and slope steeply downwards and outwards. Rejuvenescence may occur.

Description: The specimen has a maximum diameter of 7 mm. and an aulos ratio of 0.35. It has been cut so as to reveal two transverse sections and a longitudinal section. There are 21 septa at the maximum diameter; these are much thickened at their axial and peripheral ends though some thickening also affects their central parts. All the septa are straight or only slightly flexed and the unbroken aulos is formed entirely by the thickening of their axial ends. In the longitudinal section it is possible to see rejuvenescence; this is the only species of Syringaxon in which it has been recorded. Tabulae within the aulos are nearly always complete; those between the axis and outer wall are thin and much more numerous. There are no dissepiments.

Remarks: Only three specimens of Syringaxon have been found in the Jenny Start Limestone despite the fact that the limestone contains an abundance of corals at most localities. All the specimens are referable to S. grossa. Webby (1964) has recorded a species of Syringaxon from the Roadwater Limestone (=Jenny Start Limestone) of West Somerset, but this differs from S. grossa in having the aulos formed by the bonding of the septa.

Syringaxon latiseptа sp. nov.

Plate 30, fig 6.
Text fig. 39,a,b,c.

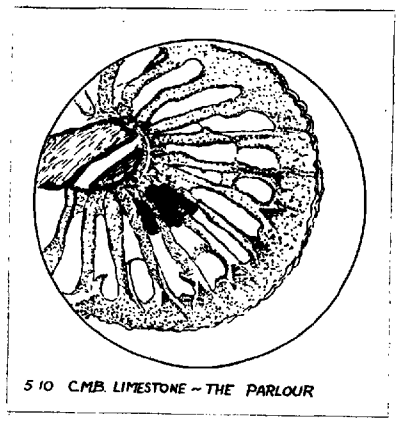
Holotype: Specimen 5.10

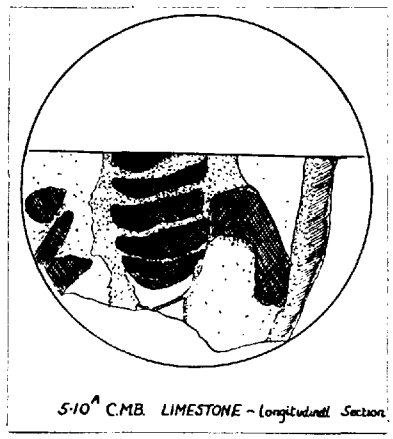
Paratypes: Specimens 2.13, 6.9, 4.3.

Horizon and locality: The Combe Martin Beach Limestone (Lower Frasnian) at Combe Martin.

Diagnosis: Solitary corals with about 26 stout septa developed at a diameter of 13 mm. The septa are swollen at their axial ends so that neighbouring ones are in contact, forming an aulos or 'stereotheca' (Grabau 1928). The aulos is complete and occupies about one-third the diameter of the corallite. No dissepiments are present. The corallite wall is much thickened by stereoplasm. Very short minor septa are present, but are embedded in the peripheral stereoplasm. Tabulae within the aulos are usually complete and are saucer-shaped. About five irregularly spaced tabulae occur in a distance of 5 mm. The tabulae outside the aulos slope steeply downwards towards the outer wall.

Description: The holotype is a broken fragment 5 mm. in length and embedded in limestone. The diameter of the specimen shows little variation over this distance, suggesting that the mature corallite had an approximately cylindrical form. The transverse section is slightly ovoid with the major axis measuring 13 mm. and the minor one 10 mm. (This may be the result of compression on a truly circular section since the rocks in North Devon are severely contorted). The epitheca is for the most part absent, but at one place it appears to be preserved and the crenulations in the transverse section would indicate marked longitudinal grooves; these grooves correspond to the positions of the major and minor septa. The specimen has been partially dolomitized and this has obscured parts of the structure, particularly in the neighbourhood of the counter cardinal septum.





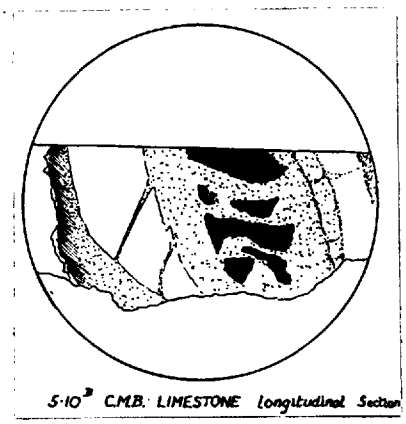


Fig 39 S. latiseptata. Freehand drawings of the holotype from polished sections
(a) Transverse section
(b) (c) Longitudinal sections

However, the septa on either side of the counter septum appear thinner than the others and this suggests that they may be accelerated minor septa comparable with those described in the type

species (Butler 1935). The inner wall of the aulos is strengthened by a deposit of stereoplasm. An appearance of dissepiments is suggested where the section has cut through the outer sloping series of tabulae which sometimes show a marked flexure just before reaching the wall of the aulos (see Text fig 39b).

Discussion: In the formation of the aulos and in the stereoplasmic thickening, this specimen resembles the type species, but it is considerably larger and has more septa. S. latiseptata most closely resembles S. bohemica bohemica from the Daleje shales (gβ) of Bohemia (Frantl 1938) but it differs in having a greater number of septa and a weaker development of minor septa.

Syringaxon parva sp. nov.

Plate 30, fig.8

Holotype: Specimen 4.6.

Horizon and Locality: The Combe Martin Limestone (?Lower Frasnian) The Parlour, Combe Martin.

Diagnosis: Solitary rugose corals with a diameter of about 6 mm. At this diameter there are 16 major septa, which are thickened at the axis and are laterally in contact, thus forming an aulos. The septa thicken again towards the periphery and are embedded in a thin peripheral stereozone. The outer wall is thick and the aulos relatively small (aulos ratio 0.2).

Description: The specimen is embedded in limestone and the recovered fragment is 4 mm. long. The diameter of the corallite does not change over this length nor does the number of septa. The polished transverse section is approximately circular. Much of the outer wall is

recrystallised but it is possible to see the peripheral stereozone clearly. The outer wall is about 1 mm. thick. The aulos is complete and there is a possibility that it is formed by a sharp bending of the septa at the axis in addition to the thickening. The aulos is not circular in the holotype but this is the result of tectonic pressures distorting the corallite.

It has not been possible to cut a longitudinal section from the holotype but there is evidence in the transverse section of an outer series of thin, irregularly spaced tabulae.

Discussion: S. parva most closely resembles S. inopinata (Frantl). However, Frantl's species is smaller and has fewer septa. It has a smaller aulos ratio than any of the other species from North Devon.

Syringaxon rota sp. nov.

Plate 30, fig 5

Holotype: Specimen 5.11.

Horizon and locality:(of holotype): The Combe Martin Beach Limestone (Lower Frasnian)

Paratype: Specimen 13.20

Horizon and locality of paratype: The Combe Martin Beach Limestone of Haggington Beach, near Ilfracombe.

Diagnosis: Small solitary corals with 18-20 septa developed at a diameter of 5 mm. Septa are thin and straight or only slightly flexed; they are thickened at their axial ends and are laterally in contact, thus forming the aulos. The aulos is unbroken and regular; its inner wall is reinforced with a thin deposit of stereoplasm; aulos ratio 2.5.

The outer wall is thick. The central tabulae are horizontal or very slightly concave; they are thin, but thicken just before reaching the outer wall; spacing is irregular. The outer tabulae are few and also nearly horizontal.

Discussion: The one short septum see in Plate 30, fig 5, is not considered a characteristic feature of this species; in longitudinal section this septum can be seen extending to the aulos at a slightly lower level and it is, therefore, most likely to be an individual pathological peculiarity.

Syringaxon cf. smithi Frantl

Plate 31, figs. 4,8

Horizon and locality: The David's Stone Limestone (Frasnian) of Sandy Bay and Broadstrand, near Ilfracombe, North Devon.

Diagnosis: Small solitary corals with a maximum diameter of about 4.5 mm. Twenty septa are developed at this diameter; they are thickened at their axial ends and are laterally in contact, thus forming an aulos. Aulos ratio 0.4. The outer wall is moderately thick.

Description: The specimen is only an imperfectly preserved fragment from which it has only been possible to cut a transverse section; the nature of the tabulae is, therefore, unknown. However, sections through some of the outer tabulae are seen on the transverse polished surface and these suggest that the tabulae are thin and irregularly spaced. The septa show a slight tendency towards a pinnate arrangement. The aulos is broken in one place as a result of

recrystallisation.

Discussion: The North Devon species agrees with S. smithi in most respects, though the indifferent preservation of the former makes precise identification impossible. The tapering of the septa towards the periphery is not seen in the North Devon species and they are somewhat stouter in the latter. There are two thinner septa which reach the aulos at one point and these may represent the counter lateral minor septa mentioned in Prantl's description; there is no evidence of any other minor septa being present.

Prantl's species is recorded from the Hlickov Limestone, horizon $g\alpha_2$. The North Devon form is thought to occur at a higher level near the Givetian/Frasnian boundary.

Genus BARRANDEOPHYLLUM Pocta

Barrandeophyllum Pocta 1902, p.109
Retiophyllum Pocta 1902, p.180

Type species: (by monotypy) Barrandeophyllum perplexum Pocta 1902, p.192; text figs 9,10; plate 108, figs 4,5,7,13,19. G_2 (Couvinian), Hlüboçep, Bohemia.

Diagnosis: Simple rugose corals with a deep calice and an aulos less perfectly developed than in Syringaxon and little or no stereoplasmic thickening. The aulos widens rapidly in diameter from the apical end. Horizontal tabulae occur within the aulos and downward, outward sloping tabulae between the aulos and outer wall.

Remarks: Pocta distinguished between Barrandeophyllum and Syringaxon largely by the absence of stereoplasm in the former genus. He also remarked that dissepiments are sometimes strongly developed though

they may be completely absent. Busch (1941) recorded dissepiments in B. reimanni and Hill (1954) noted them in B. cavum, but they are by no means common and certainly not typical of the genus. The aulos is often oval in transverse section and may be broken; it may also be penetrated by one of the septa - a feature never observed in Syringaxon. The type species has minor septa, but Hill (1939) has included within the genus forms lacking minor septa; with this I agree since at least one species from North Devon is without minor septa.

The calice is deep and the length of the septa diminishes rapidly above the calicular floor where the aulos is undeveloped. The aulos is formed in part by the expansion of the inner ends of the septa, but may also be caused by a deflection of the axial ends of the septa; (this is well shown in the type species - Pocta 1902, pl.108, figs 5,13).

I have followed Hill (1939,1956) in including Retiophyllum as a synonym of Barrandeophyllum; this would seem justified from the figure given by Pocta (1902, pl.108, fig 6), which shows the imperfect aulos. There is an irregular cystose structure developed on one side of the coral which Stumm (1949) suggested was the result of the coral growing on its side: since, as Pocta himself (1902) observed, the internal structure is essentially similar to that developed in Nicholsonia (Syringaxon) and Barrandeophyllum, the significance of the cystose structure is probably unimportant except at species level.

The genus is typical of the Middle and Upper Devonian.

Bamandeophyllum intervallum sp. nov.

Plate 32, figs 2,8,9

Holotype: Specimen 5.9

Paratypes: Specimens 5.5 and 5.8

Horizon and locality: Combe Martin Beach Limestone (Frasnian) of The Parlour, near Combe Martin.

Diagnosis: Small solitary corals. Maximum diameter 6-8 mm. Aulos is small (ratio 0.2). There are 16 major septa at a diameter of 6 mm; they are straight or only slightly flexed and are thickened both at the periphery and at the axis; they are not laterally in contact except where joined by tabulae. Peripheral tabulae are numerous and regularly spaced (about three in 1 mm.). Axial tabulae complete and the aulos is completed by their down-turned outer edges. Outer wall moderately thin. There is an incipient development of minor septa.

Remarks: In size and number of outer tabulae B. intervallum resembles B. cf. perplexum, but differs in having only sixteen septa at the same diameter and a smaller, more regular aulos. The septa are also thicker and straighter in the present species.

Bamandeophyllum newberriense sp. nov.

Plate 31, figs. 2,5,10,11
Text fig. 40

Holotype: 5.7

Horizon and locality: The Combe Martin Beach Limestone (Lower Frasnian), West end of Newberry Beach, near Combe Martin, North Devon.

Paratypes: 13.46, 13.26

Horizon and locality: The Combe Martin Beach Limestone on West Hagginton Beach.

Diagnosis: Small solitary corals with an irregularly formed aulos. Aulos ratio about 0.3

22 septa are present at a diameter of 6 mm; these are moderately thin but show slight thickening at both their peripheral and axial ends. The septa are not laterally in contact except where they are joined by tabulae. Tabulae within the aulos are horizontal or slightly convex; most of them extend the whole way across the aulos but others may curve down to join the preceding tabulae before reaching the aulos wall. Tabulae outside the aulos numerous, sloping downwards and outwards at about 45°; in this outer zone additional tabulae may develop which are more steeply inclined and only occur in the vicinity of the aulos wall. The outer wall is moderately thin but with slight stereoplasmic thickening.

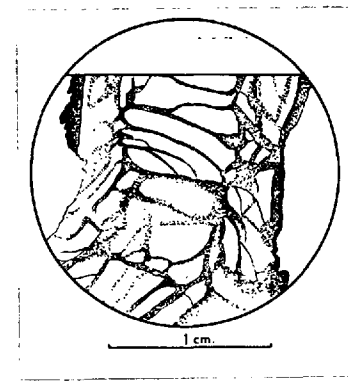


Fig 40 Polished longitudinal section of the holotype.

Description: The holotype has a mean maximum diameter of 6 mm. It has been sliced longitudinally to show the arrangement of the tabulae. Length of preserved fragment, which is embedded in limestone, 7 mm; there is no variation of the diameter over this length, suggesting that the mature corallite was essentially cylindrical. As a result of

distortion the coral appears oval in transverse section, the major and minor diameters being 7 mm. and 4.5 mm. respectively. The aulos is elliptical but not regularly defined; it is formed largely as the result of the down-turned edges of the central tabulae and not by the expansion of the axial ends of the septa. Occasionally a septum appears to extend a short distance into the aulos, but this is caused by the septum extending over the horizontal floor of the tabulae, where the aulos walls are irregular (see text fig 41).

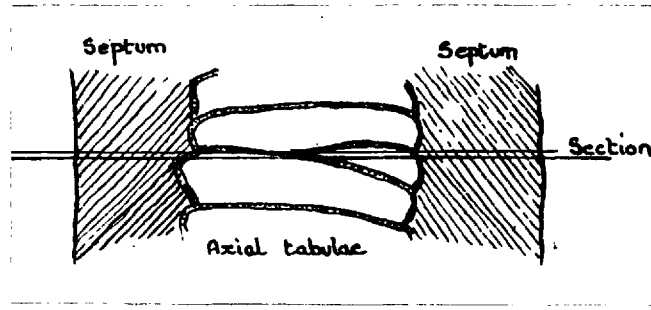


Fig 41. Diagram showing the irregular wall of the aulos and septa extending for a short distance across the tabulae

Remarks: There is a small amount of stereoplasmic thickening in this species but it is much less than in most species of Syringaxon. The irregular form of the aulos, however, clearly separates this form from Syringaxon. The species is similar to B. perplexum Poeta, but differs in lacking minor septa, having fewer major septa, and being generally smaller in size.

Barrandeophyllum sp. cf. B. symmetricum (Frech) 1886

Plate 31, figs 6,9

Description: Specimen 6.4 is a broken fragment 9 mm. long and embedded in limestone. The diameter of the coral increases from 5.5 mm. to 7 mm. over this length, suggesting that the complete

coral was tall but with a trochoid form. There are 22 septa at the maximum diameter and these are straight or only slightly flexed until they reach the edge of the aulos; here many of the septa are bent sharply so as to rest against their neighbours, thus forming the aulos. The aulos is wide, with a ratio of 0.5, and its form is somewhat irregular; there is no stereoplasmic thickening. The outer wall is thick, averaging 0.5 mm. The tabulae within the aulos are irregularly spaced and are horizontal or slightly depressed; most of them extend the whole way across the aulos. The tabulae between the aulos and the outer wall slope downwards and outwards; they do not correspond in height to those within the aulos.

Remarks: The North Devon species differs only slightly from Frech's species from the lower middle Middle Devonian of Blankenheim, Germany. The former has a wider aulos and a greater number of septa at the same diameter; the septa are also somewhat more slender. Frech (1886) does not mention the bending of the septa at their axial ends to form the aulos and unfortunately I have not had the opportunity to examine his original specimens, but his figures (plate 7, figs.17, 18, and 22) all suggest that the aulos is at least partly formed by a deflection of the axial ends of the septa. The arrangement of the tabulae is exactly comparable with the German specimen which is illustrated in Plate 7, figure 5 (of Frech).

Hill (1940) has described a new species of Barrandeophyllum (B. rubrum) from the Upper Givetian or Lower Frasnian of the Rough Series, Kimberley, Western Australia which is also very similar to the North Devon species. The Australian species has fewer septa and its tabulae are more regularly horizontal and less numerous.

Occurrence: Seven specimens from North Devon have been found in the David's Stone Limestone at Sandy Bay, near Combe Martin and at Broadstsand Beach, near Ilfracombe.

Family METRIOPHYLLIDAE Hill 1939

Genus Amplexiphyllum Stumm 1949

Type species: A. hamiltonae (Hall) 1876

See Stumm (ibid) for generic description.

Amplexiphyllum spinum sp. nov.

Plate 32, figs 6,10,11

Holotype: 5.18.

Paratype: 5.21

Horizon and locality: The Combe Martin Beach Limestone (Lower Frasnian) The Farlour, Combe Martin, North Devon.

Diagnosis: The mean diameter of the holotype is 6.5 mm. The septa are short and thick at the periphery but taper to a point in less than a millimetre, thus giving the appearance of sharp spines projecting from the thick outer wall; the septa are developed on the upper surface of the tabulae; the major ones may be equal to or slightly longer than the minor ones; the major ones are also stouter. The total number of septa is about 32-36.

The tabulae are thin and widely spaced, about 2 mm. apart being the average; they thicken very slightly just before joining the outer wall.

The length of the longest recovered portion is about 1 cm. and there is no change of diameter over this length, suggesting that the complete coral was cylindrical in form.

Remarks: The only species of this genus so far described is A. hamiltonae from the Hamilton Group, Western New York, though Stumm (1949) commented that Caninia tabulata Busch should also be referred to this genus. The North Devon species differs from A. hamiltonae in being smaller, and having fewer, more spine-like septa. There is

also less contrast between the size of the two orders of septa in A. spinum, suggesting that it is more closely allied with Amplexus from the Lower Carboniferous than with A. hamiltonae.

Stumm (1949) regards the genus Amplexiphyllum as a derivative of a stereolasmoid form since he found the neanic stage in A. hamiltonae to be almost identical with Stereolasma. Unfortunately the neanic stage is not seen in any of the specimens collected from North Devon.

Meniscophyllum crescentum sp. nov.

Plate 32, fig 1
Plate 3, fig. 12

Holotype: 13.4.

Horizon and locality: Combe Martin Beach Limestone (Lower Frasnian), The Parlour, (near Combe Martin) and Hagginton Beach (near Ilfracombe), North Devon.

Diagnosis: Small solitary corals with a maximum diameter of 5-6 mm. Major septa number 18-20; they are thin but those of the counter and alar quadrants expand near the axis to become contiguous, thus forming a crescentic shaped wall into which the remaining septa project. Towards the periphery the septa gradually thicken until they unite with the narrow stereozone of the outer wall. The outer wall is relatively thin. Minor septa are present as small bulges projecting from the outer wall; they are not attached to any of the major septa.

Discussion: The species is somewhat doubtfully referred to the genus Meniscophyllum Simpson since it lacks the solid axial structure which characterises the genus; instead the septa develop an incomplete aulos which is suggestive of Barrandeophyllum. But in Barrandeophyllum the aulos is larger and much more imperfectly developed

and all the septa are involved in the aulos structure; in M. crescentum the septa in the cardinal quadrant are never involved in the aulos.

Family PHILLIPSASTRAEIDAE C.F. Roemer 1883

Subfamily PHILLIPSASTRAEINAE C.F. Roemer 1883

Included genera from North Devon:-

Disphyllum de Fromentel 1861

Cylindrophyllum Simpson 1900

Billingsastraea Grabau 1917

Hexagonaria Gurich 1896

Subfamily PHACELLOPHYLLINAE Wedekind 1921

Included genera from North Devon:-

Thamnophyllum Gurich 1896

Phillipsastraea d'Orbigny 1849

Family description: see Hill 1956

Remarks: In the above, I am following the classification of Hill (1956) and it is essentially the same as that suggested by Stumm (1949) and Roukowska (1953). I reject the classification which is implicit in Smith (1945); he united asteroid forms with horse-shoe dissepiments (Pachyphyllum) with asteroid forms lacking them (Phillipsastraea). Phillipsastraea (type species P. hennahi) is the prior name. There is a well marked morphological series ranging from solitary to astreoid for forms both with and without horse-shoe dissepiments and these series form the basis of Hill's classification. However, Schouppé (1958) has figured a longitudinal section of the lectotype of P. hennahi which clearly shows horse-shoe dissepiments. The generic name Phillipsastraea must, therefore, be applied to forms with horse-shoe dissepiments and Pachyphyllum is indeed a junior synonym. An astreoid coral belonging to the Phillipsastraeidae, but lacking horse-shoe dissepiments, is Billingsastraea and it is to this genus that many forms, originally placed in Phillipsastraea but lacking horse-shoe dissepiments, must now be assigned.

The morphological scales of the two sub-families is shown in the following table:

Form	With horse-shoe dissepiments	Without horse-shoe dissepiments
Solitary	Macgeea	Temnophyllum
Dendroid or phaceloid	Thamnophyllum	Disphyllum
	Trapezophyllum	Hexagonaria
Astreoid	Phillipsastraea	Billingsastraea

Schouppé (1949), and Schouppé and Stacul (1963) have included Thamnophyllum Penecke Phacellophyllum Gurich, Pexiphyllum Walther and Peneckiella Soshkina as synonyms or subgenera of Macgeea. Hill (1956) on the other hand, has given each of these full generic status within the sub-family Phacellophyllinae Wedekind. I accept Schouppé's arguments based on skeletal structure and gradational forms between each of these genera, and I agree with him in placing Phacellophyllum as a synonym of Thamnophyllum, but the other type specimens are all differentiated from each other by well marked features and to create subgenera based on subjective reasoning merely makes the nomenclature clumsy without achieving any advantage, since their close affinity is already recognised by placing them in the same sub-family.

Genus Disphyllum Fromentel 1861

Cannophyllum Chapman 1893, p. 45
Pseudostringophyllum Soshkina 1939, p.36 after Stumm 1949
Megaphyllum Soshkina 1939, p.14

Type species: By subsequent designation of Lang and Smith 1935, p.80, Cyathophyllum caespitosum Goldfuss 1926, p.60, pl.19,fig 2b (=Cladocora goldfussi Geinitz 1845, p.569) from the Middle Devonian of the Eifel and Bensburg, Germany.

Diagnosis: see Stumm 1949.

Remarks: Smith (1945) included forms with 'horse-shoe' dissepiments within the genus Disphyllum since he regarded this character as 'merely a trend' (Lang and Smith 1935) within the genus. This view has not been shared by most later workers (e.g.Stumm 1949, Hill 1956) and I do not accept it. Horse-shoe dissepiments are a peculiar structure with which other modifications of the coral skeleton are closely associated and these appear to be at least of generic significance. In fact, Rozkowska (1958), Schouppé (1963) and Schouppé and St eul (1963), who have all made special studies of this group, regarded this morphological feature as of family or higher significance.

Disphyllum goldfussi (Geinitz)

Plate 22, fig 2

Synonomy: Cladocora goldfussi Geinitz 1845, p.569
Disphyllum goldfussi Lang and Smith 1935, p. 568-570.

Lectotype: Cyathophyllum caespitosum Goldfuss 1826, pl.19, fig 2b.
See Lang and Smith (1935) for full discussion and synonomy.

Diagnosis: see Lang and Smith 1935.

Description of the North Devon specimens: Two specimens (14.93,10.63) have been collected and these agree with the lectotype in all essential features. There are, however, only 48 septa in both specimens at a diameter of 13 mm. (in the lectotype there are 50 at 11 mm.) Smith (1945) commented upon the variability in length of the minor septa and this is well seen in the North Devon specimens (Plate 22,fig 2). The major septa stop about 1 mm. short of the axis; the central tabulae are horizontal, but the paraxial ones are more steeply inclined and less globose than in the lectotype.

Horizon and localities: D. goldfussi has been collected from the Jenny Start Limestone (Givetian) of Widmouth Head and Rillage Point, near Ilfracombe, North Devon.

Disphyllum haggintonense sp. nov.

Plate 22, figs 3,4,5
Plate 23, figs 3,4
Plate 24, fig 1
Plate 25, figs 1,2,

Synonomy: Diaphyllum aequiseptatum Smith 1935
Disphyllum aequiseptatum Webby 1964

Holotype: Specimen 13.124

Horizon and locality: The Jenny Start Limestone (Givetian) of Haggintón Beach.

Paratypes: Specimens 10.24 and 14.101 from the Jenny Start Limestone of Rillage and the Old Coast Road respectively.

Diagnosis: Phaceloid corals in which the major septa are only slightly longer than the minor ones and both series may approach the axis but do not quite reach it. Septa thicken at the outer wall and form a

stereozone. There is a wide dissepimentarium filled with numerous inflated dissepiments which are irregular in size. The tabulae are horizontal and usually complete.

Description: The corallites reach a maximum diameter of 15-20 mm. and they develop colonies 30 cm. and more across. There are 24-26 major septa at the maximum diameter. The corallites are loosely fasciculate and only rarely do neighbouring ones interrupt the regular cylindrical growth of each other. The outer wall is thin but re-inforced by stereoplasm. The dissepiments are small, unequal in size and strongly inflated. The tabulae do not cross the tabularium and slope down towards the axis at an angle of about 30°; there are also peripheral tabellae which resemble elongate dissepiments.

Remarks: This species is very common in the Jenny Start Limestone especially at the foot of the steps leading on to Haggirton Beach. It differs from the type species in having more numerous dissepiments and minor septa which are almost equal in length to the major ones; the corallites are also larger and more loosely fasciculate.

D. haggintonense is conspecific with the species described by Lang and Smith (1935) as D. aequiseptatum Edwards and Haime, but the holotype of this species (Geol. Surv. Mus. No. 6140) has only 36 septa according to the authors' original description, and its internal structure is unknown since the specimen is recrystallized (Lang and Smith, 1935, p.572). It is unfortunate that Edwards and Haime should have selected such a specimen as a holotype; it was undoubtedly collected from the Jenny Start Limestone on the West side of Rillage Point. Here the Limestone is effected by a peculiar form of ankeritization which is very local in its development; all the corals have been pseudomorphed by ankerite and their internal structure has been completely obliterated. I have therefore abandoned

Edwards and Haime's species with which D. haggintonense may or may not be conspecific, and have referred the species figured by Lang and Smith (1935) and also that recorded by Webby (1964) as D. aequiseptatum to the new species D. haggintonense.

Genus Cylindrophyllum Simpson 1900

Synonomy: Cylindroheliium Grabau 1910
Spinophyllum Wedekind 1922
Spinophyllum Taylor 1951

Type species: By original designation, C. elongatum Simpson 1900, p.217, text fig 42, from the lower Middle Devonian (Onondaga Limestone), Clarkesville, Albany County New York.

Diagnosis: Simple or weakly aggregate sub-cylindrical to cone shaped corals. The internal structure is similar to Disphyllum but the septa are carinate. Peripheral tabellae are poorly developed or may be completely absent.

Remarks: I agree with Stumm (1949) and Hill (1956) in regarding both Cylindroheliium Grabau and Spinophyllum Wedekind as congeneric with Cylindrophyllum. Wedekind distinguished Spinophyllum by the presence of peripheral tabulae and Taylor (1952) retained Wedekind's genera for solitary forms, but referred all phaceloid forms to Cylindrophyllum. These appear artificial distinctions since within the closely related genus Disphyllum solitary and phaceloid forms are grouped together within the one genus. In fact, Lang and Smith (1935) suggested Cylindrophyllum within Disphyllum but the presence of strongly developed carinae clearly separates the two genera.

Range: Upper Lower Devonian to Upper Devonian.

Cylindrophyllum cf. elongatum Simpson 1900
Plate 33, figs 1,2,3

Material: Two specimens from the Jenny Start Limestone (Givetian) of Rillage. 14.57, 14.92

Description: At a diameter of 18 mm. there are 30 major septa; these are thickened within the dissepimentarium and they only extend a short distance into the tabularium, within which they are very attenuated and zig-zag. There is a corresponding number if minor septa and these are thinner, especially near the periphery; they do not extend into the tabularium. Both series of septa carry stout yard-arm carinae. The outer wall is thin.

Only a fragment showing the longitudinal section has been obtained, but this shows numerous irregular dissepiments, and horizontal (sometimes slightly depressed) tabulae most of which extend across the tabularium. The calice appears to be steep-sided with a flat floor.

Remarks: The North Devon species resembles the type species, C. elongatum, very closely in longitudinal section, but unfortunately Simpson did not figure a transverse section. Alternate septa are described as 'very short', whereas in the North Devon species they are about a half the length of the major ones; the diameter is aulcsgreater than in the type specimen. Taylor (1951, 1952) has figured three species of Spinophyllum (=Cylindrophyllum) from South Devon; of these, S. stonehousense is comparable with C. cf. elongatum but it is smaller, has longer septa, and the tabulae are less regularly complete.

Cylindrophyllum stonehousense (Taylor) 1951

Plate 33, fig 4

Holotype: Specimen No.D4/151 (Sedgwick Museum, Cambridge) from the northern beds of Richmond Walk quarry, Plymouth. These beds are considered to be of upper middle Middle Devonian age.

Diagnosis: (Revised after Taylor 1951) Cylindrophyllum with simple

trochoid form and major septa which almost reach the axis; minor septa alternate with the major ones and are about half as long. The major septa are much dilated within the dissepimentarium; the minor septa are only slightly thickened. The peripheral wall is thin. The dissepimentarium consists of several rows of small globose dissepiments which dip at an angle of 60°. The tabularium is wide with distally convex tabulae and one or two rows of distally arched peripheral tabellae.

Remarks: The single specimen from the Jenny Start Limestone of Rillage Quarry (14.91) consists of a fragment about 18 mm. long from which a transverse thin section has been made. The periphery of the coral is not completely preserved but the approximate diameter is 14 mm. At this diameter there are 30 major septa; (in the holotype there are about 28 major septa at the same diameter). The arrangement and structure of the septa is, however, exactly similar to the holotype.

C. stonehousense differs from C. cf. elongatum in having longer septa, and in the arrangement of the tabulae.

Cylindrophyllum inequalis sp. nov.

Plate 33, fig 5,6,9,10

Holotype: Specimen 10.81

Horizon and locality: The Jenny Start Limestone (Givetian) of Widmouth Head.

Paratypes: Specimens 10.82, 14.67 from the Jenny Start Limestone of Widmouth Head and Rillage.

Description: The holotype consists of a fragment about 20 mm. long. Transverse sections have been cut and it has also been sliced longitudinally. The form of the corallite is unknown. At a diameter

of 18 mm. there are thirty to thirty-two major septa which are unequal in length, some reaching the axis and being slightly rhopaloid. There is a corresponding number of minor septa. The major septa are thickened within the dissepimentarium and again at the periphery; the peripheral wall is thin but it is strengthened by the thickening of the septa. The minor septa are only slightly thickened and are about half the length of the major ones. Carinae are weakly developed on both series of septa.

In transverse section the dissepiments are characteristically developed in pairs on either side of a minor septum. The dissepiments are numerous, very globose and unequal in size. The tabulae are horizontal or slightly concave and complete; there is a row of peri-axial tabulae.

Remarks: C. inequalis differs from both C. elongatum and C. stonehousense in having fewer and less prominent carinae, in the length of septa, and in the number of dissepiments. (The specific name refers to the unequal length of the major septa).

?Billingsastraea cf. devonense (Edwards & Haime) 1853
Plate 23, fig 2

Description: There are twenty septa of each order, the major ones almost reaching the axis, while the minor ones stop at the border of the tabularium. All the septa are strongly dilated at the inner margin of the dissepimentarium, and they may be confluent with those of neighbouring corallites, or the corallites may be separated by dissepimental tissue. Within the tabularium the septa are wavy.

Only one specimen which can be compared with B. devonense has been found; this measured 6 cms. by 4 cms. and it has been sliced longitudinally and transversely. The former shows little

beyond the crowded nature of the dissepiments but there is no evidence of horse-shoe dissepiments being present.

Remarks: The specimen differs from B. devonense in having fewer septa and less dissepimental tissue between the corallites.

Material: The one specimen (18.15) so far obtained comes from the Jenny Start Limestone of Widmouth Head, near Ilfracombe, North Devon.

Genus Hexagonaria Gurich 1896

Polyphyllum de Fromentel 1861 (non Polyphyllum Blanchard 1850)

Prismatophyllum Simpson 1900

Hexagoniophyllum Gurich 1909

Prismatophyllum Yu 1934

Prismatophyllum Smith 1945

Type species: Cyathophyllum hexagonum Goldfuss 1826, p.61, pl.19, figs 5e-f, and pl.20, figs 1a-b.

Lang and Smith (1935) chose as lectotype of C. hexagonum the original of pl.20, figs 1a-b, and Lang, Smith and Thomas (1940) designated C. hexagonum the type species of Hexagonaria.

Diagnosis: see Stumm 1949.

Remarks: This genus is particularly common in the Middle and Upper Devonian, though it is also recorded from the lowermost Carboniferous beds of China (Yu 1934). Smith (1945) points out that Hexagonaria (Prismatophyllum) grades into the phacelloid Disphyllum on the one hand and into the ploccoid Phillipsastraea on the other.

Hexagonaria boloniensis (de Blainville) 1830

Plate 26, figs 1,2,

Synonomy: Monastaea boloniense de Blainville 1830, p.339. 1834, p.374,

Cyathophyllum hexagonum Goldfuss partim. Michelin 1845, p.181.

Lithostrotion arachnoides (DeFrance) partim; D'Orbigny 1850, p.106; non Astrea arachnoides DeFrance 1826, p.383.

Cyathophyllum boloniense (de Blainville) partim. Edwards and Haime 1851, p.385. 1853, p.230.

Prismatophyllum boloniense (de Blainville); Smitt 1945, p.50-51.

Diagnosis: see Smith 1945, pp.50,51.

Remarks: The North Devon forms of Hexagonaria boloniensis differ in minor details from the specimens figured and described by Smith (1945). The most apparent difference is the shorter septa of the North Devon form - usually they stop 1-2 mm. from the axis, though occasionally they do reach the axis. The corallum is typically globose and colonies up to 30 cms. in diameter occur, especially as large beach pebbles at Samson's Bay. The corallites vary considerably in size owing, as Smith pointed out, to the frequent intercalations of young individuals. The calices are funnel-shaped and deep.

There may be as many as 30 septa but the average is 25-26; there is a corresponding number of minor ones, which are about half the length of the major. The septa of both orders are thickened at the periphery and this reinforces the relatively thin walls separating the corallites. Carinae are weakly developed.

There are three or four rows of irregular dissepiments, the peripheral ones being generally smaller and more globose than those near the tabularium. Tabulae are irregular; the axial ones are commonly horizontal but sometimes they show a prominent central depression; the periaxial tabulae are steeply inclined and somewhat globose so that they are similar to the inner dissepiments.

Material: Two specimens (13.34, 7.4) have been sectioned; these were both obtained from the Jenny Start Limestone (Givetian), the first from Haggington Beach and the second from Jenny Start. The species is common at most outcrops of the Jenny Start Limestone.

Genus Thamnophyllum Gurich

Synonomy: I include all the forms listed by Schouppé and Stacul (1963) in their synonomy of the sub-genus Macgeea (Thamnophyllum).

Type species: Thamnophyllum stachei Penecke.

Diagnosis: Fasiculate corals with major and minor septa and a single row of horse-shoe dissepiments outside which is a series of flat or only slightly curved dissepiments. Tabulae are usually complete and horizontal; there may be a single series of slightly inflated peri-axial tabulae.

Remarks: The essential differences between Macgeea and Thamnophyllum have been listed by Rozkowska (1952) and with these I entirely agree.

Rozkowska (1957) has made a biometric study of variability in the genus Thamnophyllum for species obtained from the Holy Cross Mountains of Poland. She has shown that the 'correlation co-efficient' is higher in Givetian forms than in Frasnian and that it is possible to use the correlation co-efficient as a stratigraphical index.

Essentially the correlation co-efficient consists in finding the mean value of $\frac{Mn}{Md}$ $\frac{\text{number of septa}}{\text{diameter in mm.}}$ using a single population.

Rozkowsha gives the following values, arranged in stratigraphical sequence for five Polish species:

Frasnian	T. kozlowskii superius	2.20
	T. kozlowskii (from Sitkowka)	2.30
Givetian	T. caespitosum	3.17
	T. trigemme	3.42
	T. skalense	3.64

In North Devon, the distorted nature of the corals and the difficulty in collecting a statistically significant number of specimens has made a comparable study impossible; nevertheless, a mean value

for 64 specimens obtained from the Jenny Start Limestone has been calculated and this gives a value of 3.2. Such a figure accords well with the Upper Givetian age for this limestone which had been deduced on other grounds.

Two types of budding occur in the genus Thamnophyllum - (a) parricidal, as in T. trigemmo; (b) lateral, as in T. caespitosum. In both cases, however, dissepimental tissue occurs between the parent and daughter corallite in the initial stages.

Thamnophyllum is by far the most abundant rugose coral in the Jenny Start Limestone and over a hundred specimens have been collected; it is probable that all of these belong to the species T. caespitosum though the possibility of other species being present is discussed below.

Range: Upper Lower Devonian - Upper Devonian.

Thamnophyllum caespitosum (Goldfuss)

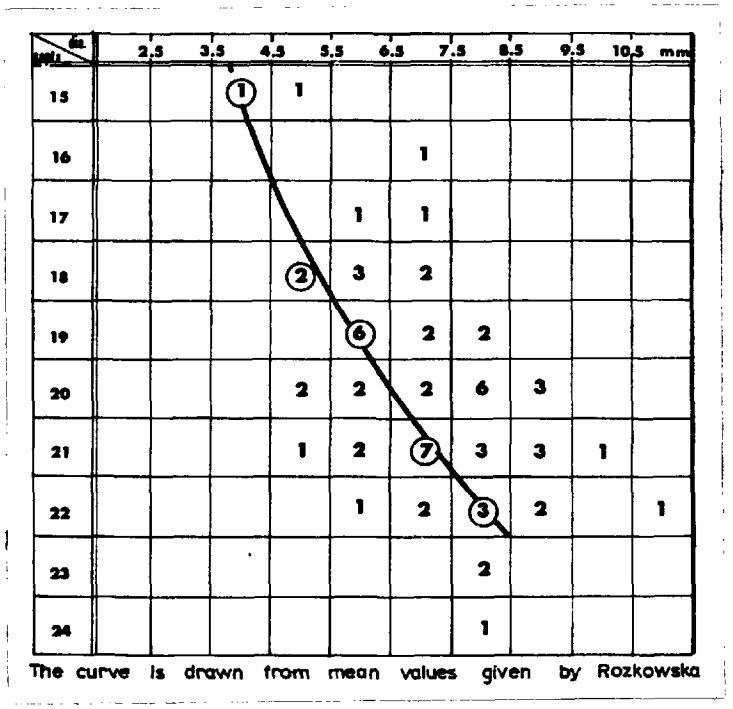
Plate 27, figs 1-2,5-8
Plate 28, figs 1-2
Plate 29, fig 1

Synonomy: see Smith (1935) and Rozkowska (1956).

Description: Fasiculate corals with an average diameter of 6 mm., at which diameter there are 19-20 major septa developed. Calices are shallow with steep sides. Increase is by lateral budding and the branches tend to make a wide angle with the parent corallite. The major septa are usually sinuous and stop about 0.5 mm. short of the axis. There is a corresponding number of minor septa which just penetrate into the tabularium. Epitheca is thin. The axial tabulae are flat flat or slightly arched and are usually complete; steeply inclined peripheral tabellae are present. There are two kinds of dissepiment -

an outer series of horizontal or slightly curved ones and an inner row of horse-shoe dissepiments.

Remarks: Smith (1935) has given a full description of the lectotype and many of the specimens from North Devon are exactly similar. Rozkowska (1956) has shown that there is a range both in number of septa and in the diameter of corallites within a single populatinn but that it is possible to determine mean values which are significant for the species; the following table shows her values in the form of a graph on which is also plotted values for 64 specimens from the Jenny Start Limestone; the circles indicate the variation range within a single colony.



There is clearly agreement between the maxima for the North Devon

specimens and Rozkowska's values, but there is also a suggestion of a second series of maxima which might indicate a second species being present in the assemblage; the evidence is, however, inconclusive and I prefer to regard them as variants of a single species since there are no significant differences in structure.

T. caespitosum is one of the few corals previously recorded from the Ilfracombe Beds. The first record is by Sedgwick and Murchison (1840). Webby (1964) has recently recorded the species from the Roadwater Limestone (Givetian) of West Somerset and Taylor (1951) has recorded it from the Couvinian of the Plymouth area; the form described by Taylor has, however, much shorter septa than is usual in T. caespitosum.

Localities: Numerous specimens from the Jenny Start Limestone (Givetian) of Jenny Start, Widmouth Head, Rillage and Hagginton Beach.

Thamnophyllum sp.

Plate 27, figs 3-4

Description: Similar to T. caespitosum but having an additional row of globose dissepiments both inside and outside the single row of horse-shoe ones and in addition to the horizontal outer ones.

Only one specimen (10.59) showing this unusual arrangement of dissepiments has been found, though occasional small globose plates within the row of horseshoes are found in T. caespitosum (cf. Schouppé (1949), pl. 9, figll; and pl.27, fig 8 of this thesis); they have not previously been recorded outside the row of horse-shoe dissepiments.

Locality: The Jenny Start Limestone (Givetian) of Widmouth Head.

Genus Phillipsastraea d'Orbigny 1849

Pachyphyllum Edwards & Haime 1850
Smithia Edwards & Haime 1851
Medusaephyllum C.F.Roemer 1855
Streptastraea Sandberger & Sandberger 1856
Pseudocaervularia Schluter 1881

Type species: By subsequent designation of Edwards and Haime (1850, p.lxxi, Astraea hennahi Lonsdale partim, 1840, p.697,pl.58, figs 3, 3a, 3b). Smith 1917, p.284, has chosen the original of Lonsdale's fig 3, 3b as lectotype.

Diagnosis: (Revised) Massive astroid to aphroid corals in which the septa are dilated at the border of the tabularium. There are major and minor septa, the latter reaching as far as the border of the tabularium, while the major ones may be only slightly longer or may extend to the axis; both series are commonly carinate. Dissepiments are small and numerous, and there is a single row of horse-shoe dissepiments; the tabularium is narrow and the tabulae may be complete or incomplete.

Remarks: Smith (1917,1945) and Schouppé (1949,1957) have discussed the genus at length but little comment has been made on its stratigraphical significance. Walther (1928) believed that Phillipsastraea first appeared in the Upper Devonian and the same opinion was expressed by Stumm (1949). However, there have long been records of Phillipsastraea occurring in the Middle and possibly Lower Devonian of Australia (see Hill 1939,1942). The genus is also recorded in the Lower/Middle Devonian of Bohemia (Počta 1902), Ellesmereland (Loewe 1913) and North America (Meek 1867). More recently, Middleton (1954) and Webby (1964) have both recorded Phillipsastraea

from the Middle Devonian of S.W. England. In North Devon, I have found the genus in association with Acanthophyllum, Mesophyllum, and Endophyllum, which indicate a Middle Devonian age.

Edwards and Haime (1850) created the genus Pachyphyllum (type species P. bouchardi) to contain aphroid corals which were otherwise similar to the astreoid Phillipsastraea (=Smithia of Edwards and Haime 1851). Smith (1945) pointed out that aphroid and astreoid forms may be found in the same corallum; hence Pachyphyllum is an exact synonym of Phillipsastraea. (See also 'remarks' under Phillipsastraeidae).

Phillipsastraea sola sp. nov.

Plate 23, fig 1

Holotype: Specimen 14.38.

Horizon and locality: The Jenny Start Limestone (Givetian) of Rillage Point, near Ilfracombe, North Devon.

Diagnosis: Phillipsastraea with major and minor septa thickened at the inner edge of the dissepimentarium and carrying a carinae. A dividing wall may develop between corallites.

Description: There are sixteen to eighteen major septa which penetrate the tabularium but do not reach the axis; a corresponding number of minor septa stop at the borders of the tabularium. Both orders of septa are thickened at the inner margin of the dissepimentarium, but they do not form a continuous inner wall. The septa are mildly carinate and are not generally confluent with those of adjacent corallites; in places there are traces of a dividing wall between corallites, which are spaced approximately 6-9 mm. apart from axis to axis. Tabulae usually complete; dissepiments numerous with a single row of horse-shoe dissepiments.

Remarks: This species most closely resembles P. cantabrica (Vernauil) but it differs in having shorter septa, which are not swollen at their axial ends and which are much less carinate.

Material: Only one specimen referable to P. sola has been collected from the Jenny Start Limestone; it consists of a broken fragment from which a transverse and three longitudinal sections have been made. Some recrystallization and distortion of the coral has taken place; nevertheless, it differs sufficiently in its characteristics to justify being placed in a separate species.

Phillipsastraea cripta sp. nov.

Plate 22, fig 1
Plate 23, fig 5

Holotype: Specimen 15.26

Horizon and locality: The David's Stone Limestone (Frasnian) of Broadstrand Beach, near Ilfracombe.

Paratype: Specimen 15.28 from the same locality.

Diagnosis: Phillipsastraea with astreoid to aphroid septa. There are up to sixteen major septa and a corresponding number of minor ones. The major ones are slightly thickened within the tabularium but do not reach the axis. At their outer ends they may be confluent with those of neighbouring corallites, but more commonly a zone of dissepiments separates them. A single row of much thickened horse-shoe dissepiments occurs at the border of the tabularium, and there are numerous small inflated dissepiments within the dissepimentarium. Tabulae are horizontal and usually complete.

Remarks: Both specimens are only broken fragments from coralla and

because of tectonic deformation and partial recrystallization, the microstructure of the corallites is obscure. The mean diameter of the tabularium is 3-3.5 mm. and the distance apart of mature corallites (axis to axis) is 10-12 mm. The horse-shoe dissepiments are much thickened and are not easily seen; the ordinary dissepiments are small and very numerous. The major septa stop about 0.5 mm. from the axis leaving a central area 1 mm. in diameter in which only occasional tabulae are seen in transverse sections. There is a series of small steeply inclined periaxial tabulae.

P. cripta differs from *P. sola* in having larger corallites with fewer septa and in its tendency towards aphroid rather than cerioid form.

Sub-order COLUMNARIINA Rominger 1876

Family CHONOPHYLLIDAE Holmes 1887

Subfamily ENDOPHYLLINAE Torley 1933

Genus Endophyllum Edwards and Haime 1851

For generic description see Jones 1929.

Endophyllum abditum Edwards and Haime 1851

Plate 20, fig3
Plate 21, fig 1

Diagnosis: Endophyllum with moderately well developed walls and large irregular dissepiments through which the septa cannot be traced or are only seen as rare septal crests. 30-40 major septa in the largest corallites and a corresponding number of short minor ones. Tabulae of two types: those which span the axis are flat but with sharply downward-flexed edges where they meet the perixial tabulae, which are shallowly concave upwards.

Description: The maximum diameter of the corallites is about 30 mm. The wall separating the corallites sometimes shows slight projections which correspond with the two orders of septa. The minor septa are rarely more than one third the length of the major ones and often much shorter; their axial ends are very slightly swollen. The major septa may reach the axis and they show a tendency to become convolute in the tabularium. All the septa are thickened at the border of the tabularium and so produce a well marked 'theca' (Grabau 1922). The large dissepiments are commonly in a single row; they are only slightly inflated and slope downwards towards the axis at about 45°. The central tabulae are usually complete and are flat or only very slightly domed; the outer ones also consist of a single series but they are much shorter and sag gently downwards.

Remarks: The species is very common in North Devon and it characterizes the Jenny Start Limestone at most outcrops between Ilfracombe and Combe Martin. It forms massive colonies often 2 feet and more in diameter, though the individual corallites are on average smaller than those of the specimen figured by Edwards and Haime (1853), and there are fewer septa in all the specimens which I have examined from North Devon. The dissepiments of the latter also tend to be larger and more irregular, and the walls separating the corallites are not always so strongly developed.

Smith (in Evans 1922) identified E. bowerbanki from the limestone at Jenny Start itself; the specimens which I have collected from the same locality all show little or no evidence of a dividing wall and the outer area of dissepiments is very irregular (Pl.20, fig 1). At first sight these specimens would seem to be most properly referred to the species E. bowerbanki, which is characterized by the absence of a dividing wall. However, the dissepimentarium of all my specimens from Jenny Start have been partially recrystallized, thus breaking up the dissepiments and possiblyaulosdestroying the outer wall if it existed. I hesitate, therefore, to identify these specimens with E. bowerbanki, especially as elsewhere in the Jenny Start Limestone the specimens found (which are not recrystallised) are closer to E. abditum. Unfortunately I have not been able to trace the specimens identified by Smith to check whether or not they too show recrystallization.

Jones (1929) suggested that there was a continuous variation in form between E. bowerbanki and E. abditum but he was not sure whether the variation was areally or in time. My own observations confirm that there is probably a continuous series between these two species and that they are the result of true variation (i.e. both E. bowerbanki and E. abditum together with the intermediate forms,

are all to be found at the same stratigraphic level.

Range: Most workers have restricted all species of Endophyllum to the Middle Devonian. Smith (1945) suggested that it might extend into the Upper Devonian but this view is not shared by Hill (1956). In the Ilfracombe Beds of North Devon and Somerset, E. abditum occurs in beds which Webby (1964) and Holwill (1962) regard as Givetian in age.

Material: Numerous specimens have been collected in North Devon; the following are the principal localities: Newberry Beach ('Low Water Limestone'), Jenny Start, The Old Coast Road, Samson's Bay, and West Hagginton Beach.

Family PTENOPHYLLIDAE Wedekind 1923

Ptenophyllidae Kettnerova 1932
Acanthophyllidae Hill 1939
Acanthophyllidae Stumm 1949
Ptenophyllidae Hill 1956
Acanthophyllidae Ganswick & Fritz 1958
Ptenophyllidae Middleton 1959
Acanthophyllidae Birenheide 1961

Family description: Simple of weakly aggregate rugose corals varying from subcylindrical to patelloid in form. Calice with a wide, relatively horizontal peripheral platform and an axial pit ('Krempenkelch' of Wedekind). Septa of two orders, both of which are greatly dilated in their early stages but become more attenuated with maturity; they may develop an axial whorl or show a rough bilateral symmetry. The major septa may retain dilation in their central portions during the ephebic stage and they may also develop rhopaloid axial ends. The minor septa usually extend to the inner borders of the dissepimentarium and may also retain their delation in the ephebic stage. Carinae may be strongly developed in some genera. Tabularium is wide and occupies from a third to half of the diameter of the corallum. Tabulae are funnel shaped, close set and often incomplete. The dissepimentarium is composed of numerous rows of small, highly inclined and very globose dissepiments.

Remarks: Wedekind's description of the Ptenophyllidae (1924, 1925) suggests that the 'krempenkelch' is characteristic of Couvinian genera. The septa show various modifications - the axial ends are frequently slightly rhopaloid and the peripheral ends may be lonsdaleoid; this latter modification, according to Hill (1956), characterizes early

members of the Ptenophyllidae.

Hill (1956) records the family as ranging from Lower Silurian (Cymatolasma) to Upper Devonian (Neostringophyllum) but its members are particularly characteristic of the Middle Devonian, and Middleton (1959) regards the family as restricted to the Middle Devonian.

Previous workers on this family have wavered between the use of the name Ptenophyllidae and Acanthophyllidae, as can be seen from the above synonomy. The former name was erected by Wedekind (1923) and the latter by Hill (1939). Wedekind's family was based on a number of genosyntypes but other workers (e.g. Hill 1939, Stumm 1949) regarded all the members of Wedekind's Ptenophyllidae (i.e. Ptenophyllum, Astrophyllum, Rhopalophyllum, Stenophyllum, and Neostringophyllum) as forms of Acanthophyllum, a genus established by Dybowski (1873-1874) and based upon the species Cyathophyllum heterophyllum Edwards and Haime. The genus Acanthophyllum has, therefore, priority over Ptenophyllum and the latter is a junior synonym. However, according to the International Code of Zoological Nomenclature (1961) the family group name is not to be changed even when the nominal type genus is rejected as a junior synonym. As both names are well established in the literature, Hill (1956) is correct in using the name Ptenophyllidae.

Genus Acanthophyllum Dybowski 1873

Synonomy: see Birenheide (1961). The following are the principal forms placed in synonomy:-

Neostringophyllum	Wedekind	1922
Ptenophyllum	"	1923
Rhopalophyllum	"	1924
Astrophyllum	"	1924
Grypophyllum	"	1925
Leptoinophyllum	"	1925
Stenophyllum	"	1925

Diagnosis: Solitary cylindrical rugose corals with a wide dissepimentarium of small inflated dissepiments. Septa of two orders; the major ones are long and may form an axial whorl. Calice deep and may be funnel shaped or 'krempenform'. Septa formed of trabecular fibres.

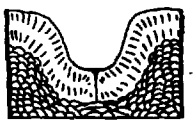
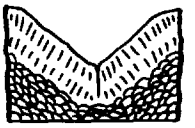
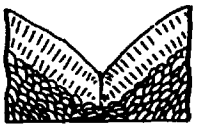
Remarks: As can be seen from the above synonomy, Wedekind erected many genera which modern workers regard as invalid. Recent work by Birenheide (1961), working on Wedekind's original collection, has shown that Neostringophyllum and Grypophyllum should be regarded as sub-genera, of which he recognizes three;

Acanthophyllum (Acanthophyllum)
A. (Grypophyllum)
A. (Neostringophyllum)

Each of these has the same basic skeletal pattern and their differences are summarized in the following table (see next page).

It is rarely possible to see any traces of the microstructure in specimens from North Devon and the calice is not often preserved; the arrangement of the dissepiments does, however, reflect the form of the calice and this, together with the nature of the septa, has

been the principal criteria in assigning the North Devon species to appropriate subgenera.

	A.(Acanthophyllum)	A.(Grypophyllum)	A.(Neostringophyllum)
CALICE	krempenform	funnel–shaped with flattened edges	funnel–shaped
DISSEPIMENTS	outer rows horizontal	numerous; rows inclined	relatively few; rows inclined
EPITHECA	thin	thin to moderately thick	thick
SEPTA	spindle-shaped, often with an axial-whorl	thin; break up at periphery common	strongly thickened; break up at periphery rare
TABELLAE	flat or inflated	flat and relatively few	inflated and numerous
LAMELLAR TISSUE	thickening with lamellar tissue common in early antogenetic stages		
TRABECULAE	trebecular groups radiating from the plane of the septum	trabecular fibres parallel to the plane of the septum and parallel to each other	
			

Most of the above differances are related to the change over from the 'Krempen' calice to the funnel-shaped one.

Range: The range of the genus has been variously interpreted. It is typically of Middle Devonian age and Wedekind (1925) regarded it as limited to the lower Middle Devonian (i.e. he did not think it occurred above his Do zone). Hill (1956) gives its range as Middle Silurian - Middle Devonian, while Birenheide (1961) regards it as ranging from upper Lower Devonian to upper Middle Devonian. Species of Acanthophyllum outside this later range are only dubiously referred to the genus but all workers are agreed that it does not occur above the Middle Devonian.

The genus is well known from Europe and Australia, but it appears to be absent from North America and Asia.

Acanthophyllum (Acanthophyllum) zonatum sp. nov.

Plate 35, figs 3-6

Holotype: Specimen 10.17

Horizon and locality: The Jenny Start Limestone (Givetian) of Widmouth Head.

Paratypes: Specimens 18.26 and 10.103

Horizon and locality: The Jenny Start Limestone of Rillage and Widmouth Head.

Diagnosis: A. (Acanthophyllum) with spindle shaped septa; there are two series - the major ones vary in length with some reaching the axis; these latter are prominently rhopaloid; the minor ones are about two-thirds the length of the major ones. The epitheca is thin. The dissepiments are irregular in size and of two kinds - an outer series which are globose and an inner series which are more elongate and steeply inclined. The tabellae are flat or slightly inflated.

Description: The recovered length of the holotype was about 6.5 cm. and over this length it had increased in diameter from 1 cm. to 3.5 cms. (these are mean diameters as the coral has been tectonically distorted). Transverse and longitudinal thin sections have been made and the remaining surfaces have been polished. There are 37 major septa at the maximum diameter and a corresponding number of minor ones. The cardinal septum is relatively short and is flanked by two long major septa with very elongate rhopaloid ends. The septa are thin at the periphery but are strongly thickened within the inner zone of dissepiments; they are also slightly thickened again within the tabularium. In transverse sections the outer dissepiments appear as irregular bars running between the septa while the inner ones

show as a zone of closely packed and more regular bars. Where the two series of dissepiments meet there is a single row of strongly thickened dissepiments; this thickening is continuous with the stereoplasm which thickens the septa.

Although the calyx is not preserved in longitudinal section, it is possible to see traces of trabecular tissue which indicate a 'krempen' calyx. The thin epitheca is strengthened by a thickening of the septa at their extreme peripheral ends. It seems probable that the holotype is showing a form of rejuvenation at the stage where the transverse section was cut for there is a distinct repetition both of the thickened ring of dissepiments and of the spindle shaped form of the septa.

Family STRINGOPHYLLIDAE Wedekind 1922

For synonomy and family description see Birenheide (1962b)

Remarks: Hill (1956) included only Stringophyllum in this family, but Birenheide tentatively includes Tabulophyllum in addition to recognizing three subgenera of Stringophyllum itself; viz.,

S. (Stringophyllum) Wedekind 1922

S. (Neospongophyllum) Wedekind 1922

S. (Sociophyllum) Birenheide 1962b

The material from North Devon is inadequate to assess the value of these subgenera and therefore no attempt has been made to assign the specimens to a subgenus, though, as they are all comparable with Stringophyllum Wedekind, they should probably be included in S. (Stringophyllum).

Genus Stringophyllum Wedekind 1922

Type species: S. normale from the Stringocephalus Limestone of Sundwig, Germany.

Diagnosis: see Hill (1942a)

Remarks: The genus is characteristic of the Givetian in Europe, China, and Australia, though LeMaitre (1934) has recorded it from the Chaudefonds Limestone which she regards as of Coblenzian or Couvinian age.

Hill (1942a) pointed out certain variations which characterized the genus:- (i) the monacanths in a septum tend to become separated

(ii) the septa tend to withdraw from the periphery

(iii) the withdrawal from the periphery affects the minor septa more than the major ones, and in the limiting case, the minor septa are completely suppressed

(iv) the withdrawal of the major septa is associated with the development of lonsdaleoid dissepiments at the periphery.

There is also some variation in the thickness of the septa and occasionally a tendency for them to withdraw from the axis. Wedekind (1922, 1924) failed to recognize the continuous variation within the one one genus and applied separate generic names to at least some of the varieties:-

Stringophyllum - withdrawal of the septa affects only minor septa; lonsdaleoid dissepiments uncommon.

Schizophyllum - (name preoccupied) - monacanths separate and withdrawal of the septa from the periphery affects major and minor septa; lonsdaleoid dissepiments common.

Neospongophyllum - Strong development of lonsdaleoid dissepiments; typically there are still traces of minor septa.

Loeopophyllum - Minor septa completely suppressed.

Stringophyllum carinatum sp. nov.

Plate 33, figs 7,8
Plate 34, figs 1,2,3

Holotype: Specimen 14.61

Horizon and locality: The Jenny Start Limestone of Rillage Point.

Paratypes: 16.23, 14.39, 16.108, 10.79

Horizon and locality: The Jenny Start Limestone of Rillage and Widmouth Widmouth Quarries.

Diagnosis: Stringophyllum with long, irregular major septa and a corresponding number of minor ones which are about half as long; both series are carinate and the carinae on the major septa may be very stout. The septa of both orders break up near the periphery in the ephebic and gerontic stages. The calice is deep and funnel-shaped. The dissepimentarium is narrow, consisting of only one or two rows of dissepiments. The tabularium is surrounded by several rows of steeply inclined periaxial tabellae and a narrow central area of horizontal tabellae.

Description: The holotype originally consisted of a fragment 30 mm. long and a maximum diameter of 15 mm.; at this diameter there are 30 major septa. The specimen has been cut in order to obtain transverse and longitudinal thin sections; the remaining surfaces have been polished.

The carinae are not regularly developed and they give the septa a ragged appearance. One septum (? the cardinal) is longer and more strongly thickened at the axis than the others, most of which approach the axis but do not quite reach it. All the septa attenuate to a greater or lesser degree as they approach the periphery, but at the periphery itself they are thickened and thus provide reinforcement for the thin outer wall.

Remarks: The form of the corallite is probably turbinate and the depth of the calice in one of the paratypes is at least 30 mm. The species is somewhat doubtfully referred to the genus Stringophyllum since carinae have not been recorded from any other species of the genus and the septa do not show signs of breaking up at the periphery until the ephebic or gerontic stage.

Stringophyllum turbinatum sp. nov.

Plate 34, figs 4,6,7,8,9

Holotype: Specimen 11.1

Horizon and locality: The Jenny Start Limestone (Givetian) of Samson's Bay.

Paratypes: 14.21, 10.88, 18.25, 19.3

Horizon and locality: The Jenny Start Limestone of Widmouth Head and Rillage.

Diagnosis: Short, turbinate solitary corals with 28-30 major septa and a corresponding number of minor ones. The major ones almost reach the axis and the minor ones are about half as long. Both series of septa are thickened within the dissepimentarium but they tend to break down at the periphery in the mature stages and

may only be represented by septal crests. The dissepiments are irregular and very elongated. The tabularium is filled with small horizontal or slightly inclined tabellae.

Description: S. turbinatum has a wide funnel-shaped calyx; the major septa tend to be flexed or slightly twisted at the axis and have a rhopaloid tendency; at the periphery they break up into lonsdaleoid dissepiments but this is only seen in the mature stage. Specimens from North Devon have an average maximum diameter of 25 mm. and a length of 30-40 mm. (Specimens invariably occur in argillaceous sediments and they are always very deformed).

Remarks: The bilateral symmetry of the type species is not well marked in the specimens from North Devon. S. turbinatum most closely resembles Neospongophyllum cf. crassum Wedekind (see Wedekind 1925, Taf. 14, fig. 86). It differs from this species in being smaller and having fewer septa. Taylor (1951) figures two species of Stringophyllum from the Plymouth area, but neither are comparable to S. turbinatum.

Some transverse sections of S. turbinatum are closely similar to the specimen figured by Edwards and Haime (1853) as Cyathophyllum obtortum and it is probable that the records of C. obtortum from North Devon refer to species identical with S. turbinatum. C. obtortum may well be a Stringophyllid, though I have been unable to locate the original specimen; I have refrained from making the two forms conspecific, however, partly because of the different outward shape (C. obtortum is sub-cylindrical), but more important, it is not certain from Edwards and Haime's description whether there is any break up of the septa, though they comment that vesicular dissepiments are well developed at the periphery.

Suborder CYSTIPHYLLINA Nicholson in Nicholson & Lydekker 1889

Family DIGONOPHYLLIDAE Wedekind 1923

Synonomy and diagnosis: see Hill 1956.

Remarks: The systematic position of this group remains uncertain despite investigation by numerous workers. Middleton (1954) made an admirable summary of the position, but in his work he followed Taylor (1951) and this classification was considerably modified by Hill (1956); even in this latest classification there is an element of doubt, for as Hill (1956, p.314) herself writes "the ancestors of the Digonophyllidae may be outside the Cystiphyllina altogether, though at present no satisfactory ancestor for such an origin can be suggested for them".

The difficulties in classifying this group arise because of uncertainty as to the true phylogenetic significance of the septal cones. Wedekind regarded the distribution and spacing of the septal cones as of considerable importance in classification, whereas Hill (1939) and Stumm (1949) regard them as a form of rejuvenescence which is not peculiar to any one group of corals. Ma (1937) believed the cones to be caused by seasonal changes in temperature. Further differences of opinion occur as to the origin of the septate forms which have a dominantly vesicular skeleton. Wedekind (1924) thought that they were produced by the close packing of successive septal cones; Hill (1939), on the other hand, considered that a degeneration of the vertical skeletal elements gave rise to the non-septate forms and hence the 'cystimorph' state could arise in many different lineages.

Forms assignable to this family are rare in North Devon and it has not been possible to shed additional light on the problems involved.

Subfamily ZONOPHYLLINAE Wedekind 1924

see Hill for description (1956)

Genus Cystiphylloides Chapman

Cystiphylloides Chapman 1893, p.46

Cystiphylloides Yoh 1937, pp.50,53

Type species: By monotypy, Cystiphyllum aggregatum Billings 1859. From the Middle Devonian, Onondaga Limestone, near Simcoe, Ontario, Canada.

Generic description: (from Stumm 1949). Simple or weakly aggregate, long, subcylindrical to cerioid corals with a characteristic bell-shaped calyx and a heavy, horizontally wrinkled epitheca. Calyx filled with dissepiments that are crossed by radiating septal striae. Periodic rejuvenescence causes septal cones to be present at varying vertical distances apart. In transverse section these appear as concentric bands of short septal crests. Dissepimentarium is wide and composed of many small inclined dissepiments. Tabularium centrally located, narrow. composed of closely set usually distally convex tabellae.

Remarks: Hill (1956) regarded Cystiphylloides as a subgenus of Mesophyllum which she classes in the subfamily Digonophyllinae. This subfamily is characterised by septa which are continuous vertical plates or else are represented in the disspelmentarium (and sometimes throughout) by septal crests; or the septa may be completely absent (Hill 1956). The other subfamily, which together with the Digonophyllinae constitute Hill's family Digonophyllidae, are the Zonophyllinae;this latter subfamily is characterised by septa which are discontinuous, being built of monacanth trabeculae and are developed only in

successive zones of skeletal dilation (i.e. in the septal cones). I have not had the opportunity to examine the type specimen, but in his redescription of the genus, Stumm (1949) specifically mentions the presence of septal cones. I therefore regard Cystiphylloides as a valid genus and place it in the subfamily Zonophyllidae.

I am not convinced by Taylor's (1951) evidence for erecting a new subgenus Cystiplasma. He recognises three subgenera of Cystiphylloides and distinguishes them on the basis of trabecular development; but there appears to be a continuous gradation between the forms with numerous septal cones (C. (Cystiphylloides)) and those with no trabecula tissue at all (C. (Paralithophyllum)). I have, therefore refrained from using Taylor's subgeneric names even though one of the species described below is almost identical with the form which Taylor figured as C. (Cystiplasma) thomasi from Plymouth.

Cystiphylloides corneolum (Wedekind and Vollbrecht) 1931

Plate 19, figs 2,4,5

Material: Specimen 10.5 and 19.6

Horizon and locality: The Jenny Start Limestone Widmouth Quarry, near Ilfracombe, North Devon.

Description: The specimen from North Devon measured 12 cm. before sectioning, but is only a part of the corallum; the proximal end and the extremity of the calyx are missing. The internal structure is well preserved, though occasional crystals of dolomite have crystallised across the structure. The preserved part of the calyx shows it to have the inverted conical form which is typical of the genus. Only fragments of the outer wall are preserved and these show it to be very thin.

Remarks: Wedekind and Vollbrecht (1931) recorded this species from the zone of Pseudocosmophyllum geigeri (= middle St zone) and Middleton has described an almost identical species - C. (Cystiplasma) sp. cf. C. schluteri (Wedekind) - from the St zone near Ogwell, South Devon; the only difference lies in the regular and more globose dissepiments which are developed in C. corneolum. The species is also very close to C. (Cystiphyllum) thomasi Taylor 1951 from the Upper middle Middle Devonian of the Plymouth area (Sp zone of Wedekind), but Taylor's species lacks septal cones and has less regular and less globose dissepiments.

Subfamily DIGONOPHYLLINAE Wedekind 1923

Arcophyllidae Morcov 1926

Arcophyllinae Stumm 1949

Arcophyllinae Taylor 1951

Genus Mesophyllum Schluter 1889

Actinocystis Schluter 1882

Mesophyllum Stumm 1949

Mesophyllum Lecompte 1952

Mesophyllum Hill 1956

Type species: by subsequent designation of Wedekind 1925, M. defectum Schluter 1889. Schluter sectioned one of the original specimens of Cyathophyllum vesiculosum and figured it as M. defectum; Stumm (1949) subsequently selected this same specimen as lectotype of C. vesiculosum, thereby making it the holotype of M. defectum.

Diagnosis: (Hill 1956) "Septa represented in dissepimentarium or throughout by septal crests by separate yard-arm carinae, or by rare traces, especially the minor septa; commonly one counter minor septum very long; keyhole fossula characteristic."

Remarks: Hill (1956) describes seven subgenera of Mesophyllum, all of which are confined to the upper Middle Devonian in Europe and elsewhere. The distinctions which Hill draws between her subgenera is very fine and it seems probable that there is a continuous gradation between at least some of the subgenera. For example, the species described below as M. (Hemicosmophyllum) irregularum has characteristics which place it midway between M. (Hemicosmophyllum) and M. (Arconhyllum). Webby (1964) has expressed similar opinions.

In my view the species lies closer to the former subgenus, hence the systematic position allotted here, but it raises a fundamental problem in the classification of this group and much further research will be needed before it is solved.

Subgenus Mesophyllum (Hemicosmophyllum)
(Wedekind and Vollbrecht) 1931

Type species: M. libatum from the middle part of the Middle Devonian, zone of Cosmophyllum duchsbergi: Dachsberg, Gerolstein and Hillesheim, Eifel district, Germany.

Diagnosis: Mesophyllum with septa dilated in the inner part of the dissepimentarium. Minor septa are either absent or represented by occasional septal crests.

Mesophyllum (Hemicosmophyllum) irregularum sp. nov.

Plate 19, figs 1,3,6

Holotype: 11.25d

Horizon and locality: The Jenny Start Limestone (Middle Devonian) of Samson's Beach, near Ilfracombe, North Devon.

Diagnosis: M. (Hemicosmophyllum) with large and irregularly developed dissepiments consisting of two series - an outer one in which the dissepiments slope gently downwards towards the axis and an inner one one on the border of the tabularium where the rows of dissepiments are vertical or nearly so. The tabellae which fill the tabularium are also large and irregular.

Description: The holotype is slightly compressed and has a mean diameter of about 3 cm. The total length of the recovered fragment, including the calyx, is 9 cm. Over this length the corallum has a regular cylindrical form. There are about twenty-eight septa which do not not reach the axis and are thickened at the border of the tabularium; they attenuate rapidly in the dissepimentarium and do not reach the axis, though they are sometimes continued outwards in the form of septal crests. Irregular isolated carinae are sometimes seen near the periphery; in longitudinal sections they appear as thin lines sloping steeply downwards and inwards (Plate 19, fig 6). The dissepimentarium occupies about two-thirds of the lumen and consists of irregularly inflated dissepiments of variable size; the steeply dipping inner series are much less inflated. The tabularium is about 1 cm. wide and is filled with irregular and globose tabellae which are generally of a larger size than the dissepiments. There are zones of skeletal dilation representing different positions of the calicular floor during the growth of the coral; these are shown in Plate 19, fig 6.

Remarks: M. (Hemicosmophyllum) irregularum differs from M. (Hemicosmophyllum) praecipitatum (Wedekind and Vollbrecht) 1931, in having fewer and less well developed septa; the dissepiments are also larger and more irregular in the North Devon form. From M. (Hemicosmophyllum) corticosum (Wedekind and Vollbrecht) 1931, it differs in having a more clearly defined tabularium, and septa which are dilated at their axial ends.

The species figured by Wedekind and Vollbrecht (1931, 1932) all come from the zone of 'Cosmophyllum dechsbergi' (upper St zone); according to Middleton (1954) this corresponds approximately to the Middle Givetian, though neither he nor Taylor (1951) record this genus from South Devon. Taylor, however, records Arcophyllum sp.

from the St zone of the Plymouth area; his figure of this species is poor, but his description suggests that it is a very closely related form.

A specimen in the British Museum (Natural History) R. 6416, labelled Cystiphyllum is almost certainly conspecific with M. (Hemicosmophyllum) irregularum; unfortunately the British Museum specimen is very much recrystallised so that the internal structure is partly destroyed.

ORDER TABULATA

Family CHAETETIDAE Edwards and Haime 1850

see Hill and Stumm (in Moore 1956)

Sub-family CHAETETINAE Edwards and Haime 1850

see Hill and Stumm (in Moore 1956)

Genus Chaetetes Fischer (in Eichwald 1829)

Genolectotype: Chaetetes cylindraceus d'Eichwald 1829

Diagnosis: (Modified from Lecompte 1939) Massive tabulate corals with prismatic corallites making an angle of 90° with the outer surface. Septa are absent or represented by rudimentary spines. No mural pores. Tabulae horizontal and tend to occur at the same level in adjacent corallites. Increase bipartite.

Remarks: Etheridge (1899) erected the genus Litophyllum for chaetetid-like forms with thickened walls; in transverse section, the polygonal form appears rounded as a result of the thickening. Lecompte (1939) included these thickened forms within the genus Chaetetes; this seems justified for within the same colony thickened and unthickened corallites can occasionally be found.

Lecompte (1939) has given a very full review of the literature on Chaetetes and he recognises the following five features as diagnostic of the genus:

1) Exclusively fissipartite (usually bipartite) increase
2) Tabulae tend to occur at the same level in neighbouring corallites
3) Mural pores are absent
4) Corallites are straight
5) Complete amalgamation of the walls between neighbouring corallites.

On this last point he admits to some uncertainty. Okulitch (1936) has observed a line marking the suture between corallites in C. radians, and Oakley (1936) has found an inclusion of dark granular material in the walls of C. akpatokensis which he attributed to recrystallization along an original suture. There are occasional dark spots within the wall structure of C. cf. rotundus described below, but there is no trace of a regular suture. The question as to whether or not a suture may be present, therefore, remains open.

C. cf. rotundus does not have straight corallites though it agrees with Chaetetes in all other respects. I have, therefore, modified the diagnosis given by Lecompte to include these curved forms.

Hill and Stumm (1956) regard Chaetetes as a Carboniferous genus, but Lecompte and many others have recorded species from the Devonian, and Whiteaves (1878) and Okulitch (1936) have described species from the Ordovician.

Smith and Lang (1930) pointed out that the walls in Chaetetes may be incompletely formed and so give the appearance of a single septum, or, in extreme cases, where the walls are locally absent, to a meandreoid colony.

Chaetetes lonsdalei Etheridge and Foord 1884

Plate 48, figs 3-4

Synonomy: see Lecompte 1939

Diagnosis: (Modified after Lecompte 1939) Large tabulate corals with straight prismatic corallites from 0.2 - 0.6 mm. in diameter. The calices may be polygonal or alveoloid in shape, with small granular or pointed spines projecting from the surrounding walls. The tabulae are well-marked - three or four occur in 1 mm. The walls are stout and increase is fissipartite.

Remarks: The form from North Devon agrees in all important respects with the ones described by Etheridge and Foord from the Middle Devonian of Queensland, and by Lecompte from the Couvinian of the Ardennes. I have modified Lecompte's diagnosis in two respects; the maximum diameter of the corallites may be as great as 0.6 mm. though it may vary considerably even within a single corallite, and I have included the alveoloid form which seems more typical of the species; The polygonal form is common, but it is almost always associated with granular spines and these, as Lecompte pointed out, are indications of incipient fission.

The tabulae are not regularly spaced but tend to occur at the same height in adjacent corallites; although they are usually horizontal, they occasionally show a slight downward projection at their centre. The walls have no dark median line though they are slightly thickened.

C. lonsdalei differs from C. multitabulatus in having much larger corallites and fewer tabulae; and from C. cf. rotundus in having larger and straighter corallites.

In North Devon all the specimens of C. lonsdalei have been obtained from the David's Stone Limestone; in the Ardennes, Lecompte found it was typical of the upper Couvinian beds. It therefore persists into later strata in North Devon.

Chaetetes multitabulatus sp. nov.

Plate 36, figs 1-2, 4-5

Holotype: 6.30 from the David's Stone Limestone of David's Stone.

Diagnosis: Chaetetes with very numerous tabulae (about 10 in 1 mm) and thickened walls from which occasional short spines project. Corallites have a diameter of about 0.25 mm.

Description: The holotype consists of a small fragment about 1 cm. square which is embedded in limestone; longitudinal and oblique (almost transverse) sections have been cut. The corallites are slightly curved in longitudinal sections and the calices are perpendicular to the external surface. The tabulae are very thin and approximately correspond in height in neighbouring corallites; they may be horizontal, slightly concave, or slightly convex. The wall structure is partially re-crystallized but a dark median line is frequently visible indicating a composite rather than fully amalgamated wall.

Remarks: C. multitabulatus differs from C. cf. rotundus in having more numerous and thinner tabulae and in the greater thickening of the walls.

Horizon: The David's Stone Limestone is considered to be Frasnian in age.

Chaetetes cf. rotundus Lecompte 1939

Plate 36, fig 3

Description: The specimen is part of a massive, branching, or irregularly lamellar colony, measuring approximately 20 x 15 mm. The specimen has been abraded prior to interment.

The corallites are in close contact and polygonal in transverse section, though the calices are somewhat rounded due to thickening of the walls. The corallites are mostly curved in longitudinal section but the calices always reach the exterior at right angles to the surface of the corallum.

The diagonal measurements of fully developed corallites vary from 0.2 - 0.25 mm; smaller ones can be seen in transverse section but that these are immature specimens is confirmed by their appearance in longitudinal section.

The width of the walls shows a marked variation - the thickest is 0.04 mm. and the thinnest 0.01 mm.; a dark median line is sometimes

visible showing that the walls are not fully amalgamated.

No spines or septa are visible, and mural pores are absent.

The tabulae are not regularly spaced (about five in 1 mm.) and they tend to become more numerous towards the distal ends of corallites. Many of the tabulae are slightly convex distally and they do not occur regularly at the same height in neighbouring corallites.

Remarks: The specimen is similar in many respects to C. regularis Lecompte; however, the tabulae are more widely spaced and less regular in C. cf. rotundus and it has thickened walls. The specimen is closest to C. rotundus Lecompte, differing only in the form of the corallum and in the slight arching of the tabulae.

Material: One specimen (No. 15.1) from the David's Stone Limestone of Hillsborough near Ilfracombe.

Family FAVOSITIDAE Dana 1846

Sub-family ALVEOLITINAE Duncan 1872

Genus Alveolites Lamarck 1801

Synonomy: see Lecompte 1933 and 1939

Genolectotype: Alveolites suborbicularis - see Edwards and Haime 1850.

Diagnosis: see Smith 1933

Remarks: Lecompte (1933,1936,1939) has fully reviewed the literature pertaining to this genus and has pointed out the features which separate it from Favosites, Thamnopora, and Coenites. Although the obliquity of the calice is apparent in most species, occasional individuals within a single colony may open perpendicularly to the outer surface. Lecompte has questioned the reality of a single large septum, suggesting that it is the first stage in fissipartite increase. The material from North Devon is so poorly preserved that it is impossible to investigate this matter further.

Range: Silurian and Devonian.

Alveolites suborbicularis Lamarck

Plate 43, figs 1-4
Plate 44, fig 1
Plate 45, figs 1-5

Synonomy: see Lecompte 1933 and 1939

Lectotype: Calamopora spongites var. tuberosa, Goldfuss p.80, pl.xxviii, figs 1a-g (not h). See Smith 1933. Lamarck's original type is lost (Lecompte 1936).

Diagnosis: see Smith 1933.

Remarks: Lecompte believed that granular spines were also developed at various positions in the corallite in addition to the prominent septum on the lower side. Smith, however, regarded the granular spines as a recrystallization phenomenon (see comments in Lecompte 1936, p.7). The recrystallized appearance of the North Devon specimens (see, for example, Plate 45, fig 1, in which the appearance of additional septa is an illusion resulting from recrystallization) suggest that Smith's interpretation is correct.

In North Devon, this species occurs in the Jenny Start, Combe Martin Beach, and David's Stone Limestones; one specimen collected measured 25 x 35 cms (Plate 45, fig 5; see also Plate 44). All the specimens are at least partially recrystallized and distorted; specimens from the Jenny Start Limestone tend to have more widely spaced tabulae (about three in 1 mm) and larger calices than those from the David's Stone Limestone (about four tabulae in 1 mm). Specimens from the Combe Martin Beach Limestone are relatively small and are frequently found encrusting Thamnopora; they are common only at the East end of The Parlour, near Combe Martin; recrystallization has obliterated most of the original wall structure but occasionally the median dark line is discernible; the tabulae are thin and spaced irregularly - about four in 2 mm.

Range: Middle and Upper Devonian. In Belgium, Lecompte has not recorded the species below the base of the Frasnian.

Alveolites suborbicularis forma gemmans

Plate 46, figs 1-2

Most commonly, A. suborbicularis is an encrusting coral which tends

to develop in relatively thin layers around some convenient object, often another coral colony (e.g. Plate 41, fig 5). Lecompte (1939) has noticed, however, a continuous series away from this simple form through ones in which there are slight or moderate swellings on the outer surface (due presumably to the more rapid and successful growth of some corallites), into forms which have developed definite branches and have abandoned the lamellar form completely; the former he classed as forma gemmans and the latter as formae subramosa and contortus. The specimen figured from North Devon still has an essentially lamellar form but has a marked swelling across its surface; it therefore falls within the morphological group forma gemmans. It occurs in the Jenny Start Limestone (Givetian).

Alveolites multiperforatus Lecompte 1933

Plate 47, figs 1-2

Type species: Alveolites multiperforatus Salée (name only in manuscript). Collection of The Musée Royal d'Histoire Naturelle de Belge.

Diagnosis: Massive or encrusting tabulate corals. Calices with polygonal or sub-alveoloid form; septal spines rare. The walls are irregularly thickened and mural pores are numerous throughout the corallum. The tabulae are thin, horizontal or slightly convex.

Remarks: The species was fully described by Lecompte (1933) but without a diagnosis. He attributed the authorship of the species to Salée, but Salée's work was never published and as Lecompte's is the first published description, the species must be attributed to him. Lecompte did not, however, give a precise diagnosis.

The abundance of the mural pores, together with the irregular thickening of the walls, gives the appearance of 'boudins' in longitudinal section. In North Devon, the species has been obtained

from the Jenny Start Limestone of Widmouth; the skeletal structure is partially recrystallized, but the thickening of the walls and the numerous mural pores are readily seen. The tabulae are irregularly spaced - about three in 1 mm; this agrees well with the specimen figured by Lecompte (Plate 3, fig 1b). The growth of the coral is also irregular and the corallites are rarely straight or parallel for more than short distances. The exterior surface shows the dominantly polygonal form of the calices but with some assuming a more alveoloid shape (Plate 47, fig 2).

In the Ardennes, the species occurs in the Frasnian, associated with Thamnophyllum, Stromatopora and Acervularia; a somewhat similar association is found in the Jenny Start Limestone (Givetian) of North Devon.

Alveolites obtortus Lecompte 1939

Plate 51, figs 1,4

Diagnosis: see Lecompte 1939

Remarks: One of the distinguishing features of this species is the arrangement of the corallites into fascicles which are irregularly disposed and often interlaced with each other; this feature is well seen in the North Devon specimens. Because of the poor preservation, however, it is not possible to see the concentration of mural pores in the outer parts of the fascicle; there is evidence that the tabulae are more numerous in these peripheral parts and there is some thickening of of the corallite walls. The calices agree with the description given by Lecompte, being polygonal or subtriangular, yet with diameters almost equal.

Lecompte records his species from the Frasnian of the Ardennes;

in North Devon, the two specimens assigned to this species occur in the Jenny Start Limestone.

Coenites d'Eichwald 1829

Synonomy: Limaria Steininger 1831.

Type Species: Coenites juniperinus d'Eichwald.

Diagnosis: see Lecompte 1939.

Remarks: Some workers (e.g. Lindström 1876, Hennig 1906) regarded Coenites as a bryozoan; Oakley (1936) showed conclusively that Coenites was, in fact, a tabulate coral. Lecompte (1939) stated that there are three main critera for recognising the genus and distinguishing it from Alveolites and Thamnopora -

a) It has considerable distal thickening of the walls
b) It has a slit-like calicular opening
c) It frequently shows three septal processes (though these are not always visible, and sometimes (as Oakley observed) there may be six).

The genus is clearly closer to Alveolites than to Thamnopora and I agree with Hill and Stumm (1956) in placing both Alveolites and Coenites in the same sub-family.

The tectonic distortion and recrystallization (the latter being particularly marked in this genus and Alveolites) has affected all the specimens to a greater or lesser extent, making it difficult to assign specific names in every case; the two species described below are, however, well represented.

In the Ardennes, Lecompte found that the genus was confined to the Middle Devonian. In North Devon it is also of Givetian age (Jenny Start Limestone) and it has not been found in the David's Stone Limestone (Frasnian).

Coenites escharoides (Steininger) 1849

Plate 48, figs 1-2, 5.
Plate 52, fig. 2

Synonomy: see Lecompte 1939.

Diagnosis: see Lecompte 1939.

Remarks: Steininger's brief original diagnosis was amplified by Schlüter (1889), but both described only the external characters. Neither Lecompte nor myself has re-examined the type and Lecompte's diagnosis, which included the internal characters, is based upon material collected in the Ardennes.

The North Devon specimens are partly affected by recrystallization, which obscures the finer details of the structure; I have little hesitation, however, in identifying them with the specimens described and figured by Lecompte from the Ardennes. Plate 52,(2) shows well the foliated form of the colony and the scaly appearance of the exterior surface. Longitudinal sections show relatively unthickened central area in which the corallites run parallel to the outer surfaces, and abruptly thickened marginal areas where the corallites are sharply bent to become perpendicular to the outer surfaces.

The lamellar coralla have a thickness of 2-5 mm. and the calicular openings, which are very restricted because of the stereoplasm, have a maximum diameter of 0.3-0.5 mm. The thickening of the surrounding walls may also be as much as 0.5 mm.

Because of the recrystallization, tabulae are not readily seen and in many cases have been completely destroyed; where they are visible, they are numerous, very thin, and often slightly concave.

All the specimens referred to this species have been obtained from the Jenny Start Limestone of Hagginton Beach and Widmouth Quarry.

Coenites gradatus Lecompte 1939

Plate 49, figs 1-4

Diagnosis: see Lecompte 1939.

Remarks: This is a very common species in the David's Stone Limestone of Broadstrand (Hillsborough). Some of the specimens are moderately well-preserved, and the zonation which characterises the species is well seen (Plate 49, fig 3). This zonation is frequently emphasised by the preservation, the exterior fringe of each zone being better preserved than the interior parts which are entirely recrystallized. This suggests that recrystallization took place at an early stage, even before the colony finally died. Tabulae are rarely seen, but in one corallite where they are preserved, they are closely spaced (three in 0,5 mm). The calices are crescent-shaped and may show a median spine. Sometimes the wall between adjacent corallites is absent (? fissipartite increase) giving the colony a meandroid appearance in transverse section.

In the Ardennes the species occurs in both the Couvinian and Givetian. Its occurrence in the David's Stone Limestone suggests that its range extends into the Frasnian.

Coenites sp.

Plate 50, figs 1-4

Description: Branching corallum with corallites straight at the axis and bending round sharply outside this in order to meet the exterior surface at right angles. The calices are much restricted by the thickening of the walls but they are commonly crescent-shaped and sometimes contain a prominent spine projecting in from the lower side (Plate 50, fig 2). The diameter of the branches varies from

2-14 mm., but the average is about 8 mm. Thickening is strong in the peripheral areas but it is also present to a lesser extent in the axial zone where the tabulae are few and widely spaced.

Remarks: Only one example of this species has been found. It was obtained from the Jenny Start Limestone of Samson's Bay. In the form of its corallum it resembles C. escharoides but the branches of the latter are much thinner and the number of corallites in the axial zone fewer. Generically, it is similar to Plagiopora (especially P. kaisini) but it lacks polygonal calices with three spines and it has greater thickening of the corallite walls. It is probably a new species, but with such limited material I have hesitated to create one.

Sub-family PACHYPORINAE Gerth 1921

Genus Thamnopora Steininger 1833

Synonomy: see Lecompte 1939.

Diagnosis: see Lecompte 1939.

Discussion: Contrary to most other workers (see especially Lang, Smith and Thomas 1941), Lecompte does not regard Pachypora Lindström as a synonym of Thamnopora. He argues that the lamellar structure seen in Pachypora lamellicornis is fundamentally distinct from the fibrous structure of Thamnopora. Lindström (1896) himself argued most emphatically against the synonomy, and it does seem strange that the lamellar structure is not present in any other species of Thamnopora. The two structures imply differences in the $CaCO_3$ deposition by the basal ectoderm and unless Hill (see Lecompte 1939) is correct in interpreting the lamellae as a recrystallization phenomenon (and I do not believe that she is), then Lecompte is justified in omitting Pachypora from his synonomy.

Range: Silurian to Trias, but it is most common in the Devonian and Permian.

Thamnopora boloniensis (Gosselet) 1877

Plate 40, figs 5-6, 9
Plate 47, fig 3

Synonomy: see Lecompte 1936 and 1939.

Diagnosis: see Lecompte 1936 and 1939.

Material: Three specimens from the Jenny Start Limestone and two from the David's Stone Limestone.

Description: a) Jenny Start Limestone: specimens from the Jenny Start Limestone agree with the diagnosis of T. boloniensis except that the size of the calices is smaller (maximum diameter about 1.5 mm). The corallites are, however, markedly larger than all other forms from North Devon. Only fragments of coralla have been collected and from one (14.23) a longitudinal section has been cut. The maximum diameter of the branch is 14 mm and its length (incomplete) is 50 mm (Plate 40, fig 9). The diameter of the corallites at the periphery varies from 1.1-1.5mmm, and the walls are thickened throughout, though most strongly at the periphery. The obliquity of the corallites varies from 60°-90°. Mural pores are numerous and are approximately 1.2 mm apart. Tabulae are moderately numerous in the axial region (4-5 in 2 mm.) but they tend to be irregularly grouped.

b) David's Stone Limestone: two specimens have been sectioned longitudinally and these agree in all respects with Lecompte's diagnosis. The branches have a diameter of at least 15 mm and the largest calices are over 2 mm across. Mural pores are common and have a diameter of about 0.15 mm. Tabulae are few and are slightly ~~concav~~ concave. The walls are thickened throughout but most strongly at the distal ends.

In the Ardennes, Lecompte found that this species was characteristic of the Frasnian; in Devon, the species occurs in both the Upper Givetian (=Jenny Start Limestone) and the Frasnian (=David's Stone Limestone) but the earlier forms appear to show slight variations. Lecompte's studies, however, showed that T. boloniensis is a very variable species even within the Frasnian, and its most persistent

feature is the large size of the calices. I have, therefore, placed the two forms described above in the same species.

Thamnopora cervicornis (de Blainville) 1830

Plate 41, figs 3-5

Synonomy: see Lecompte 1936 and 1939.

Diagnosis: see Lecompte 1939.

Remarks: The species has been identified from the Rillage and the Combe Martin Beach Limestones. The single specimen from the Rillage Limestone (Plate 41, fig 5) is remarkable because of its prominent spines seen in longitudinal section. The calices have a diameter of 1-1.2 mm. and the thickness of the walls is irregular, though most prominent at the distal ends of the corallites. The branch is irregular in diameter but reaches a maximum of 15 mm. Along the sides of the branch the corallites bend round to reach the exterior at right angles, but at its extremity, they make an angle of about 60°. Tabulae are irregularly spaced and may be slightly convex or concave.

In the Combe Martin Beach Limestone the species is locally common (especially at the entrance to The Parlour). Specimens are frequently overgrown by Alveolites and appear to be preserved in their growth positions. The corallites are smaller and more numerous in the corallum than in the specimen from the Rillage Limestone. The corallites have a diameter of about 0.9 mm. and make an angle of 50°-60° with the outer surface at the extremity of the branches; along the sides, however, they are perpendicular or even directed posteriorly (see Plate 41, fig 4). Thickening of the walls is again irregular but most strong at the distal ends.

In the Ardennes the species is only recorded from the Givetian.

Lecompte (1939) found that the corallites of specimens from horizon Gib were smaller on average than those from Gid (Upper Givetian). This is most probably an ecological rather than evolutionary variation and although the North Devon specimens approximate more closely to Lecompte's Gib specimens, the evidence is too uncertain to draw definite conclusions.

Thamnopora cronigera (d'Orbigny) 1850

Plate 40, figs 1-4,7-8

Synonomy: see Lecompte 1936 and 1939.

Diagnosis: see Lecompte 1939.

Remarks: Lecompte (1939) regarded T. cronigera as intermediate between T. polymorpha and T. cervicornis and he found difficulty in defining the precise limits of each species. Typically, the corallum of T. cronigera is smaller and has less tendency to branch than T. polymorpha; it also has fewer tabulae. However, it is less thickened by stereoplasm than T. cervicornis and the calices are in consequence not so rounded.

The specimens from North Devon referred to this species are all broken fragments but are closely similar to those which were described and figured by Lecompte from the Dinant Basin; these differed from the type selected by d'Orbigny (Goldfuss 1831, pl.27, fig 3) in being more 'robuste' and having calices more rounded in the axial zone.

In the Dinant Basin, the species occurs in beds Gib and Gic of the Middle Givetian. In North Devon, the species is common in the Jenny Start Limestone but has not been identified from any of the other limestones.

Thamnopora dubia (de Blainville) 1830

Plate 39, figs 5,7-12

Synonomy: see Lecompte 1936 and 1939.

Diagnosis: see Lecompte 1939.

Remarks: The species is common in the Jenny Start Limestone of North Devon. Several specimens have been sectioned and these agree well with those figured and described by Lecompte. The diameter of the branches is 6 - 8 mm., except for specimen 13.71 which is slightly larger (10 mm). The latter specimen (figured in plate 39, figs 11-12) shows well the septal spines, though it is possible that recrystallization in the centre of the corallite has accentuated them. The thickening of the walls is well-marked in all the specimens and it characterises the whole corallum. The average diameter of the calices is 1.7 mm; none reaches the maximum diameter of 2 mm. mentioned by Lecompte in his diagnosis.

Lecompte (1936) made a detailed study of the species and refigured and described the original of Goldfuss, which shows no trace of septal spines. He accepted Quenstedt's (1881) view that the species should be interpreted more liberally and framed his diagnosis accordingly. The specimens from North Devon are too few and too poorly preserved to be used either in support of, or against, Lecompte's interpretation; his views are, therefore, accepted uncritically.

In the Ardennes, the species ranges from Givetian to Frasnian. In North Devon it characterizes the Givetian Jenny Start Limestone though a single specimen from the David's Stone Limestone is doubtfully referred to the species.

Thamnopora irregularis Lecompte 1939

Plate 41, figs 1-2,6-7
Plate 42, figs 1-2

Diagnosis: see Lecompte 1939.

Remarks: The specimens from North Devon agree very closely with the diagnosis and description given by Lecompte, though the tabulae tend to be more closely spaced and the distal thickening somewhat greater than the holotype. The species has only been found in the Jenny Start Limestone, where it frequently forms large ramifying masses. In the Dinant Basin the species is found in the Gia and Gib beds of the Givetian.

Thamnopora polymorpha (Goldfuss)

Plate 37, fig 1
Plate 38, figs 1-5

Synonomy: see Lecompte 1936 and 1939.

Lectotype: Calamopora polymorpha var. tuberosa Goldfuss 1826, plate 27, figs 2a, 2b, 2c, 2d.

Diagnosis: see Lecompte 1939.

Remarks: This species is very characteristic of the David's Stone Limestone and has not been found in any of the other limestones of the Ilfracombe Beds. The original fibrous structure is still visible in most of the examples collected. The form of the corella is irregular but they tend to be branching or lamellar with marked bulbous projections.

The average diameter of the corallites is slightly smaller than in the examples from the Ardennes, but otherwise the North Devon specimens agree closely with the type.

In placing the species within the genus Thamnopora I am following Lecompte 1939, who argued that the internal thickening resulting in rounding of the calice is never found in true favositids, only in species of Thamnopora. He admits, however, that T. polymorpha forms a transition between indisputable species of Favosites with thin walls and angular calices, and typical Thamnopora with well-rounded calices and branching corallum. Lecompte makes the point that Favosites is typical of Middle Devonian strata, and does not extend into the Upper Devonian except for occasional aberrant forms, while Thamnopora showing intermediate characteristics appears in the Couvinian and by the Givetian and Frasnian has developed the typical thamnoporid features. This leads him to suggest that Thamnopora may have evolved from Favosites during the Lower Couvinian. Earlier (Holwill 1964) I reported the presence of Favosites in the David's Stone Limestone, but I was then interpreting T. polymorpha as a favositid; no other species of Favosites occurs in the limestone.

In Belgium, T. polymorpha occurs in Couvinian and Givetian beds (including bed Gid - uppermost Givetian). In North Devon the species appears to persist into the Frasnian, though its presence suggests that the David's Stone Limestone is at a low horizon within the Frasnian.

Thamnopora tumefacta Lecompte 1939

Plate 39, figs 1-4

Diagnosis: see Lecompte 1939.

Remarks: Three specimens have been referred to this species. All of them are fragments but they agree closely with Lecompte's diagnosis and description except that they are somewhat smaller - the maximum diameter of the corallum being 6-7 mm. The maximum diameter of the

corallites is 0.9 mm., but the walls are strongly thickened, especially distally, so that the aperture may be reduced to 0.2 mm. or less. The corallites bend round so as to reach the outer surface at right angles.

Lecompte has recorded the species from the Upper Couvinian and Givetian of the Dinant Basin. In North Devon the species occurs in the David's Stone Limestone, i.e. it extends upwards into the Frasnian.

Aulopora tubaeformis Goldfuss 1826

Plate 51, fig 2
Plate 52, fig 1

Synonomy: see Lecompte 1936.

Diagnosis: see Lecompte 1939.

Remarks: Only two very small and incomplete colonies, both from the David's Stone Limestone, have been collected. One of them shows two corallites, partly broken and revealing a thin horizontal tabula (Plate 52, fig 1). The other specimen is slightly larger, but is embedded in argillaceous limestone and therefore not seen in relief. The diameter of the calices is about 1.5 mm., and they are about 5 mm. long; they are linked together in a single chain. The preservation prevents any of the other details of the species being observed but its size and the form of the corallites are sufficiently diagnostic.

Pleurodictyum sp.

Plate 51, fig 3

Remarks: Valpy 1867 recorded Pleurodictyum from the Hagginton Beach area. I have not been able to trace his specimen but it may be the one in the British Museum (Nat.Hist.) No.R6421; this is the

specimen figured. It consists of a very poorly developed mould into which dolomite crystals have grown. There is no precise record of its locality beyond the fact that it comes from Hagginton Beach, but its preservation and the appearance of the limestone matrix make it almost certain to have been obtained from the Combe Martin Beach Limestone which crops out in many localities along Hagginton Beach. Specific identification is impossible.

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With the Author's Compliments

The Succession of Limestones within the Ilfracombe Beds (Devonian) of North Devon

by F. J. W. Holwill

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ABSTRACT: Previous workers in North Devon have, in general, considered that there are numerous limestone bands developed within the Ilfracombe Beds. The present paper demonstrates that there are only two main limestones, each about thirty feet thick, which, though similar in lithology, have a markedly different coral fauna. These limestones are separated by about 250 feet of slate in which occurs a further limestone only three to four feet thick with a distinctive lithology.

The fauna so far obtained from these limestones suggests an upper Givetian or Frasnian age for the succession; the coral fauna from the thin intermediate limestone is not recorded elsewhere in the British Isles, but it is comparable with a fauna from the Hlubočepy Limestone (Middle Devonian) of Bohemia.

The total thickness of the beds in which the limestones occur is only about 350 feet.

1. INTRODUCTION

THE CALCAREOUS nature of many of the beds in the neighbourhood of Ilfracombe has long been recognised. The first map showing these calcareous beds was made by Vancouver (1808). Although not a geologist he paid some attention to the distribution of the limestones on account of their value to the local agriculture—most of the Devon soils being deficient in lime. His map shows two continuous calcareous bands running ESE. from the Ilfracombe region, but it is clear from the text that he regarded these bands as 'veins' in the slaty killas, and not as part of the stratigraphical succession.

William Smith's map of 1815 shows a series of lenticular patches of limestone in the North Devon area. They are by no means accurately

placed with reference to the present outcrops of limestone, and the map does no more than show diagrammatically that Smith probably regarded the limestones as lenticular in their development. This interpretation has been followed by almost all later workers.

Sedgwick & Murchison (1837, 1840) were the first to publish detailed observations on the Ilfracombe Beds and the limestones in particular. They thought that there were 'at least eight or nine courses of highly calcareous slate in some places passing into great bunches of bluish crystalline limestone' (Sedgwick & Murchison, 1840). The section published with this paper, as well as the text, suggests that these writers also regarded the limestones as lenticular in their development.

De la Beche (1840) is even more definite in his opinion—'The Combe Martin limestones do not, as has been supposed, form regular bands continuous for considerable distances through the country. They seem to constitute lenticular masses of variable size, developing amid argillaceous slates, some fining off very gradually, others more abruptly.'

Little further progress was made in elucidating the stratigraphy and structure of the Ilfracombe Beds during the latter part of the nineteenth century. Most geologists seemed content to place the Ilfracombe Limestones in the Middle Devonian by analogy with the great calcareous development of this age in South Devon and Northern Europe. Jukes (1856) was almost alone in disagreeing with this 'orthodox' interpretation; he placed them in the Lower Carboniferous because of the lithological similarity between the strata in North Devon and the Lower Carboniferous beds of Southern Ireland. Etheridge (1867) clearly demonstrated that the palaeontological evidence in North Devon made Jukes's idea quite unacceptable.

The only detailed work on the Ilfracombe Beds which has been published in this century is that by J. W. Evans. He first concluded (Evans, 1919) that a great part, if not the whole, of the Ilfracombe Beds must be referred to the Upper Devonian since *Calceola sandalina* and *Stringocephalus burtini* are both absent, and *Spirifer verneuili* and *Rhynchonella* (*Hypothyridina*) *cuboides* occur at a low level within the Ilfracombe Beds. Three years later he subdivided the beds as follows (Evans, 1922a):

			Thickness (feet)	
FRASNIAN	ILFRACOMBE BEDS	Woolscott Cleave Slates	250	1290
		Slates with subordinate grits and limestones	1000	
		David's Hole Beds	250	
		Red Limestone Series	355	
		Jenny Start Beds	30	
		Slates and limestones of Oakestor Bay ...	135	
		Newberry Beds	520	
		Lester Series	1050	
GIVETIAN		Wild Pear Beds	400	
COUVINIAN	HANGMAN GRITS	... ...	3600	

Later still, Evans (1929) omitted the slates and limestones of Oakestor Bay from the succession, regarding these as the probable equivalents of the Lester Series.

Important limestone horizons were thought by Evans to occur in each of the divisions from the Newberry Beds to the David's Hole Beds. The Hangman Grits are placed in the Couvinian and the Ilfracombe Beds are

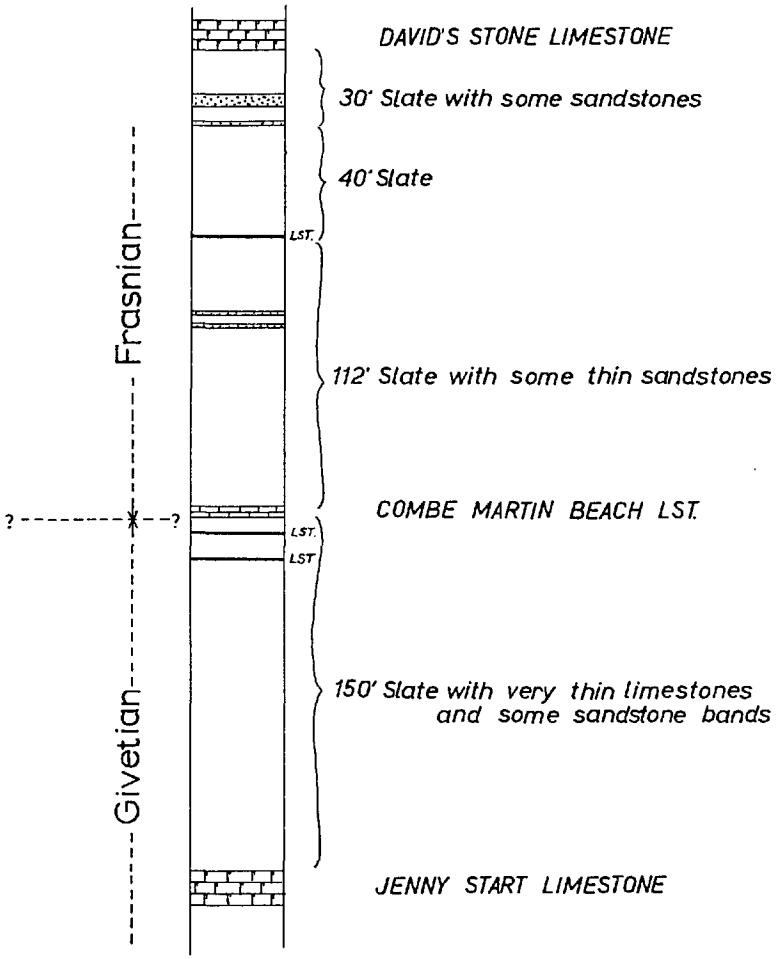


Fig. 1. The revised succession of beds within the middle part of the Ilfracombe Beds based on the section seen at the west end of Newberry Beach, near Combe Martin

split between the Givetian and the Frasnian, though the Givetian–Frasnian boundary is only given tentatively.

Within the last eight years much work has been done on the structure of the Ilfracombe Beds by D. J. Shearman. Except for a short paper on the Combe Martin Fault read to the Association (April 1962), though his ideas on the structure of the Ilfracombe Beds were expressed during his leadership of a Geologist Association Field Meeting to the area in 1956, and to the present author on many subsequent occasions. Shearman suggests that on structural and lithological grounds there could be either one or two (not more) main limestones within the Ilfracombe Beds. He has also shown that all the NW.–SE. trending faults along the North Devon coast have a dextral transcurrent component. It is the purpose of this present paper to show that on palaeontological grounds there must be two quite distinct main limestones and that between them occurs a third thin, but highly distinctive, limestone. The revised succession is shown in Fig. 1.

2. THE SUCCESSION BETWEEN COMBE MARTIN AND DAVID'S STONE

This succession was termed the Newberry Beds by Evans (1922a). The oldest strata of the Newberry Beds are a succession of flaggy limestones with numerous shaly partings towards the top. The beds are only exposed at lowest spring tides and even then are completely concealed below a cover of seaweed, barnacles and other encrusting organisms. From the upper thin-bedded limestones the coral *Endophyllum* has been obtained. It occurs in large colonies and although partly recrystallised and bored by recent molluscs, it can be recognised as identical with the species of *Endophyllum* obtained from Jenny Start and identified by Smith (*in* Evans, 1922b) as *E. bowerbanki*. In thin section the main part of the limestone shows what appears to have been an oolitic texture. The 'ooliths' are much compressed and slurred out (Plate 13 A). Grains of quartz are moderately abundant, and there are occasional traces of bryozoa and crinoids. The matrix surrounding the 'ooliths' is fine-grained crystalline calcite.

This limestone is overlain by about eighty feet of slate with occasional very thin limestones and some sandstone bands about the middle of the succession. Then comes a limestone about three feet thick which is very distinctive in its appearance and fossil content. Evans merely described it as a highly ferruginous limestone containing a considerable amount of pyrites and associated above and below with green calcareous shales. It is well seen on the west side of Combe Martin Beach and it has been termed the Combe Martin Beach Limestone (Holwill, 1961); it can be traced westwards across the foreshore at Combe Martin as far as the Parlour, at which point it is faulted out to sea.

In the Combe Martin and Newberry area, the Combe Martin Beach Limestone is approximately four feet three inches thick, though it often gives the impression of being thicker as a result of drag folds. It is intimately associated with a greenish (? chloritic) shale which forms partings within the limestone and 'streaks out' into it. A typical exposure of the limestone on Newberry Beach shows the following subdivisions:

	ft.	in.
Very impure limestone crowded with fossil fragments, especially fenestellids, crinoid ossicles and occasional solitary corals ...		4
Green shale		1
Limestone		11½
Green shale		1½
Limestone		8
Green shale		1
Limestone		5½
Greenish shale and limestone		2
Limestone		4½
Green shale		4
Limestone		7
	4	3

All the limestones contain fossil fragments but corals are extremely rare except in the uppermost band. Plate 13 B shows the appearance of the limestones in thin section. The limestones also contain wisps and pellets of green shale in hand specimens. Freshly broken surfaces of the limestone have a purplish grey colour but weathered surfaces are a rusty brown on account of the abundance of pyrite.

The Combe Martin Beach Limestone forms a marker horizon of great importance because it retains its characteristic appearance and fauna when it crops out again on Hagginton Beach and at Beacon Point some two miles farther west. From it have been obtained the following corals: *Barrandeophyllum*, *Syringaxon*, *Metriophyllum*, *Alveolites* and *Thamnopora*, together with an abundance of bryozoa, poorly preserved brachiopods and occasional small gastropods. The corals are always fragmentary and often so distorted and recrystallised as to be of little value for specific identification. However, it has been possible to identify some of the better preserved specimens and it is hoped to describe these in a subsequent paper.

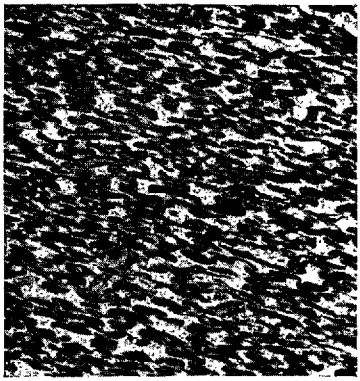
Above the Combe Martin Beach Limestone there is about 190 feet of slates with occasional very thin 'pleated' limestones and some sandstones up to about two feet thick. (The term 'pleated' is used to describe thin drag-folded limestones where the folding bears a marked resemblance to the pleats in a skirt.) At this point in the succession, which is the top of Evans's Newberry Beds, occurs another thick limestone. It crops out in the very top of an almost unscaleable cliff above the Parlour and it has also been

quarried in former times from the top of the cliffs, but it is impossible to measure the thicknesses of these beds accurately as the quarries are largely infilled with refuse from the adjacent caravan site. The estimated thickness is twenty to thirty feet and it consists of bands of massive limestone separated by calcareous slates which weather to a very rotten papery shale. The limestones are blue when fresh and mostly recrystallised; they weather to a rusty brown rotten-stone. Numerous blocks of the limestone have fallen on to the beach below, but in none of them has any trace of corals been found, except for doubtful fragments of *Thamnopora*. In thin section, parts of the limestone are seen to be detrital with a microscopic 'augen' structure sometimes developed. The 'eyes' are formed of calcite crystals—probably derived from crinoid ossicles (Plate 13 C); the finer matrix is often dolomitised so that there is differential weathering of the rock, producing a characteristic pock-marked appearance (Plate 13 D). Quartz grains are much less common than in the limestone seen at low water on Newberry Beach.

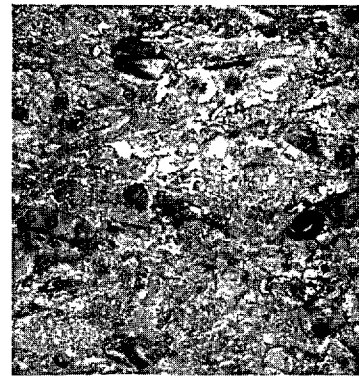
The lowest part of this limestone has been examined in the cliff face and shows a normal succession upwards from the slates of the Newberry Beds. The limestone can be followed westwards high up in the cliffs, but is stepped progressively to the north by the dextral displacement of the NW.–SE. faults.

3. THE SUCCESSION AT DAVID'S STONE

On the beach at the foot of the path leading down to David's Stone is a prominent limestone. It has been quarried from the foreshore at this point but it can still be seen in the cliffs immediately to the south. It can also be found in the gully immediately to the north and again where it is caught up in the core of a syncline plunging westwards, on David's Stone itself (Fig 2). This limestone is termed the David's Stone Limestone (Holwill, 1961) and is massive and flaggy. The total thickness of the David's Stone Limestone at this point is approximately thirty feet. This thickness is made up of a lower band of massive limestone twelve feet thick which has been quarried out from the gully that separates David's Stone from the main cliff. This limestone is overlain by six to eight feet of calcareous slate and then there is a further ten to twelve feet of massive limestone. At the top of the lower limestone is a very fossiliferous band of impure limestone varying from twelve to eighteen inches in thickness. Above the upper band of massive limestone are two bands of detrital limestone three to six inches thick. These two bands are also fossiliferous and in addition to abundant crinoid ossicles and bryozoa they contain occasional solitary corals of the family Laccophyllidae (mostly *Syringaxon*, but also *Barrandeophyllum*) and the tabulate coral *Thamnopora*. A similar fauna is found in the upper fossiliferous band of the lower limestone. Both upper and lower bands of



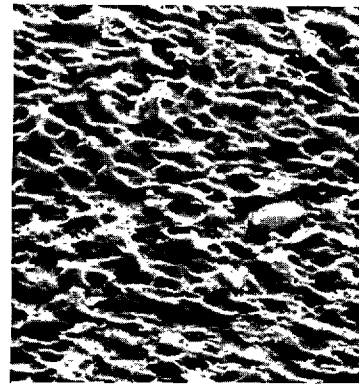
A



B



C



D

A. A thin section (ordinary light) of the Jenny Start Limestone showing the slurred ooliths. (From the low water exposure on Newberry Beach) × 4

B. A thin section (ordinary light) of the Combe Martin Beach Limestone showing the abundance of fossil fragments—mostly crinoid ossicles, bryozoa and algae. (From the west end of Newberry Beach) × 4

C. A thin section (ordinary light) of the David's Stone Limestone showing the augen structure formed by large calcite crystals. (From the cliffs above Newberry Beach) × 4

D. Subaerially weathered surface of David's Stone Limestone showing a typical 'pocked-marked' surface. × 2

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massive limestone show a pock-marked appearance on weathered surfaces.

About eighty yards south of these outcrops at David's Stone, at the head of a narrow fault gully can be found a similar limestone dipping at about 70° to the south. With it are associated two thin detrital limestones, exactly similar to those mentioned in the previous paragraph, but these are apparently *below* the main limestone. The obvious inference is that the limestone is inverted and this interpretation is amply confirmed by the structural criteria (drag folds and cleavage).

The inverted limestone can be followed up into the cliffs where there is a readily accessible exposure in which the limestone with its fossiliferous bands at the top can be followed over the crest of an anticline to dip south on a normal limb beyond. There can be no doubt that this limestone is the same as the David's Stone Limestone. This is unequivocally established by palaeontological, lithological and structural observations. Fig. 2 shows a section of the structure at David's Stone, and the cliffs above.

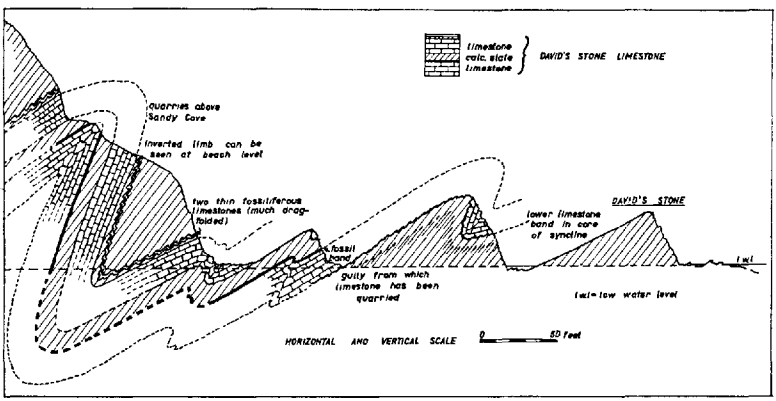


Fig. 2. Composite section showing the structure at Sandy Cove, near David's Stone

Evans regarded this limestone (which he includes with the David's Hole Beds) as being at a much higher horizon than anything in the Newberry Beds, since he thought that a major fault at the west end of the Parlour 'cuts out a considerable portion of the succession and brings in a much higher series consisting of white limestone and calcareous slate' (Evans, 1922a). In fact, the same series of relatively small NW.–SE. faults which carry the Combe Martin Beach Limestone out to sea in the Parlour, bring the massive limestone, seen at the top of the Newberry series at the east end of the Parlour, down nearly to beach level in the gully immediately east of David's Stone. There can be little reasonable doubt therefore that this limestone at the top of the Newberry Beds is in fact the same as the David's Stone Limestone.

Above the David's Stone Limestone at Sandy Bay are striped grey and green shales with lenticles of fine-grained calcareous grits and occasional very thin limestones. Below there is a succession of shales with some massive grits and thin limestones.

4. THE SUCCESSION BETWEEN DAVID'S HOLE AND JENNY START

Evans (1922a) supposed the David's Hole Beds to continue to the west across Sandy Bay until cut off by an 'important NE.–SW. fault', and to be separated by 'a gap of unknown amount' from an underlying series of striped calcareous slates which he refers to as the Red Limestone Series. He was therefore unable to define the natural base of the David's Hole Beds.

The Red Limestone Series was so called because it contains a limestone which has a prominent red coloration where it crops out in a large isolated stack on the foreshore about 120 yards south of Jenny Start. The same limestone can also be seen in the cliffs displaced about forty feet to the north, but here the reddening is much less noticeable, and traced up the cliff it loses all its red colour. The colour is clearly only a local development, probably the result of iron staining in the vicinity of the fault.

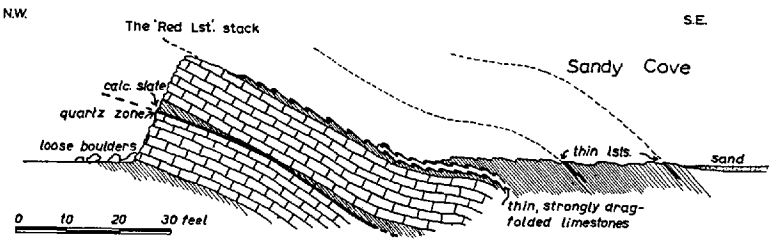


Fig. 3. Sketch section through the 'Red Limestone' sea stack in Sandy Cove, near Combe Martin.

The total thickness of limestone seen in the stack is twenty-four to thirty feet, and this is made up of two bands of massive limestone, each about ten to twelve feet thick, separated by a wedge of calcareous slate about two feet thick (Fig. 3). In the cliff forty feet to the north, the two massive limestone bands are separated by about six to eight feet of slate and it is therefore considered that some of the slate has been cut out on the stack as a result of differential movement between the two competent limestone bands. The movement has no importance in considering the sequence of limestones in the area.

Two thin limestone bands very much contorted by drag folding occur above the topmost limestone, and there is a crinoidal band at the base of

the lower massive limestone. The two thin limestones contain poorly preserved solitary corals (*Syringaxon* and *Barrandeophyllum*) which are identical with the species found at David's Stone. Weathered faces have a pock-marked appearance which has already been remarked upon in connection with the David's Stone Limestone. In fact the Red Limestone shows precisely the same palaeontology, lithology and thickness as the David's Stone Limestone. Shearman's structural analysis of this area further confirms that the 'Red Limestone' of Evans is the same as the limestone seen at David's Stone.

5. THE SUCCESSION AT JENNY START AND OAKESTOR BAY

Evans placed the Jenny Start Beds below the Red Limestone Series. These are thirty to thirty-five feet thick at Jenny Start, with fifteen feet of massive flaggy limestone at the base, passing up into fifteen to eighteen feet of thin argillaceous limestone in which there is an abundant coral fauna. However, as this limestone is followed north around Oakestor Bay, its thickness diminishes rapidly, and is no more than three feet thick, high up in the cliffs at the north end of Oakestor Bay; the argillaceous coral limestone is completely absent at this point, being either cut out by thrusting or by a lateral facies change; the latter seems the more likely interpretation.

Three species of corals have been previously recorded from the limestone at Jenny Start (Evans, 1929)—*Endophyllum* (*Spongophyllum*) *bowerbanki*, *Phacellophyllum caespitosum* and *Thamnopora* (*Pachypora*) *cervicornus*. The fauna is, however, more extensive than this though it has not yet been fully worked out. Massive compound corals, mostly Rugosa, are abundant, especially members of the Disphyllidae. The corals all occur in the argillaceous horizon, and colonies up to two feet in diameter have been observed. The fauna is in sharp contrast with that found in the David's Stone Limestone, where the only colonial forms are tabulate corals and *Barrandeophyllum* and *Syringaxon* the only rugose corals so far recognised.

Shearman suggested during the Geologists' Association excursion to Combe Martin that there need only be one main limestone about fifteen feet thick within the Ilfracombe Beds and that the apparent multiplicity of limestones could be explained by folding and thrusting. This suggestion is further supported by the lithological similarity of all the main limestone bands. It is certainly true that the limestones are repeated again and again along the coastal section between Combe Martin and Ilfracombe as a result of folding and faulting. There is, however, such a marked contrast between the faunas obtained from the David's Stone and Jenny Start Limestones that it would be unreasonable to explain this as a facies change, especially as the lithologies are so similar. Further, the fossil bands within

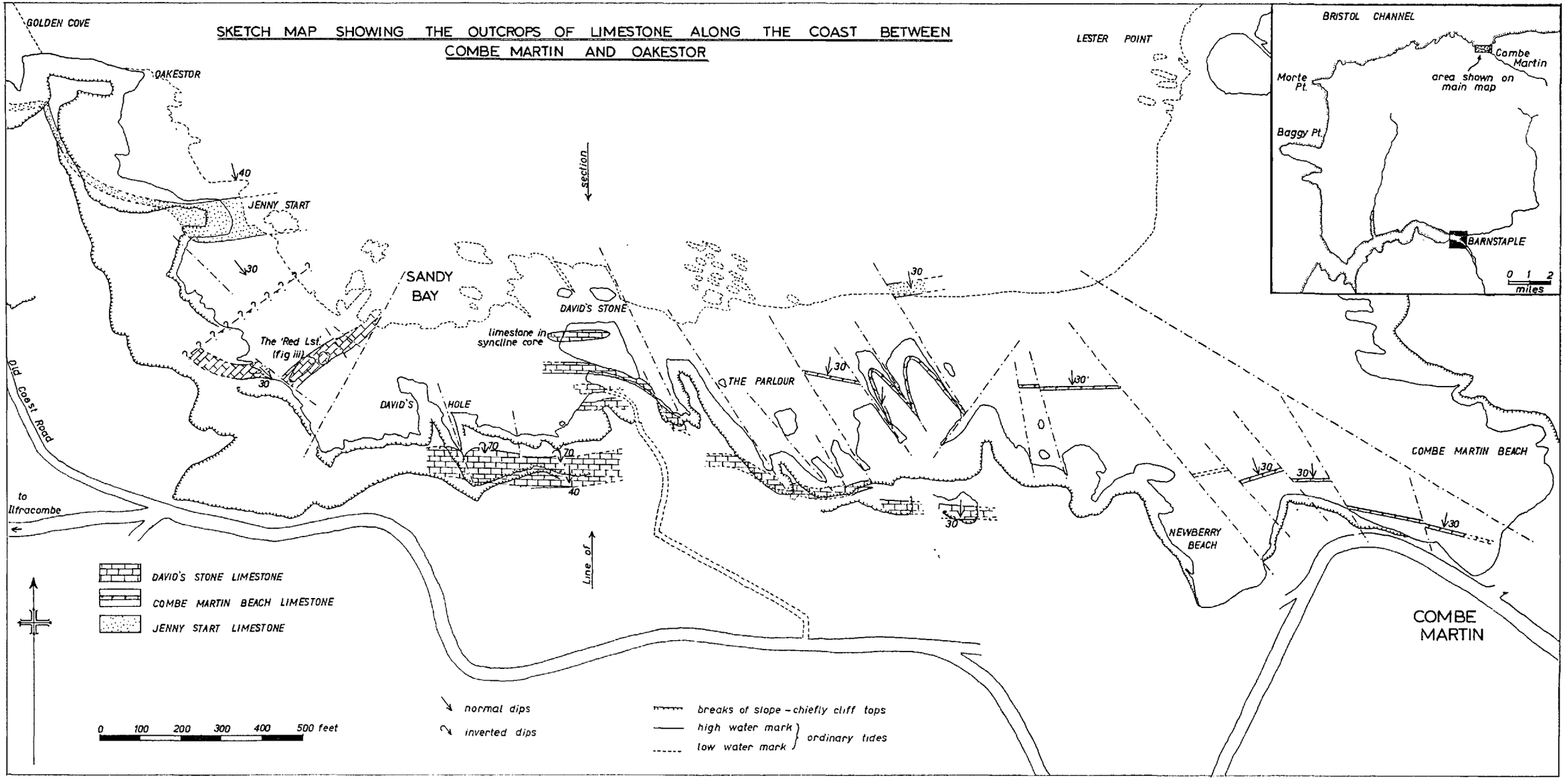


Fig. 4

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the David's Stone Limestone are detrital and therefore would be expected to contain fragments broken off from any coral reefs which were growing in the same sea, and in the same area. In fact, it is only such ubiquitous corals as *Thamnopora* which are common to the two limestones.

The Jenny Start Limestone, however, does contain the same fauna as that found in the limestone at the base of the Newberry Series, as has already been pointed out above. Hence, it is reasonable to correlate these two limestones and term them the Jenny Start Limestone. Thus between Newberry Beach and the Parlour is exposed the apparently complete succession between the Jenny Start Limestone and the David's Stone Limestone. The succession of distinct limestone horizons is then as follows:

	feet
David's Stone Limestone	30
Combe Martin Beach Limestone	4
Jenny Start Limestone	30–35

Each of the limestone beds is separated by slates with occasional sandstones and very thin limestones. Fig. 1 summarises the sequence of beds between the Jenny Start and David's Stone Limestones.

There is, however, one problem raised by establishing this succession of limestones: the Combe Martin Beach Limestone should crop out somewhere between the 'Red Limestone' stack and Jenny Start. Its absence is accounted for by postulating a normal strike fault as shown on the sketch-map (Fig. 4). There is ample evidence that such faults exist from sections farther to the west, and it is highly probable that the postulated fault occurs at a position where the cliff has crumbled away some fifty yards south of Jenny Start.

6. THE STRATIGRAPHICAL POSITION OF THE LIMESTONES

Evans (1922a) placed the Hangman Grits at the base of the Middle Devonian (instead of in the Lower Devonian as had been customary) for three main reasons:

1. A scale of *Coccosteus* (Middle and Upper Devonian) had been found in the middle of the Hangman Grit succession (Rawns Beds).

2. A brachiopod closely akin to *Stringocephalus burtini* occurs abundantly in a siliceous limestone at the top of the Hangman succession. Unfortunately the brachiopod fragments are completely recrystallised and it is impossible to extract them from the matrix; sections of the brachiopods seen on wave-worn surfaces are, however, suggestive of *S. burtini* which is indicative of an Upper Couvinian or Givetian horizon.

3. If the Ilfracombe Beds represent a Givetian or Frasnian age, the Lower Couvinian must be absent unless the Hangman Grits are of this age. As Evans could find no break in the succession, he concluded that the Grits must then be of Couvinian age.

The present writer is in broad agreement with Evans's dating, but for different reasons. An intensive study of the coral fauna from the Combe Martin Beach Limestone has shown it to contain a fauna not previously recorded from Devonian strata in the British Isles (with the exception of a doubtful species of *Metriophyllum* from South Devon). The Syringaxonidae (Laccophyllidae) are similar to those described by Prantl (1938) from the Middle Devonian of Bohemia (Hlubocěpy Limestone (g*γ*)—i.e. upper Middle Devonian) and the species of *Metriophyllum* is close to *M. bouchardi* from the Frasnian of the Boulognais. Hill (1939) has described a similar faunal assemblage of *Syringaxon*, *Barrandeophyllum* and *Metriophyllum* from Australia, which she considers to indicate a Givetian or Lower Frasnian age; on account of the association of *Alveolites* with *Thamnopora* (which are also found in North Devon), she inclines to a Lower Frasnian horizon. From this evidence it seems likely that the Combe Martin Beach Limestone occurs at a horizon very close to the Middle–Upper Devonian Boundary.

The fauna from the David's Stone Limestone is similar to that found in the Combe Martin Beach Limestone, while that from the Jenny Start Limestone contrasts with the other two. It seems probable, therefore, that the Combe Martin Beach Limestone and David's Stone Limestone represent horizons in the Lower Frasnian while the fauna so far identified from the Jenny Start Limestone would suggest that it should be placed in the Givetian.

7. THE THICKNESS OF THE LIMESTONE SUCCESSION

It is clear from these studies that the limestones are not lenticular as has been frequently thought in the past. They can be traced westwards as far as Ilfracombe where the strike carries them out to sea. The Combe Martin Beach Limestone shows little variation of thickness or lithology throughout its outcrop. The David's Stone and Jenny Start Limestones do vary in thickness, but this is almost entirely the result of the associated shaly beds becoming more calcareous, and at the same time more fossiliferous; the massive limestones remain of fairly constant thickness from twelve to fifteen feet.

Evans gave a thickness of 1290 feet for the sequence between the Newberry Beds and David's Hole Beds (inclusive). This thickness is now reduced to about 350 feet in the above succession (Fig. 1). Detailed work has not yet been done on the Lester Series and the Wild Pear Beds, nor on the succession above the David's Hole Beds, but it is probable that the thicknesses of these beds will also be very much less than originally thought by Evans.

8. CONCLUSIONS

It has been of prime importance to establish the sequence and number of the limestones within the Ilfracombe Beds before interpreting the structural complexities of the area. It has been established that there are two main limestones each about thirty feet thick which are similar in lithology but have a contrasting fauna, and it has been possible to give a relative stratigraphy for that part of the Ilfracombe Beds in which the limestones are developed.

It has seemed sensible for the time being to use the term 'David's Hole Beds', and 'Newberry Beds' to cover the same succession of strata as was included by Evans under these terms in order to avoid ambiguity and confusion. The fauna from the David's Hole Limestone has not yet been fully worked out but it seems probable that Evans was right in placing these beds in the Frasnian. The fauna from the Combe Martin Beach Limestone with *Syringaxon*, *Barrandeophyllum* and *Metriophyllum* appears to indicate a horizon very close to the Middle–Upper Devonian boundary, probably at the base of the Frasnian. The fauna so far recognised from the Jenny Start Limestone suggests that it is of Givetian age.

ACKNOWLEDGMENTS

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F. J. W. Holwill
Geology Department
Imperial College
Royal School of Mines
London S.W.7

DISCUSSION

THE PRESIDENT enquired if Mr. Holwill had been able to find any goniatites in the rocks, which he had described so clearly.

In reply THE AUTHOR said that he himself has not, as yet, found any such fauna.

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The coral genus *Metriophyllum* Edwards and Haime

BY

F. J. W. HOLWILL

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THE CORAL GENUS *METRIOPHYLLUM* EDWARDS AND HAIME

by F. J. W. HOLWILL

ABSTRACT. The morphology of the genus *Metriophyllum* has been investigated with the aid of serial sections and the skeletal structure of the coral is described in detail. A review of all recorded species of *Metriophyllum* is made and a revised description is given of *M. bouchardi* and *M. gracile*; in addition a new species is described from the Ilfracombe Beds (Middle/Upper Devonian) of north Devon.

THE genus *Metriophyllum* was established by Edwards and Haime in 1850 with *M. bouchardi* as the type species; they did not, however, publish a full description with figures until the following year (Edwards and Haime 1851). The known range of the genus extends from Middle Devonian to Lower Permian, though the genus is particularly characteristic of the Middle and Upper Devonian. It includes some of the smallest corals yet described—*M. gracile* has an average length of 6–7 mm. and an average maximum diameter of 3–4 mm.

Edwards and Haime (1851) originally placed *Metriophyllum* in the Stauridae, but Hill (1939) proposed a new family—the Metriophyllidae, with *M. bouchardi* as type genus—to contain *Metriophyllum* and allied forms; subsequent writers, notably Stumm (1949) and Lecompte (1952), have accepted the new family though they differ in their opinions as to the genera which should be included.

Possibly because of the small size of most species, the morphology of *Metriophyllum* has not been studied in detail hitherto. Even in the present study, it has been found difficult to discover specimens in which the apical end is completely preserved, and the earliest ontogenetic stages are therefore still not fully known.

In preparing this paper, I have collected extensively from the type locality of *M. bouchardi* at Ferques (Boulogne, France) and also from the Gerolstein area of Germany. In addition, I have studied collections from the British Museum (Nat. Hist.) and the Geologisch-palaeontologisches Institut und Museum at Bonn; I have also had original photographs of type specimens from the New York State Museum available for comparisons.

Techniques. Thin sections were made in the normal way, except that because of the small size of most of the specimens, a dental cutting wheel, making a cut of less than 0·5 mm., was used instead of the normal petrological slicing wheel. For serial sections, the specimens were embedded in a transparent plastic such as 'CEEMAR'; the resulting block was then milled flat on both sides and all subsequent grinding was done by hand. The advantage of this is that the specimen can be kept under constant observation and drawings made at minute intervals to record the rapidly changing arrangement of the septa and the carinae. At convenient intervals, cellulose peels were taken and these were mounted between glass slides and used as photographic negatives. The peels were made by dipping the etched surface of the coral into a 2/1 solution of butyl and amyl acetate

[Palaeontology, Vol. 7, Part 1, 1964, pp. 108–23, pls. 16–19.]

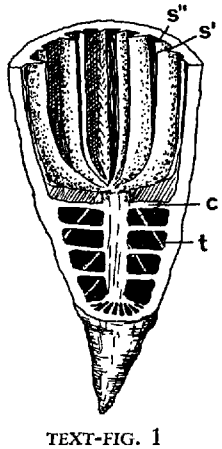
and then pressing the saturated surface on to a piece of transparent cellulose 0·01 in. thick. The advantage of this method over the one described by Butler (1935) is its speed and the ease with which the peel can be removed from the coral. The interval between successive serial sections was found by measuring the total thickness of the specimen plus plastic, before and after grinding, by means of an engineer's micrometer.

In some specimens there was little or no colour contrast between the coral structure and the infilling calcite. The latter was found to be slightly richer in iron than the coral itself, so that by dipping the polished surface of the coral into a solution of potassium ferricyanide and dilute hydrochloric acid (see Henbest 1931) it was found possible to stain the infilling material differentially. This greatly facilitated both photographic and microscopic examination of such specimens.

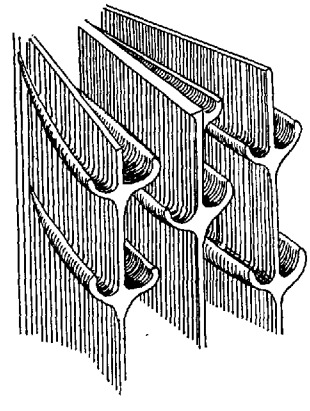
Genus METRIOPHYLLUM Edwards and Haime 1850

Metriophyllum Edwards and Haime 1850, p. lxix.
Lopholasma Simpson 1900, p. 206, figs. 19–21.

Type species (*by original designation*). *Metriophyllum bouchardi* Edwards and Haime 1850, p. lxix; 1851, p. 318, pl. 7, figs. 1, 1*a*, 1*b*, 2, 2*b*. Upper Devonian, Frasnian (Beaulieu Shales and Ferques Limestone), Ferques, near Boulogne, France.



TEXT-FIG. 1



TEXT-FIG. 2

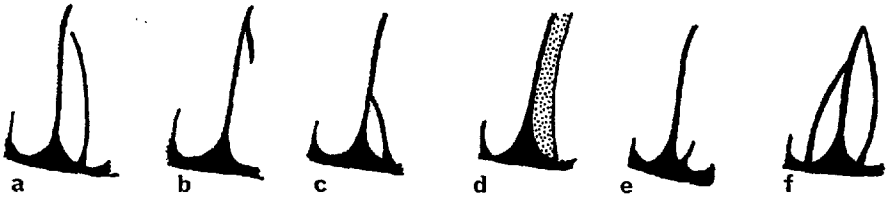
TEXT-FIG. 1. Exploded diagrammatic view showing the main morphological features of *Metriophyllum*. s′ = major septa; s″—minor septa; t = tabulae; c = carinae.

TEXT-FIG. 2. Diagram showing the form of the horizontal trough-shaped carinae developed at alternating levels on adjacent septa.

Description. Small solitary turbinate to ceratoid corals. Calice deep and steep sided with septa projecting as sharp low ridges on the inner side. The floor of the calice is flat or slightly concave and the septa extend across this floor to meet at the axis where they are welded together with sclerenchyme to form a pseudo-columella (text-fig. 1; Pl. 16, fig. 2). The outer walls are also much thickened with sclerenchyme. The sides of the septa below the calice carry horizontal or nearly horizontal carinae which have upturned outer edges (text-fig. 2). The carinae may occur at the same or differing levels on either side of a septum but they always alternate in level with those on the neighbouring septa.

Tabulae are very thin and steeply inclined downwards away from the axis. Rejuvenation is uncommon but has been observed in *M. bouchardi*. It is doubtful whether true dissepiments are present in any species.

Remarks. The genus *Lopholasma* (type species *L. carinatum* Simpson 1900) is regarded as congeneric with *Metriophyllum* since transverse and longitudinal sections (Pl. 16, figs. 2 and 3) clearly show the presence of horizontal carinae so typical of *Metriophyllum*. (The dissepiments which Simpson (1900) described in *L. carinatum* are in fact the steeply sloping tabulae being cut by the transverse section; longitudinal sections confirm this.) I prefer to follow Stumm (1949) and Hill (1956) in regarding *Stereolasma* Simpson 1900 (type species *Streptelasma rectum* Hall 1876 (in part)) as a separate genus and not congeneric with *Metriophyllum* as Smith (1945) suggests; the horizontal carinae appear



TEXT-FIG. 3. Diagram showing some characteristic appearances of the carinae when cut by transverse sections.

to be a well marked and persistent character in the genus *Metriophyllum* and although *Stereolasma* is clearly a related form, the absence of any carinae makes it inadvisable to include it within the genus *Metriophyllum*. The same comments also apply to the specimens in the New York State Museum labelled *M. ungula* (Hall); longitudinal sections of this species clearly show that it lacks horizontal carinae and almost certainly belongs to the genus *Stereolasma*; (compare median longitudinal sections of *M. carinatum*, *S. rectum*, and '*M.*' *ungula*—Pl. 16, figs. 3, 5, and 7).

Range. Middle Devonian–Lower Permian.

Carinae. Edwards and Haime failed to recognize the true nature of the carinae and they interpreted the strong horizontal processes seen in the median section (text-fig. 1; Pl. 16, fig. 1) as tabulae. Barrois (1882) was the first to publish a diagram showing the spur-like appearance of carinae in longitudinal sections and Simpson (1900) recognized the existence of the horizontal carinae, but he did not appreciate the significance of the spur-like processes on the sides of the septa. Soshkina (1928) appears to have been the first to recognize their true significance.

Because of the unusual form of the carinae within the genus *Metriophyllum* much confusion may arise when interpreting their appearance in sections. In transverse sections they may simulate septa or appear as spurs on either side of the true septa (Pl. 18, fig. 2); they may also give the impression that a septum is splitting. Text-fig. 3 shows some of the appearances of carinae in transverse sections. Where the plane of section cuts through the junction between a septum and carinae the septum will appear to be much thickened (text-fig. 3*d*). In longitudinal sections the carinae commonly appear as lobed hooks or spurs but in median sections they show as strong horizontal bars.

In *M. bouchardi* and *M. gracile* the carinae are very delicate trough-shaped structures (Pl. 18, figs. 6, 10, and Pl. 19), but in *M. carinatum* they are stouter and less upturned at their outer edges (Pl. 16, fig. 3). In all the species which have been examined the outer upturned edges of the carinae tend to be thickened (text-fig. 2) so that they appear lobed in longitudinal sections.

Wang (1950) demonstrated that the carinae are built up of fibrous tissue, as are the septa; the outer wall is made up of lamellar tissue. These skeletal structures are clearly seen in the section of *M. bouchardi* (Pl. 16, fig. 6).

The carinae only start to develop at the base of the calice, and the septa extend across the floor of the calice before any carinae are formed. It is often possible to distinguish a suture between the septum and its attached carinae (see Pl. 16, figs. 3 and 6) where impurities have become trapped.

Tabulae. These are very thin and not always seen even in median sections. They slope at about 45° down from the axis (Pl. 16, fig. 1, and Pl. 19, fig. *a*) and may terminate against the carinae. In longitudinal sections, not passing through the axis, they appear as plates which link the carinae (Pl. 19, fig. *c*, and Pl. 18, fig. 6). Barrois (1882) recognized the true tabulae, though not in median sections; his figure (pl. vii, fig. 2*d*) shows very regularly developed tabulae linking the outer lips of neighbouring carinae and he described them as 'planchers ondulés'. Hill (1939) was the first to note that they are 'steeply domed' when seen in median section.

Plate 19 shows longitudinal serial sections from the axis to the outer wall of *M. bouchardi*. The form of the carinae can be appreciated by tracing them individually through the series from the strong horizontal cross-bar appearance (fig. *a*) to the spur-like appearance seen in off-median sections. The outward sloping tabulae are clearly seen in the median section (fig. *a*) and the way in which they cut the carinae is seen in fig. *b*. Later sections show the way in which tabulae extend between the carinae—very much less regularly than suggested by Barrois's figure in his description of the Asturian specimens.

Metriophyllum bouchardi Edwards and Haime 1850

Plate 16, fig. 6; Plate 17, figs. 1–6, 11; Plate 18, figs. 7, 11; Plate 19; text-fig. 4

1845 *Cyathophyllum mitratum* (Schlotheim); Michelin, p. 183, pl. xlvii, fig. 7 (*non Hyppurites mitratus* Schlotheim 1820, p. 352).
1850 *Metriophyllum Bouchardi* Edwards and Haime, p. lxix (*nom. nud.*).
1851 *Metriophyllum Bouchardi* Edwards and Haime, p. 318, pl. 7, figs. 1, 1*a–b*, 2, 2*b*.

Description. Small solitary turbinate to ceratoid corals with a maximum diameter of about 10 mm. Overall length rarely exceeds 20 mm. The outer surface usually shows longitudinal striations corresponding to the internal positions of the septa, and about three well-marked transverse constrictions or wrinkles (Pl. 17, fig. 1); more rarely the outer surface is nearly smooth. The calice is deep and steep sided; it may occupy a third of the total length of the coral, but the walls are frequently broken off near the base of the calice (Pl. 19, fig. 11); the floor of the calice is flat or gently concave. Septa within the calice are short and project from the wall as sharp ridges; both major and minor septa are seen in the calice, the latter being slightly less prominent than the major ones (Pl. 17, figs. 3 and 4); subsequently the septa and the wall are thickened with the result

that the minor septa are completely embedded in sclerenchyme; however, it is at these minor septal positions that the carinae join the outer wall. The number of major septa is commonly 18–20, though Edwards and Haime (1851) give 22–24 as characteristic of the species; the septa are straight or only slightly flexed and they extend across the floor of the calice to meet at the axis; the axial ends are slightly swollen and they are cemented together by sclerenchyme to form a pseudocolumella. In some specimens the columella is narrow, while in others it occupies nearly one-third of the lumen (Pl. 16, fig. 6).

The major septa carry horizontal carinae which have upturned outer edges. They are developed at alternate levels on adjacent septa and usually at different levels on opposite sides of the same septum. The carinae are spaced at about 1 mm. intervals. Tabulae are thin discontinuous plates sloping downwards away from the axis; they are irregularly spaced.

Rejuvenation is rare but does occur (Pl. 17, figs. 2 and 5; Pl. 18, fig. 7).

Horizon and locality. Upper Devonian (Frasnian); from the Beaulieu Shales and Ferques Limestone, Ferques, near Boulogne.

Discussion. Lang, Smith and Thomas (1940) designated the specimen figured by Edwards and Haime (1851, pl. vii, figs. 1, 1*a*) as lectotype. The original specimen appears to be lost. Their figure shows 22 major septa though Edwards and Haime, in their text, mention 22 to 24 as typical. Topotype specimens have been figured by Smith (1945) and these show 19 septa. Of some 20 specimens from the type area which I have examined, only 2 have more than 20 septa and none has as many as 24; the vast majority have only 18 or 20.

Barrois (1882) described specimens of *M. bouchardi* from Moniello and Arnao (Asturia) in which the calice is very shallow. He suggested that the specimens may have broken before interment and this seems the most probable explanation, since the distal parts of the calice are thin, having no secondary stereoplasmic thickening.

Smith (1945) stated that *Lopholasma carinatum* agrees with *M. bouchardi* in all essential characters and differs from it only in size and unimportant details. His remarks suggest that he regarded them as conspecific. There can be no doubt that *L. carinatum* is a species of *Metriophyllum*, but I cannot agree that they are conspecific, since *M.*

EXPLANATION OF PLATE 16

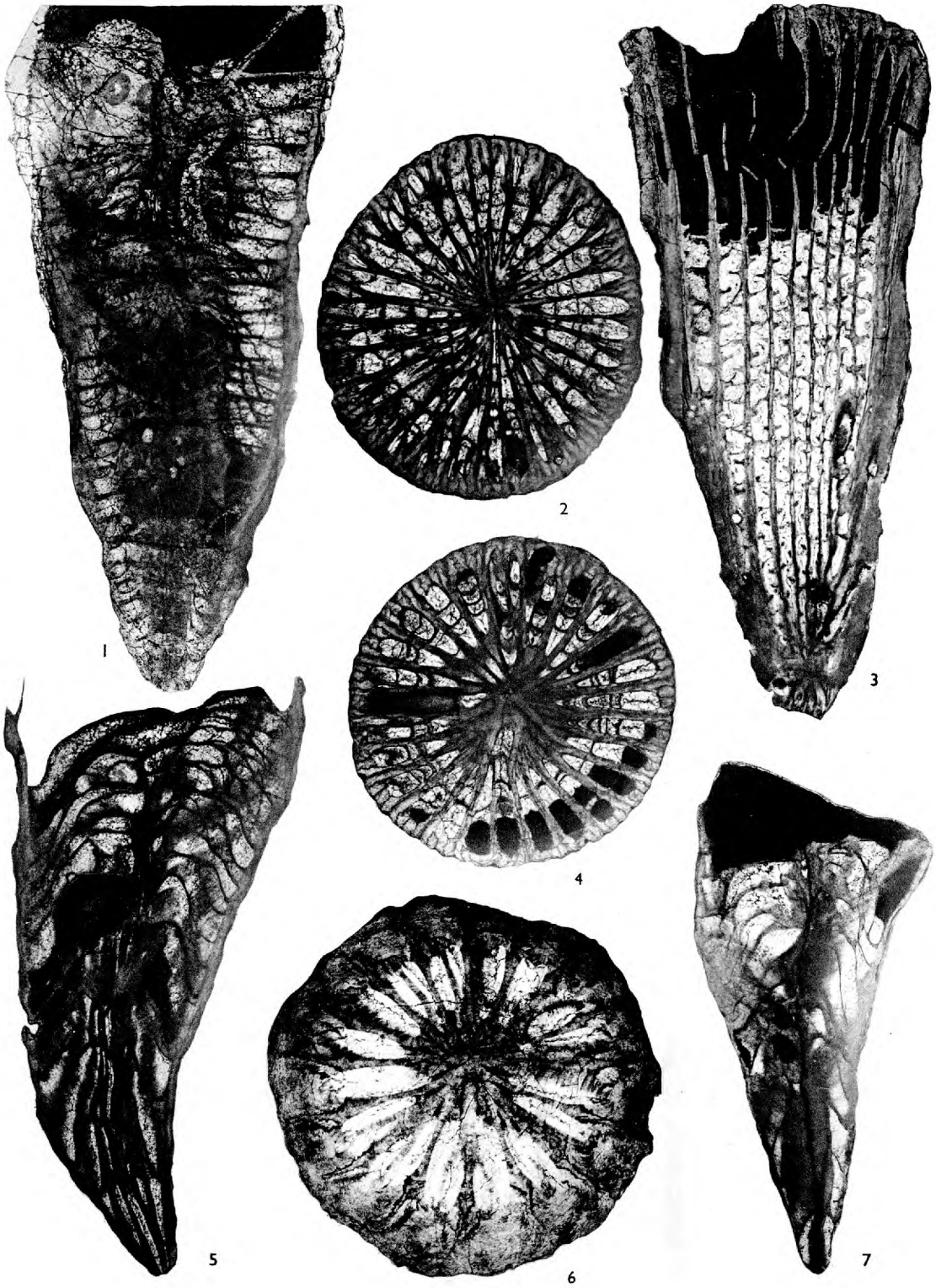
Figs. 1–3. *Metriophyllum carinatum* (Simpson), Hamilton Beds, Livonia salt shaft, Livingstone Co,. N.Y. 1, Longitudinal thin section (median) of a cotype showing the tabulae and horizontal carinae. NYSM 292, ×3·3. 2, Transverse thin section of a cotype; major and minor septa are visible; the skeletal elements between the septa are sections through tabulae; NYSM 291, ×3·3. 3, Longitudinal thin section (off median) showing the carinae appearing as spurs on either side of the septa. NYSM 290, ×3·3.

Figs. 4, 5. *Stereolasma rectum* (Hall). 4, Transverse thin section of hypotype, NYSM 320, ×3·3. 5, Longitudinal thin section of hypotype, NYSM 322, ×3·3.

Fig. 6. *Metriophyllum bouchardi* (Edwards and Haime). Transverse thin section showing the lamellar structure of the outer wall and the fibrous structure of the septa and carinae. The suture between septa and carinae is well seen in the upper part of the plate. BMNH R16237, ×7. Middle Devonian, Ferques, Boulonnais, France.

Fig. 7. *Streptelasma ungulata* (Simpson). Longitudinal thin section of hypotype, NYSM 322, ×3·3. Hamilton Beds, Hamburg-on-the-Lake, Erie Co., N.Y.

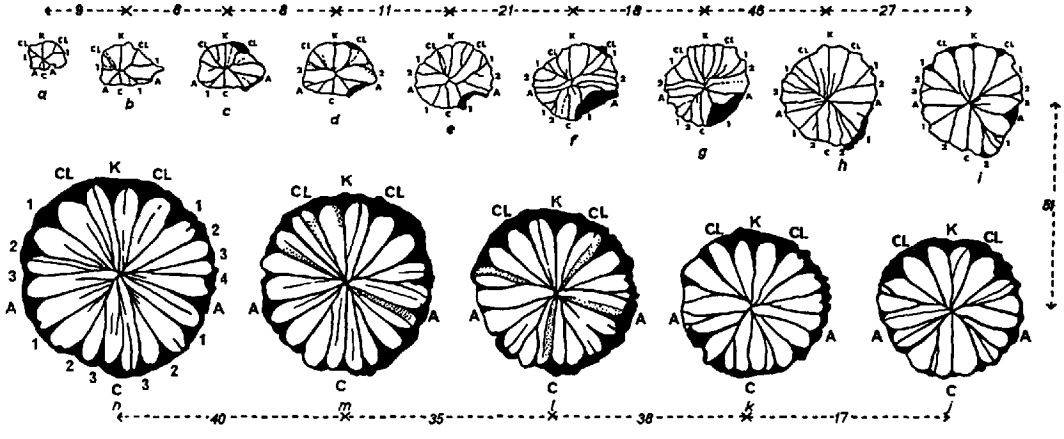
(The original photographs of figs. 1–5, 7 were kindly supplied by the New York State Museum.)



HOLWILL, *Metriophyllum*

bouchardi has only about twenty septa while *L. carinatum* shows thirty; also the carinae of *M. bouchardi* are larger and more strongly curved, thus producing deeper troughs; the carinae are also more widely spaced than in *L. carinatum*.

Septal development. Investigation of septal development in *M. bouchardi* presents unusual difficulties because, as has been pointed out above, the carinae simulate septa in transverse sections; in fact new septa and carinae arise in a similar way from the sides of the earlier formed septa. The fundamental difference between the two is that new septa arise only in four positions whereas the carinae may develop within any of the interseptal loculi. In making the present study it was found necessary to record sections at intervals of 0·003–0·005 inches and sixty-eight sections were made in a distance of 0·26 in. The sections were recorded by means of cellulose peels and a selection of critical



TEXT-FIG. 4. Selected serial sections to show the septal development of *M. bouchardi*. The figures indicate the distances between each section in thousandths of an inch. BMNH R16249, ×4.

sections is reproduced in text-fig. 4. The septa in *M. bouchardi* show a radial arrangement in all stages of growth. However, there is a basic bilateral symmetry associated with a pinnate method of septal insertion.

The apical ends of several apparently complete specimens have been sectioned and the most juvenile arrangement of septa observed is that illustrated in text-fig. 4*a*. Two metasepta (marked 1 on the figure) are present in addition to the six protosepta (C = cardinal septum; K = counter cardinal septum; A = alar septa; CL = counter lateral septa; the septal nomenclature used here is that advocated by Hill (1935). The axial ends of the protosepta are swollen and welded together with sclerenchyme (this is not shown on text-fig. 4 as the sclerenchyme has been omitted for the sake of clarity). There is also thickening along the sides of the septa. The first formed metasepta are those which develop on the cardinal side of the counter lateral septa; those on the cardinal side of the alar septa follow almost simultaneously (text-fig. 4*b* and *c*), and this pattern is maintained with only minor exceptions throughout the development of the coral.

The newly formed septa grow until they almost reach the centre and their axial ends are within the central sclerenchyme. However, they always remain attached to the

protosepta from which they originated so that it is possible to distinguish four distinct groups of septa even in the mature corallite (see text-fig. 4*n*).

Within the calice the septa occur as longitudinal ridges; between these are a further series of ridges, usually somewhat less prominent, from which at a later stage of growth the carinae develop. These latter ridges occur in the position of minor septa and the outer surface of the epitheca has grooves which correspond to them. Because of the thickening of the epitheca below the calice, these ridges are not always apparent in sections made through the earlier formed parts of the corallite, but they can sometimes be distinguished embedded in lamellar tissue if the preservation is good. Whether or not these ridges should be regarded as true minor septa is open to question; they are closely linked with the subsequent development of the carinae and this suggests that they are not in fact minor septa. On the other hand, their regular position between the major septa, the septal grooves in the outer wall which correspond to them, and their formation from lamellar tissue would suggest a contrary interpretation. I incline to the view that they are true minor septa, and they are described as such in the systematic part of this paper.

Carinae are present in all but the earliest ontogenetic stages and each septum bears them. In the mature corallite the carinae run closely parallel to their parent septum, but in earlier stages they are more radially disposed and this increases the difficulty of distinguishing them from newly formed septa.

Metriophyllum gracile Schlüter 1884

Plate 17, figs. 7–10, 12, 13; Plate 18, figs. 1, 5, 6, 9, 10, 12–16

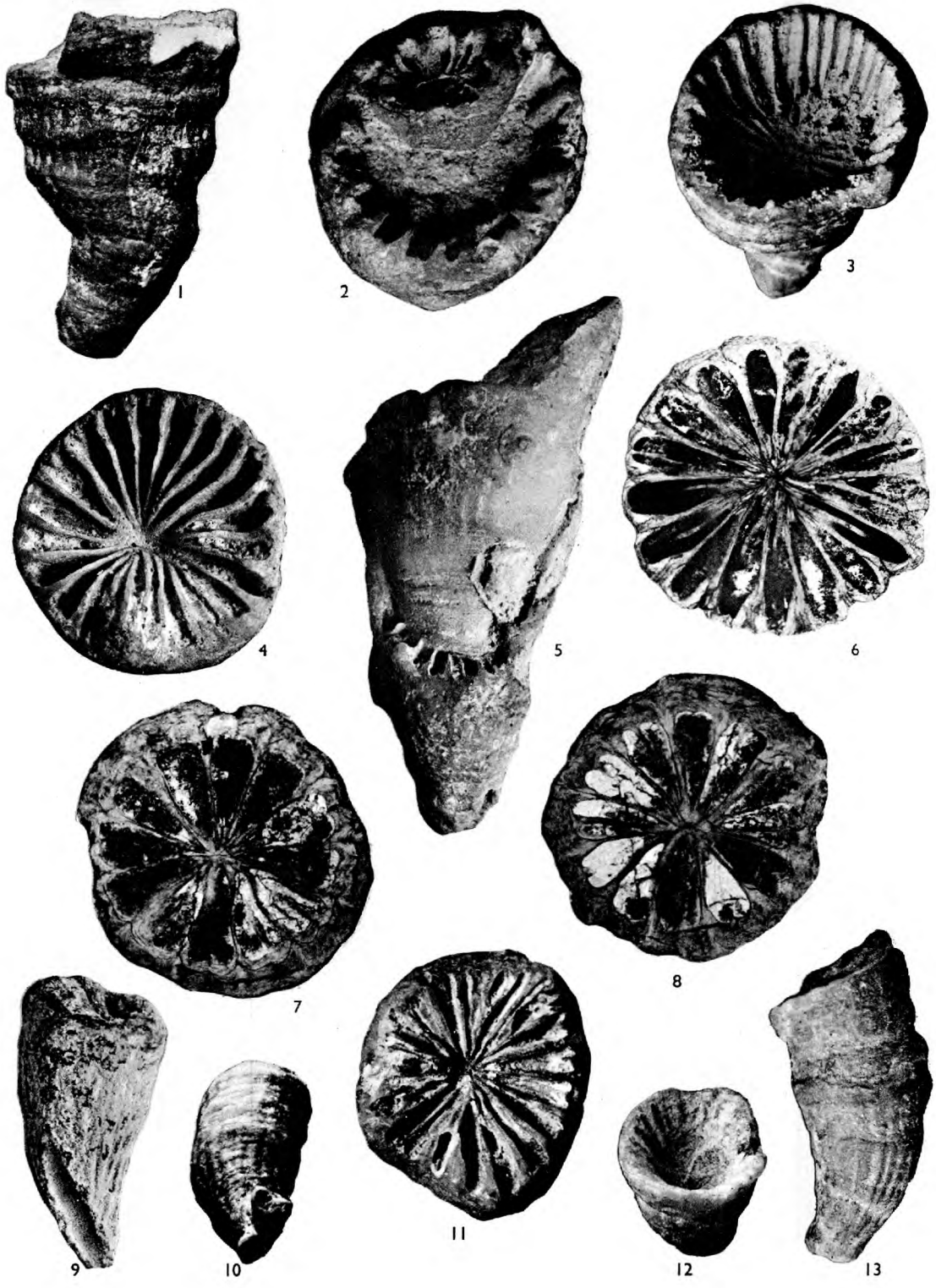
Metriophyllum gracile Schlüter 1884, pp. 82, 83.
Metriophyllum gracile Schlüter 1889, pp. 18–20, pl. 2, figs. 5–8.
Metriophyllum laeve Schlüter 1889, p. 18.
non Lopholasma gracile Soshkina 1928, p. 369.

Lectotype. Schlüter's species is based upon a number of syntypes in the Geologisch-palaeontologisches Institut und Museum at Bonn. From these syntypes the specimen illustrated in Plate 17, fig. 13 is here selected as the lectotype (Bonn, 161c).

EXPLANATION OF PLATE 17

Figs. 1–6, 11. *Metriophyllum bouchardi* (Edwards and Haime). Middle Devonian limestones and shales of Ferques, Boulonnais, France. 1, Exterior showing typical trochoid form and rugae; calicular margin is damaged. BMNH R18517, ×5. 2, Calicular view of a specimen starting to rejuvenate. BMNH R18513, ×5·4. 3, Specimen showing the deep steep-sided calice with major and minor septa appearing as ridges. BMNH R18517, ×5·4. 4, Calicular walls have been broken revealing the form of the major and minor septa across the floor of the calice with carinae not yet formed at this level BMNH R16246, ×4·7. 5, Specimen showing rejuvenation. BMNH R16248, ×4·8. 6, Thin section (transverse) of a typical specimen; the flexure and thickening of the septa at the outer margin is well seen. BMNH R16249, ×8. 11, Specimen in which the calicular walls have been completely abraded revealing the arrangement of septa across the calicular floor; some carinae are visible. BMNH R16231, ×5·4.

Figs. 7–10, 12, 13. *Metriophyllum gracile* (Schlüter). Gerolstein area of Germany. 7, 8, Thin sections (transverse) showing the typical arrangement of the septa meeting at the axis and cemented by sclerenchyme. MM11120, ×14. 9, Specimen showing the attachment groove which typifies individuals from a locality 1 km. south of Gerolstein (472.644). MM11119, ×6. 10, Specimen with prominent root-like processes at the apical end. MM11117, ×6. 12, Paralectotype showing the deep calice. Bonn, ×7·7. 13, The lectotype, Bonn 161*c*, ×6·5.



HOLWILL, *Metriophyllum*

Description. Small solitary trochoid corals with an average length of 8 mm. and a diameter of 3–4 mm. The calice is deep and steep sided and may occupy as much as half the length of the corallite; the septa project into the calice as low ridges. The outer wall is relatively thick and marked by longitudinal grooves corresponding to the septal positions. There are 14–18 major septa in the average-sized specimen; these are slender and straight or only slightly flexed; at the axis they are welded together, though in ephebic stages they may withdraw slightly from the axis leaving a narrow aulos (compare Pl. 17, figs. 23 and 27). Minor septa are seen only in the calice, where they alternate with the major septa. Horizontal trough-shaped carinae occur on each septum though not within the calice; they are spaced at about 0·8 mm. intervals (Pl. 18, figs. 6 and 10). Tabulae are thin and slope steeply downwards away from the axis.

Range. Metriophyllum gracile has only been recorded from the Gerolstein area of Germany in beds which are of Upper Couvinian age. Hill (1939), in her remarks on *M. sp.* from Western Australia, suggests that *M. gracile* may extend up into the lower Givetian.

Remarks. Schlüter's original description records 16–18 septa but a re-examination of the syntypes and other specimens shows that there are not more than 18 septa and commonly only 14. No tabulae were observed in any of Schlüter's original specimens, but topotype material has been sectioned and this shows the thin, steeply inclined tabulae which are characteristic of the genus. The carinae are very delicate structures and they usually occur at the same level on opposite sides of a single septum, though they alternate in height with those on adjacent septa. The outer surface is usually strongly ribbed, though in larger specimens the distal end shows prominent transverse growth striae; this feature and some observations on the mode of attachment of the species have been the subject of a separate paper (Holwill 1963).

The main ways in which this species differs from *M. bouchardi* are in size, in number of septa, and in the positioning of the carinae.

M. sp. cf. *gracile* was recorded by Wade (1938) from the Rough Range of Western Australia; this record was based on a preliminary determination by Hill, who subsequently described the form (Hill 1939) merely as *M. sp.*, considering it inadvisable to give the form a name based on a single oblique section. Hill's figure of this specimen shows it to have well-developed minor septa, and on this basis alone it is to be distinguished from *gracile.* It is likely to be a new species, but until further material is available Hill is right in refraining from giving it a specific name.

Metriophyllum gracile (Soshkina) 1928

Soshkina recorded this species as *Lopholasma gracile* (Soshkina 1928, p. 368, pl. 12, fig. 14; text-fig. 12). Since *Lopholasma* is here regarded as synonomous with *Metriophyllum, M. gracile* Soshkina is a junior secondary homonym and as such the specific name must be rejected; I have communicated with Dr. Soshkina informing her of this and have invited her to publish a replacement name.

The form described by Soshkina is very small, having a maximum diameter of 2 mm. and a length of 5 mm. Only two individuals are recorded, both from the Lower Permian of the eastern Urals (Shchugor River). There are twelve major septa at this diameter and

no minor ones are apparent. The septa and outer walls are much thickened by sclerenchyme. The carinae are stout horizontal ridges developed irregularly from the sides of the septa; there is very little upturning of their outer edges. Tabulae are not seen.

Metriophyllum laeve Schlüter 1889

1889 *Metriophyllum laeve* Schlüter, p. 278(20), no figures.

Schlüter was uncertain whether *M. laeve* should be regarded as a distinct species. In his original description (Schlüter 1889) he describes the species as similar to *M. gracile* but nearly twice as large and with a smooth epitheca; he stated that *M. laeve* characterized a dolomite bed at the same horizon as the marl bed in which *M. gracile* occurs. A study of Schlüter's specimens shows that the smooth epitheca is not a consistent characteristic (compare Pl. 18, figs. 13 and 16); neither is size alone a reliable criterion for distinguishing species. However, thin and polished sections (Pl. 18, figs. 14 and 15) suggest that the septa are stout and slightly withdrawn from the axis leaving a small aulos; the axial ends of the septa are also swollen. At first sight these features would seem to be of specific importance, distinguishing *M. laeve* from *M. gracile*, but having examined several sections of *M. laeve* it was found that (i) the stout septa are caused by a recrystallization of the original calcite to form dolomite (some specimens were only partly recrystallized and these showed slender septa comparable with those typical of *M. gracile*). (ii) The swelling of the septal ends, and their slight withdrawal from the axis to form an aulos, can also be found in the ephebic stages of *M. gracile* (Pl. 18, fig. 5). It is true that the specimens of *M. laeve* are of larger average size than those of *M. gracile*, but it is not difficult to find specimens of *M. gracile* which are of comparable size; since *M. laeve* characterizes a particular lithology it is reasonable to suppose that the slightly different environment which facilitated dolomitization also tended to prolong the life of *Metriophyllum* so that a higher percentage of the individuals attained old age and developed senile characteristics.

Metriophyllum lituum sp. nov.

Plate 18, figs. 2–4, 8

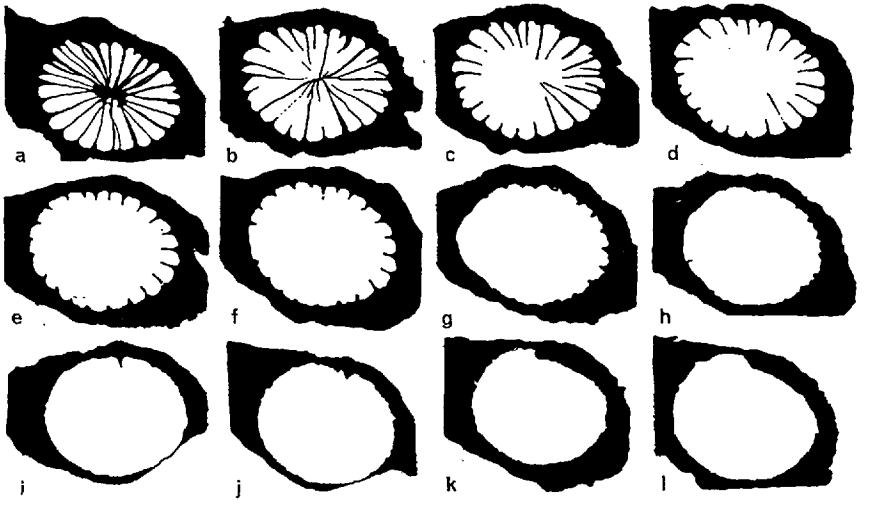
Description. Small solitary corals with a maximum observed diameter of 8 mm. At this diameter there are twenty-two major septa which are slender and usually slightly flexed; they reach the axis (except within the calice) and are welded together at the axis by a small amount of sclerenchyme, thus forming a pseudocolumella. Horizontal trough-shaped carinae are developed regularly up each septum; they are spaced at approximately 1·1 mm. intervals and are the same level on either side of any one septum, but alternate in height with those on adjacent septa. The septa are thickened just before reaching the outer wall, which is moderately thick. The calice is deep and steep sided; its floor is almost flat and the septa project into it as sharp ridges in the lower part; the distal end of the calice shows no evidence of septa on its inner surface (see serial sections, text-fig. 5). Minor septa are absent. The tabulae are steeply inclined downwards away from the axis and are numerous.

Holotype. Specimen MM11113 from the Combe Martin Beach Limestone (Middle/Upper Devonian), Ilfracombe Beds, north Devon.

Material. Much of the material from north Devon is poorly preserved and no complete specimens of *M. lituum* have been obtained; hence the overall length and the form of the corallum are not known with certainty. Altogether eight specimens have been collected (MM11113, 4, 11122, 11125–9).

Locality and horizon. All the specimens have been obtained from the Combe Martin Beach Limestone in the neighbourhood of Newberry Beach, Combe Martin, north Devon. On the basis of the associated fauna the bed is dated as Upper Givetian or Lower Frasnian (see Holwill 1962 for a discussion of the probable age).

Derivation of name. From the Latin *lituus*—a curved staff or wand—referring to the thin flexed septa.



TEXT-FIG. 5. Serial sections through the distal parts of *M. lituum* sp. nov. The sections were taken at approximately equal intervals through a thickness of 0·14 in. MM11114, ×4.

Discussion. M. lituum closely resembles *M. bouchardi*, but it differs from the latter both in size and in the number and slenderness of its septa; also in the very regular development of the carinae on either side of each septum. It differs from *M. gracile* in being larger and in having a greater number of septa.

Text-fig. 6 shows serial sections through a small specimen (probably in its nepionic stage, hence the small diameter and few septa). The sections show very clearly the way in which carinae may appear as spurs from the septa and even themselves simulate septa.

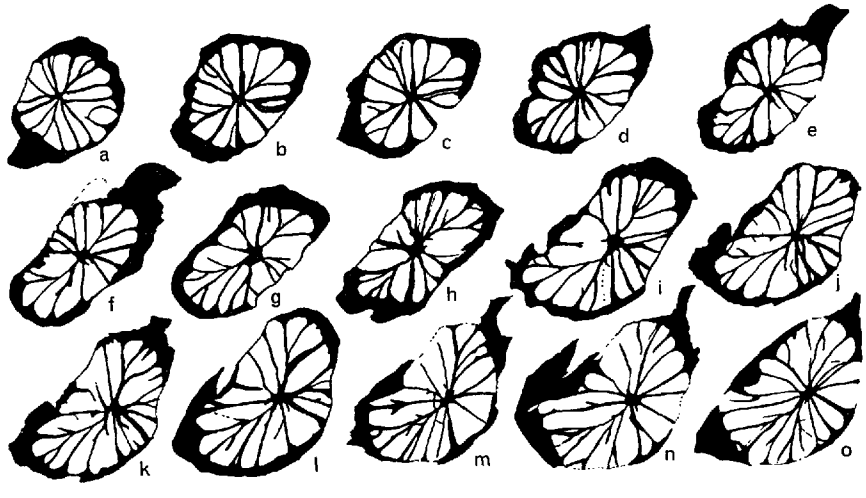
Metriophyllum battersbyi Edwards and Haime 1851

1851 *Metriophyllum Battersbyi* Edwards and Haime, p. 318.
1853 *Metriophyllum Battersbyi* Edwards and Haime, p. 222, pl. 49, fig. 4.

In 1851 Edwards and Haime recorded the coral *M. battersbyi* from the Middle Devonian Limestones of Torquay. They figured this specimen and gave a fuller description of it in their monograph of 1853. Many subsequent workers have referred to this identification and have doubted its validity (e.g. Hill 1939, Smith 1945). Apart from a species of *Metriophyllum* from north Devon (Holwill 1962), and a doubtful identification of *Metriophyllum* by Smith (1953) (see below), it is the only form of *Metriophyllum*

recorded in the British Isles and it differs in so many obvious characters from other known species of this genus that it is not surprising that doubt has been cast on the generic determination.

In describing it in 1853, Edwards and Haime made particular reference to the 'quadrifascicular mode of arrangement of the septa' of which there were said to be forty-eight major ones, 'somewhat thickened', in a section taken just below the calice. These alternate with minor septa which are thinner. Dissepiments were also recognized. The authors distinguished the species from the type species by the more numerous septa and the fact that they were slightly thickened near the centre.



TEXT-FIG. 6. Serial sections through a juvenile specimen of *M. lituum* sp. nov. The sections were taken at approximately equal intervals through a thickness of 0·14 in. MM11114, ×5.

Unfortunately the original specimen figured by Edwards and Haime has been lost, but their figure (pl. xlix, fig. 4) is closely similar to other specimens labelled *M. battersbyi* which are in the British Museum (Nat. Hist.) and which were obtained from the same area in south Devon as the holotype. A study of these specimens, from which several thin sections have been made, makes it clear that *M. battersbyi* is not a species of *Metriophyllum*; in fact Edwards and Haime's own description of the holotype is sufficient to show that it cannot be included in this genus as defined above. Briefly the chief characters which exclude it from the genus are as follows:

(*a*) Absence of horizontal trough-shaped carinae.
(*b*) The presence of minor septa extending half-way (or more) to the centre.
(*c*) The presence of dissepiments.
(*d*) The thickening of the septa in their central parts and their attenuation towards the periphery.
(*e*) The presence of numerous inflated tabellae in a central tabularium.
(*f*) The presence of an axial whorl.

Other less significant factors are the large size, the numerous septa, and the thin outer wall; none of these features characterizes any known species of *Metriophyllum*. It is

most probable that '*M.*' *battersbyi* should in fact be referred to the genus *Acanthophyllum* as redefined by Birenheide (1961).

Metriophyllum carbonaria (Grabau 1922)

1922 *Lopholasma carbonaria* Grabau, pp. 43–45, pl. i, figs. 5*a–b*, 6*b*, 7*b*, 7*d*, 8*b*, 8*d*, 9*b*, 9*d*, 10*b*, 10*d*, 11*d*, 12; text-figs. 54–56.

This species from the Viséan or Lower Moscovian of China differs from other known species of *Metriophyllum* in having a well-marked fossula and a cardinal septum which does not reach the axis. Grabau describes dissepiments which are 'fairly numerous, thin and for the most part cystiform, i.e. convex upwards', but later he writes: 'between the septa are cystose dissepiments . . . these probably being also in many cases sections of carinae.' His published figures do not support the suggestion that dissepiments are present and I consider that the structures observed by Grabau are either sections through the carinae as he himself suggests, or, even more probably, sections through the outward sloping tabulae. This contention is supported by a later remark of Grabau: 'the dissepiments break up into spines and finally these spines disappear'—this is the behaviour of the carinae in successive serial sections which has been demonstrated above.

Metriophyllum carinatum (Simpson 1900)

Plate 16, figs. 1–3

1900 *Lopholasma carinatum* Simpson, p. 206, figs. 19–22.

Some comments have already been made on this species in the foregoing descriptions and it is illustrated in Plate 16, figs. 1–3. Minor septa are well developed in addition to about thirty major ones which extend to the axis, where they are welded together by sclerenchyme. The minor septa extend slightly beyond the outer thickened wall and usually abut against a major septum (see Pl. 16, fig. 2). The carinae numerous and occur at alternate levels on either side of a septum; they are stouter and less upturned at their outer edges than in *M. bouchardi*.

The species is recorded from the Hamilton Shales (Middle Devonian) of U.S.A.

Metriophyllum deminutivum Easton 1944

1944 *Metriophyllum deminutivum* Easton, pp. 31, 32, pl. 3, figs. 1–3.

This species occurs in the lower part of the Chouteau Limestone (Mississippian) of Missouri, and must unquestionably be included within the genus *Metriophyllum* as defined above. In size and general form of the carinae, *M. deminutivum* resembles *M. gracile*, but at least one marked difference lies in the form of the septa during the middle ephebic stages: Easton describes them as 'grouped somewhat in pairs, five pairs on each side between single thick cardinal septum and thin counter septum with single minors joining it on either side to form tripartite counter system'. The presence of 'not more than three very fine dissepiments' is mentioned and, if true dissepiments are indeed present, this feature alone distinguishes it from other known species.

Metriophyllum erisma Hill 1949

1949 *Metriophyllum erisma* Hill, p. 142, pl. 6, figs. 11, 12.

Hill created this new species for forms in which the septal flanges (carinae) are inclined inwards and downwards and in which the inner tabulae sweep vertically downwards about the axis; there are also occasional outer tabulae. Hill does not indicate whether the carinae are of the trough-shaped variety which are typical of the genus, and unfortunately her figures do not clarify this point; the fact, however, that in the transverse section they 'appear as thickenings of the septa or as slender plates like extra septa running parallel to the septa' suggests that they may have upturned outer edges. The inclination of the carinae downwards towards the axis is exceptional (they make an angle with the horizontal of about 20°), and it has not been noted in any other species. The two sets of tabulae are also unique to this species.

Metriophyllum (*Aemulophyllum*) *exiguum* (Billings 1860)

1860 *Heliophyllum exiguum* Billings, p. 261, figs. 9, 10.

M. (*Aemulophyllum*) was erected as a subgenus of *Metriophyllum* by Oliver (1958) to contain forms of *Metriophyllum* with a calceoloid flattening; to the new subgenus he assigned the form *Heliophyllum exiguum* Billings. In his redescription of this species Oliver mentions the presence of a 'deep fossula on the convex . . . side which is occupied by a short cardinal septum'; he also describes crossbar carinae 'which descend gently

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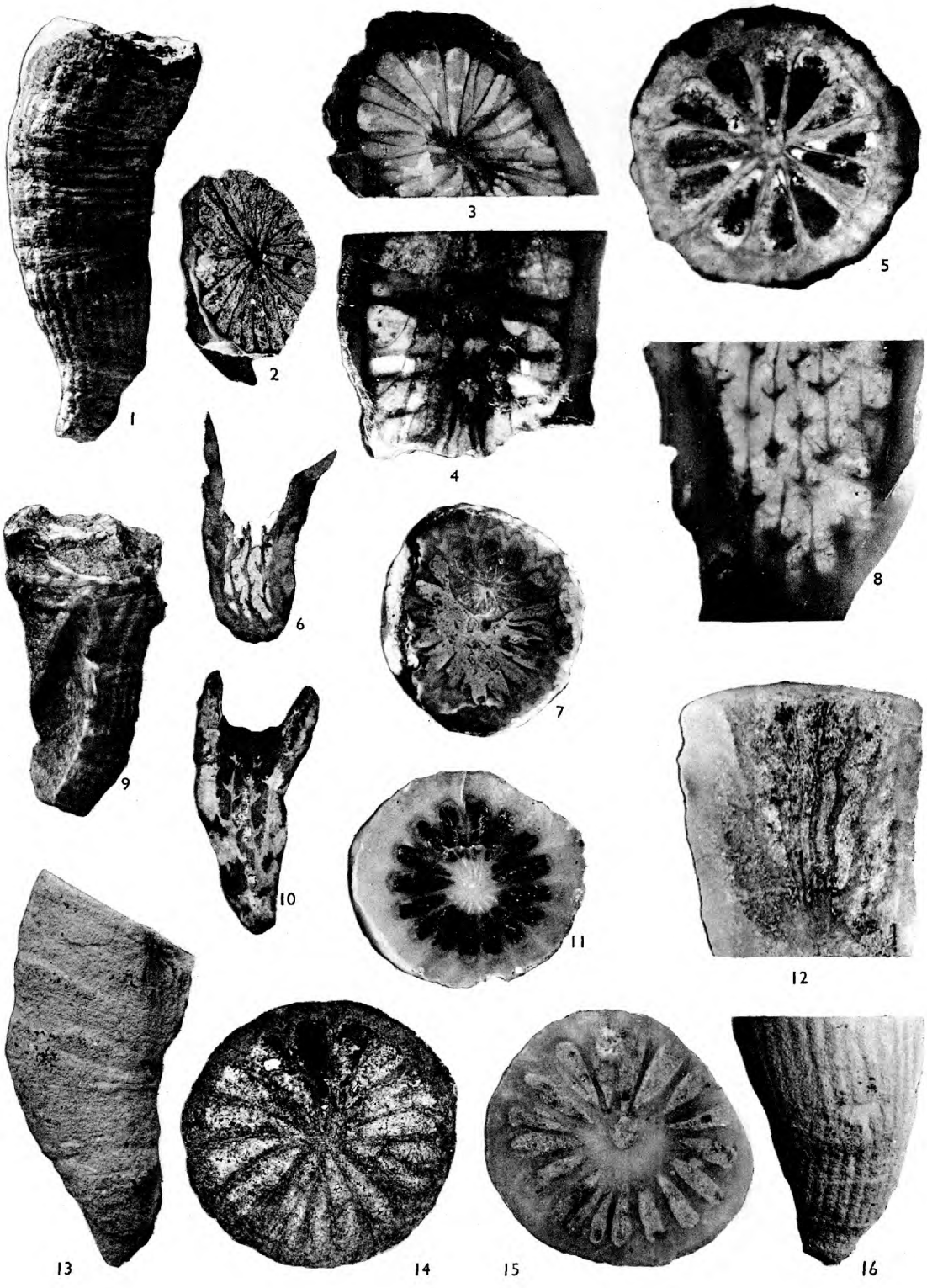
EXPLANATION OF PLATE 18

Figs. 1, 5, 6, 9, 10. *Metriophyllum gracile* (Schlüter). Gerolstein area of Germany. 1, Typical external appearance with longitudinal ridges prominent at the apical end and concentric growth striae in the distal parts. MM11115, ×6·8. 5, Thin section (transverse) of a specimen in which the septa are slightly withdrawn from the axis leaving a narrow aulos. MM11121, ×15. 6, 10, Thin sections (longitudinal) showing the deep calice with walls thickened near the base and the delicate carinae developed on either side of the septa, MM11124, ×5·3; 11123, ×7. 9, Specimen showing the attachment groove which typifies individuals from a locality 1 km. south of Gerolstein (472.644). MM11116, ×7.

Figs. 2–4, 8. *Metriophyllum lituum* sp. nov. Combe Martin Beach Limestone (Ilfracombe Beds), Combe Martin, north Devon. 2, Polished section (transverse) of a paratype. Much of the outer wall has been abraded away but the form of the septa and carinae is well shown. MM11122, ×6. Holotype. MM11113. 3, Transverse section, ×6·3. 4, Median longitudinal section showing the horizontal carinae and steeply outward sloping tabulae, ×6·3. 8, Off-median section showing the regular arrangement of the carinae on either side of the septa, ×8·8.

Figs. 7, 11. *Metriophyllum bouchardi* (Edwards and Haime). Middle Devonian limestones and shales of Ferques, Boulonnais, France. 7, Polished section of a specimen showing the early stages of rejuvenation. BMNH R18513, ×4. 11, Thin section (transverse) of a specimen with a much thickened outer wall and axis. BMNH R16237, ×5·3.

Figs. 12–16. *Metriophyllum gracile* (Schlüter). Gerolstein area of Germany. All these are original specimens of Schlüter, in the Bonn Museum, which he named *M. laeve*; they are here regarded as conspecific with *M. gracile*. 12, Polished longitudinal section. Bonn 162*b*, ×9. 13, A large specimen with relatively smooth epitheca. Bonn 162, ×7. 14, Thin section (transverse) of a specimen which has recrystallized, thus destroying the original skeletal structure and creating the impression of much thickened septa. Bonn 162*c*, ×10·75. 15, Polished transverse section of a specimen showing the septa slightly withdrawn from the axis and laterally in contact, thus forming an aulos. Bonn 162*a*, ×8. 16, Same specimen, showing longitudinal ridges, ×5.



HOLWILL, *Metriophyllum*

towards the exterior' and are 'apparently limited to the peripheral zone'. These features suggest that the species is incorrectly regarded as a subgenus of *Metriophyllum*, which lacks a fossula, has horizontal carinae developed throughout its length (except in the calice), and has septa all of which reach the axis, Unfortunately I have not had the opportunity to examine the type material which is in the New York State Museum; however, the Museum has kindly sent excellent photographs of the holotypes, and these, together with Oliver's own figures and descriptions, suggest that the form should be regarded as a subgenus of *Heliophyllum* rather than of *Metriophyllum*.

Metriophyllum ilitchense (Soshkina 1928)

1928 *Lopholasma ilitchense* Soshkina, pp. 369–70, fig. 13*a*, *b*; pl. 12, figs. 12, 13.

This species is recorded from the Lower Permian of the eastern Urals. Soshkina has compared it with *M. carbonaria* (Grabau) but is reluctant to make the species synonymous because of their wide geographical separation and the fact that they occur in different geological systems. Only one incomplete specimen is recorded which has an elongate conical form and has seventeen major septa at a diameter of 6·5 mm.; there are a corresponding number of minor ones which are short and sinuous. The outer surface is covered by numerous spiny tubercles which are scarcely visible to the naked eye. Horizontal carinae typical of the genus are developed irregularly on either side of each septum. Soshkina specifically states that dissepiments occur running between the septa but that tabulae are absent. It is clear, however, from her figures that the structures she refers to as dissepiments are the same structures as Hill has interpreted as tabulae and which have been described as tabulae in this present paper; they run downwards away from the axis.

Metriophyllum poshiense Mansuy 1912

1912 *Metriophyllum poshiense* Mansuy, pp. 47, 48, pl. 7, fig. 8*a–d*.

Grabau (1922) doubts the generic identification of this species though his opinion was based only on a study of the published figures. The species, which has a maximum diameter of 7–8 mm., shows two series of septa: the major series meet at the axis and are welded together with sclerenchyme while the minor series are about half as long. The outer wall is thick and some of the septa show a thickening which may be the result of the section cutting through carinae. Unfortunately the reproduction of the plate is not clear enough to be certain on this point. I think Mansuy was probably correct in placing the species in *Metriophyllum*. The species occurs in the Middle Devonian of Indo-China.

? Metriophyllum sp. Smith 1953

1953 ? *Metriophyllum sp.* Smith, pp. 305–6, no figures.

Smith described a species of rugose coral from south-west Devonshire and assigned it tentatively to the genus *Metriophyllum*. The slates in which these fossils occur are thought to be of Lower Devonian age. All the specimens are somewhat compressed, and Smith did not feel justified in giving the form a specific name. I have examined the specimens, and I am very doubtful whether they should be referred to the genus *Metriophyllum* since carinae are completely lacking. The septa are much dilated in their axial parts

and laterally contiguous, thus forming a solid structure which fills most of the lumen; tabulae are absent. Smith suggested that the form probably represented an early species of *Metriophyllum* and this may well be, since it has already been noticed above that the Couvinian form, *M. gracile*, often shows septa which are swollen at the axis, sometimes with the development of a narrow aulos. (Such characteristics are also suggestive of *Syringaxon*—a fact which suggests that Lecompte (1952) is correct in placing *Metriophyllum* and *Syringaxon* in the same family (the Metriophyllidae).) However, until better-preserved specimens become available, I prefer not to regard *?Metriophyllum* Smith as a species of *Metriophyllum* s.s.

Repositories. Corals illustrated in this paper are located in the following museums:
The New York State Museum, Albany 1, U.S.A. (NYSM).
The British Museum (Natural History), London (BMNH).
The Geologisch-palaeontologisches Institut und Museum, Bonn (Schlüter collection) (Bonn).
The Murchison Museum, Dept. of Geology, Imperial College, London (MM).

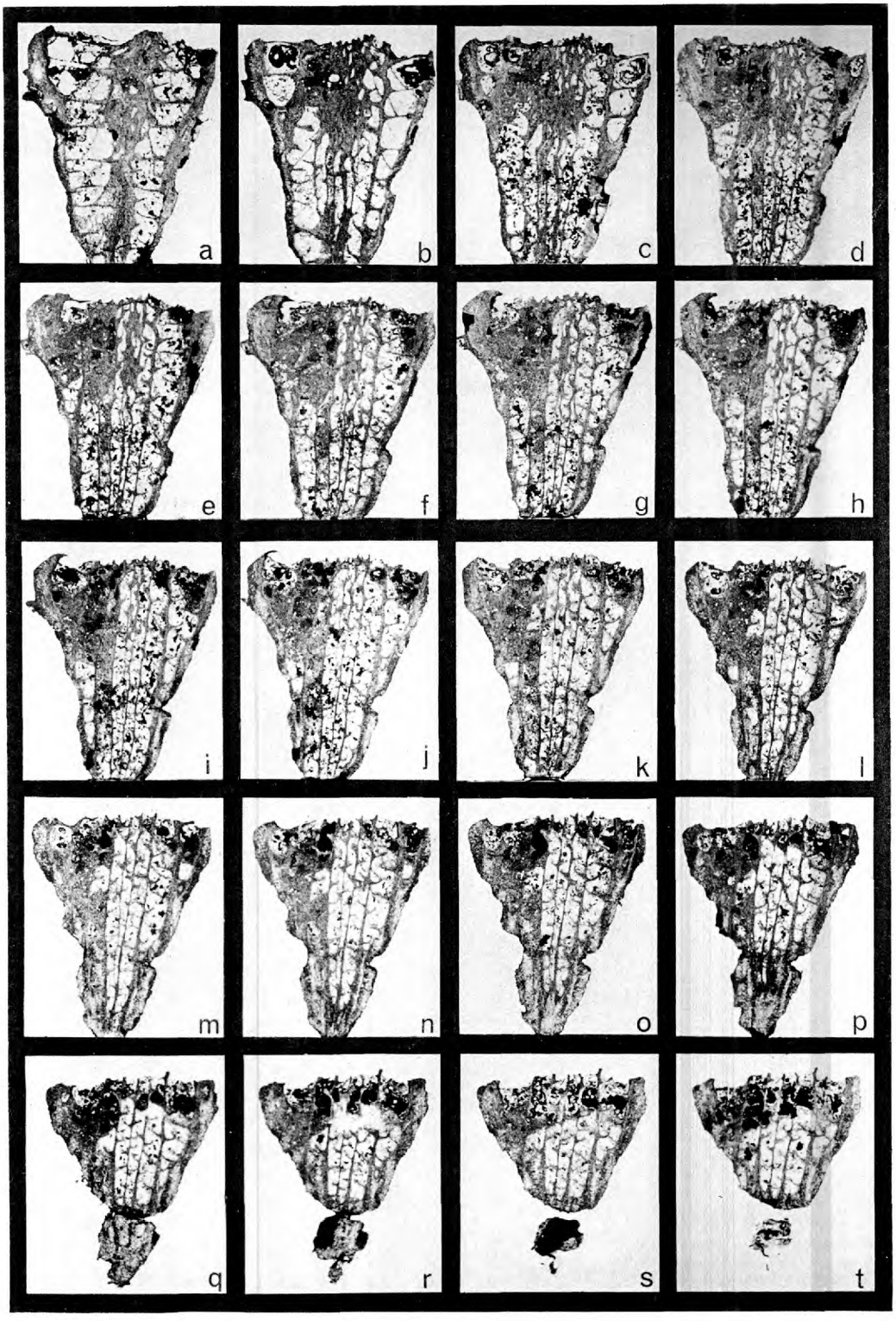
Acknowledgements. I have very much appreciated the co-operation given to me by the staffs of the British Museum (Nat. Hist.) and the Geologisch-palaeontologisches Institut und Museum at Bonn, who have permitted the loan of numerous specimens in their charge; and also the kindness of the New York State Museum in supplying me with excellent photographs of type specimens in that museum. I also express my sincere thanks to Dr. Gwyn Thomas for helpful criticism during the preparation of this paper. The help given by Mrs. J. Creighton and Miss M. Simpson in the preparation of material and by Mr. J. Gee in photographing it, is also gratefully acknowledged.

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EXPLANATION OF PLATE 19

Metriophyllum bouchardi (Edwards and Haime). Sequence of longitudinal sections from the axis (fig. *a*) to near the outer wall (fig. *p*). The outward sloping tabulae are well shown in the near axial sections. BMNH R16242, ×4.



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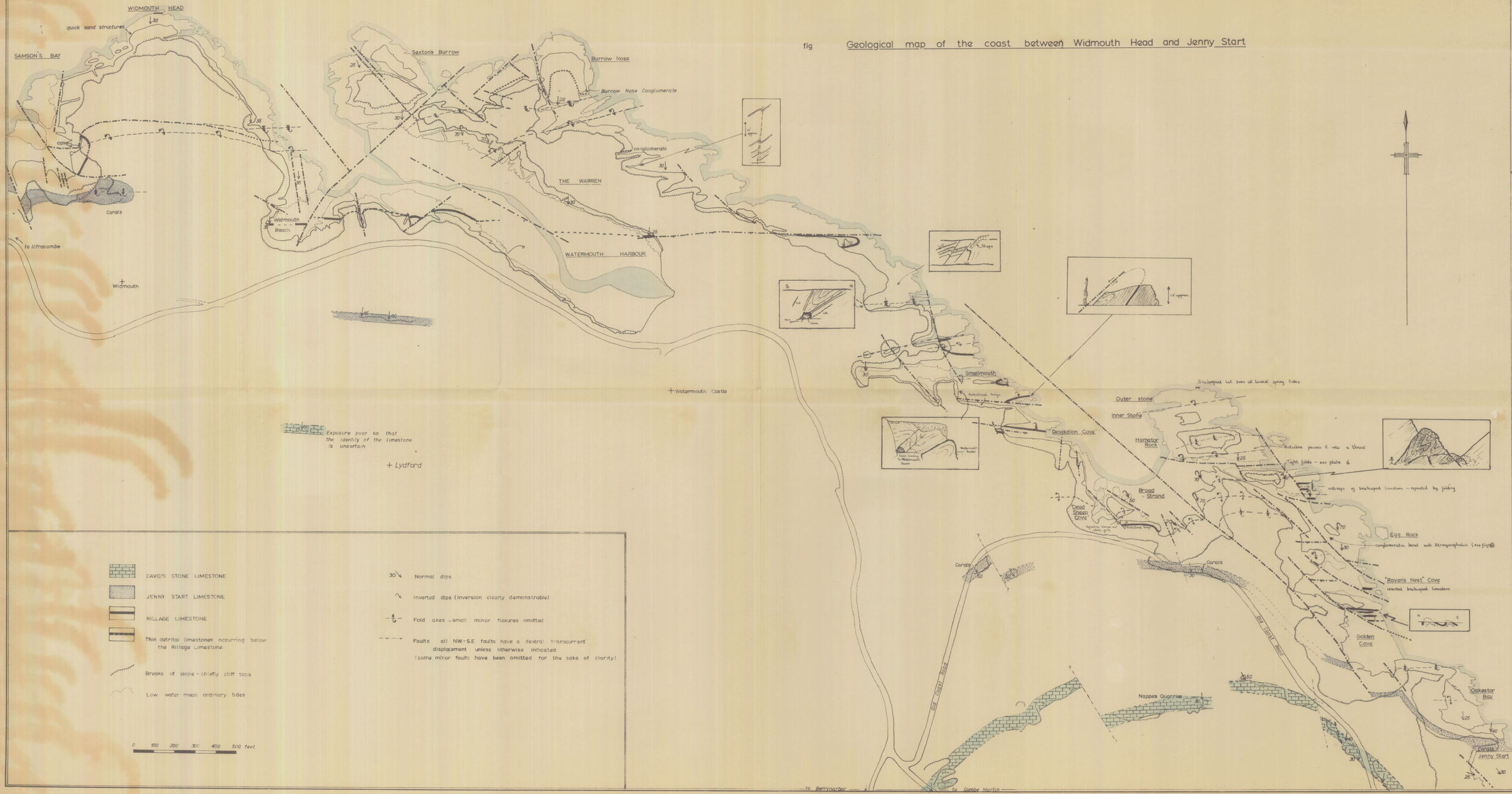
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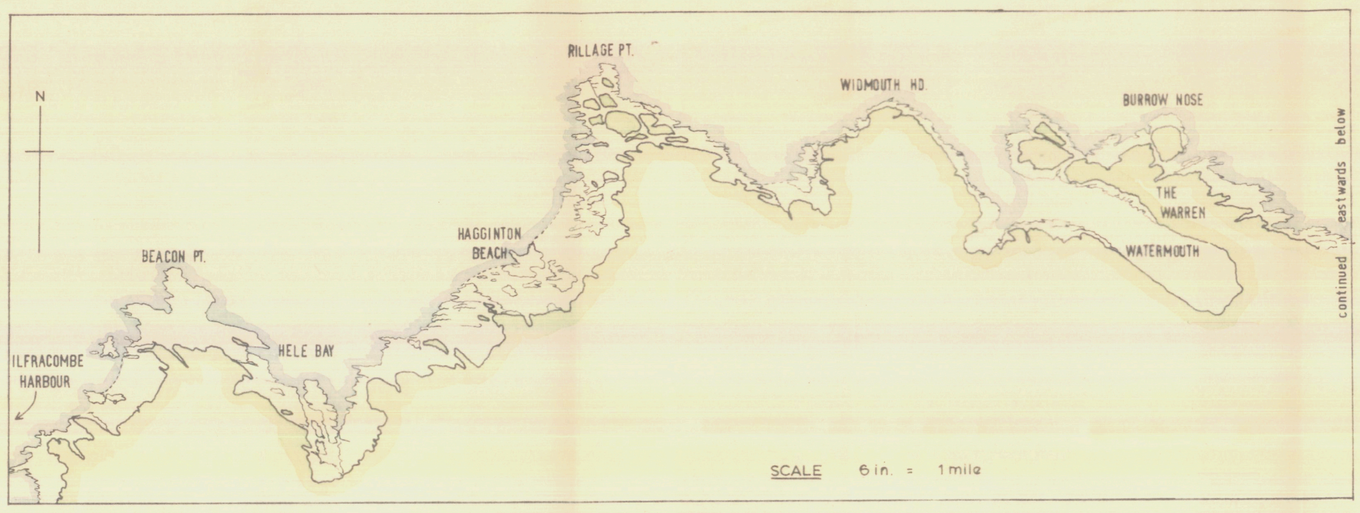
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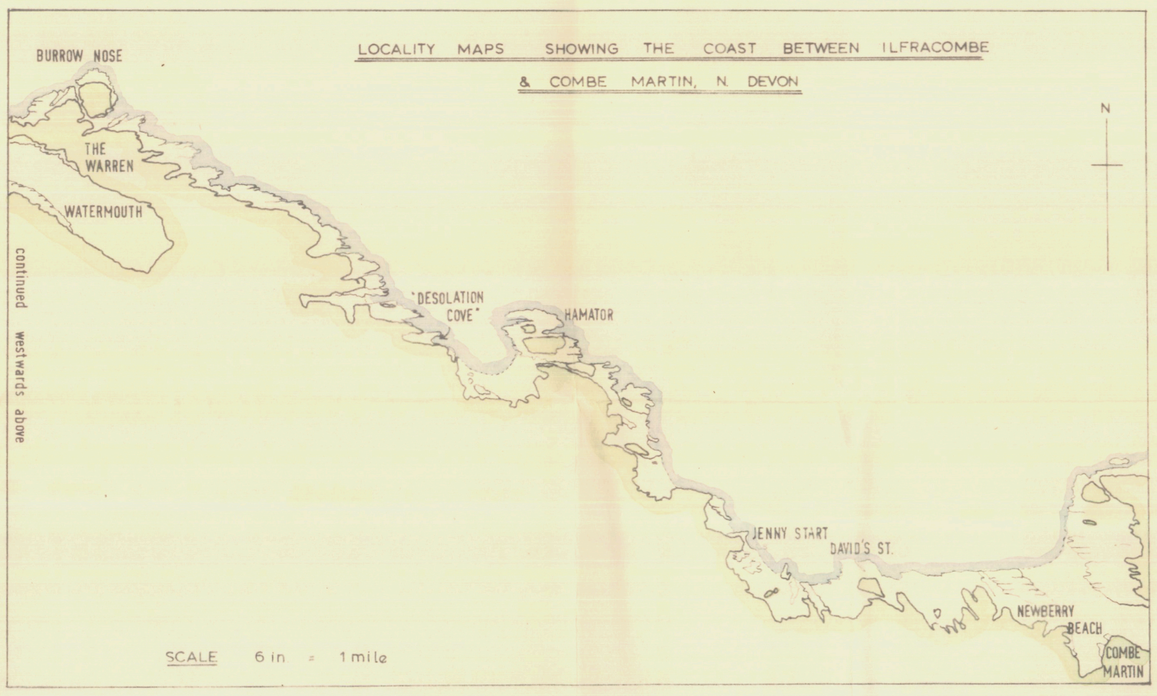
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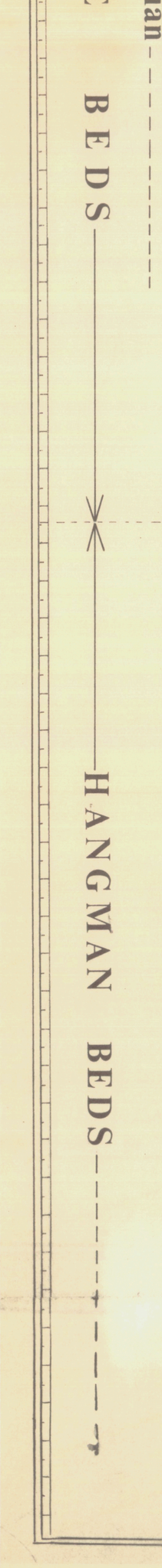
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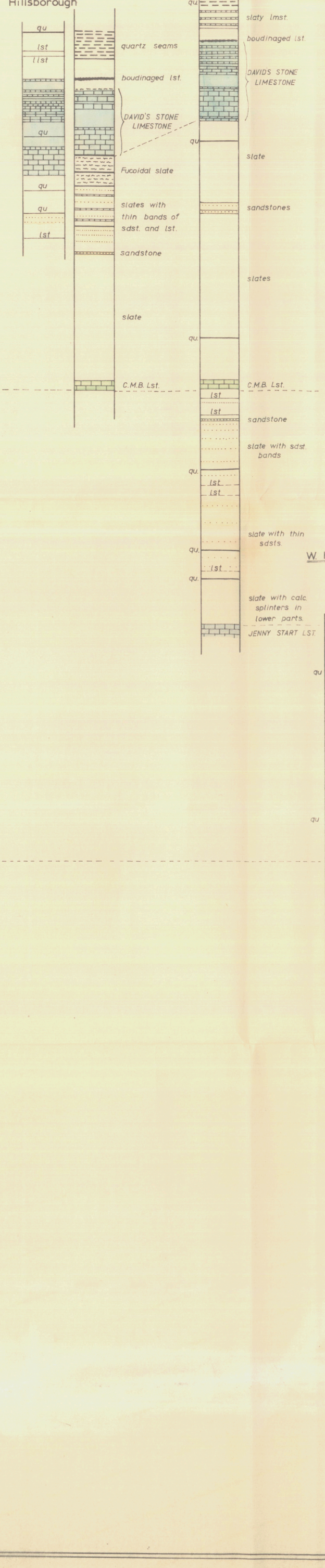


CORRELATION CHART
showing the SUCCESSION within the ILFRACOMBE BEDS of NORTH DEVON









NOTE: Limestones less than 6 ins thick shown thus- lst