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ABSTRACT OF THESIS

Name of Candidate JOHN MYLES BOWEN
Degree Doctor of Philosophy Date 1st. August 1954
Title of Thesis The Upper Palaeozoic Rocks of the Berwick District.

A geological survey has been made of the Upper Palaeozoic Rocks of the Berwick district, and the stratigraphy, tectonics and palaeontology of the area are described. The following significant points have been noted.

1. A series of andesitic lavas and agglomerates occur on the southern flank of Lamberton Moor; they closely resemble the volcanic rocks of the Eyemouth and Ayton district and they are therefore believed to be of Lower Old Red Sandstone age.
2. The lowest sandstones on the downthrown side of the Burnmouth Fault are of Upper Old Red Sandstone facies and of probable Upper Old Red Sandstone age. The thickness of the Cementstone Group at Burnmouth is therefore 1600 feet, compared with over 3500 feet in the Tweed Valley.
3. The rocks of the Cementstone Group were deposited in a rapidly subsiding basin between the Southern Uplands and Cheviot axes; the marine conditions which prevailed in the Cumberland area in Z₂ to C₂ times do not appear to have extended to the north of the Cheviot axis.
4. The Fell Sandstone overlies the Cementstone Group with marked disconformity at Burnmouth, but to the south of the Tweed the lower members of the sandstone group are intercalated with sediments of Cementstone facies.
5. A marine band at Lamberton in the upper part of the Scremerston Coal Group is correlated with the Lower Cove Marine Band and the Redesdale Ironstone Shale; the Duddo Limestone and the Stocking Burn Limestone at Alwick may also represent the same horizon.
6. In the Lower Limestone Group, the Dun Limestone is correlated with the Upper Cove Marine Band and the Redesdale Limestone. The Woodend Limestone is not represented at Cove or Hilton Bay and it is probable that it was not deposited across the Southern Uplands axis; in south Northumberland it is represented by the Furlaws Limestone. The significance of the unconformity beneath the Red Shin Sandstone has been overestimated. The Watchlaw Limestone of the Ford district is represented by the Red Shin Marine Band. Another marine horizon, a discontinuous limestone, has been found above the Red Shin Sandstone.
7. The significance of rhythmic sedimentation in the Middle Limestone Group for purposes of short-distance correlation is emphasised; e.g. the Budle Limestone is correlated with the 2nd. Limestone at Berwick (**fig. 9**).
8. The structure of the Berwick district is influenced by the presence of the stable block formed by the Lower Palaeozoic rocks of Lamberton Moor. Reversed faults at Burnmouth and Lamberton were initiated by approximately east-west compressive forces which had already given rise to the Scremerston Anticline; stress was

relieved by north-east to south-west dextral tear-faults, and east-west normal faults downthrowing to the south.

9. The principal features of the geology of the Berwick district are related to the position of the area between the Southern Uplands and Cheviot axes.

THE UPPER PALAEOZOIC ROCKS OF THE BERWICK DISTRICT

by

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B.A., F.G.S.

1954



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INTRODUCTION

1) The Area Surveyed.

The field work upon which this investigation is based included the mapping of an area of approximately one hundred square miles. The area of the survey lies largely to the south and west of Berwick upon Tweed (fig. 1), but in addition, it includes a narrow coastal strip extending as far as Burnmouth, some six miles to the north-west. The area surveyed includes the valley of the Whiteadder Water as far as its junction with the Blackadder, the valley of the lower Tweed, the lowest reaches of the River Till and the area to the north of a line extending from Tillmouth to the village of Goswick on the coast opposite the western point of Holy Island. It has also been found necessary to visit the majority of rock outcrops, recorded and unrecorded, within the districts surrounding Duns, Kelso, Coldstream and Wooler.

2) Summary of the Geology and Scenery.

The lower valleys of the Whiteadder Water and the Tweed form the eastern part of the Merse of Berwickshire, a pleasant undulating vale, which extends from Duns to the Tweed, and from Kelso to Berwick; the southern part of this vale lies in Northumberland where it is drained by the River Till. The Merse lies between two areas of high relief, the Southern Uplands to the north, and the Cheviot Hills to the south.

Red sandstones and conglomerates, which are assigned to the Upper Old Red Sandstone Group form the foothills of the Southern Uplands, flanking the Merse to the north and west. The conglomerates lie unconformably upon sediments of Silurian age and in places upon Lower Old Red Sandstone igneous rocks.

The Kelso Lavas, which succeed the Upper Old Red Sandstone, form a number of features in the west of the Merse, but they do not extend far to the east.

The Merse is the type area of Tate's Tuedian succession (1856), particularly the lower member of that division, namely the Cementstone Group, great thicknesses of which were deposited under lagoonal and estuarine conditions. To the south the Cementstone Group is faulted against the Lower Old Red Sandstone lavas of the Cheviot Hills (Plate I, fig.i).

The Fell Sandstone Group, which constitutes the upper part of the Tuedian division, overlies the Cementstone Group forming a series of escarpments, bordering the Merse to the south-east.

The higher of these escarpments are formed by the sandstones of the lower part of the Scremerston Coal Group, which overlies the Fell Sandstone. To the east of the watershed a flat, featureless countryside, which contrasts strongly with the Merse, slopes imperceptibly towards the North Sea. In the highest parts of this area many disused coal workings indicate the presence underground of the Scremerston Coals, a group of rocks which show their greatest

development a short distance to the south of Berwick, where coal is still mined. Near the top of this group the first significant marine beds, containing a D_1 fauna, are found.

On the coast to the south-east of Burnmouth (Plate I, fig.ii), the Cementstone Group, Fell Sandstone and Scremerston Coal Group are reduced in thickness.

The Dun Limestone forms the base of the Lower Limestone Group. It is seen dipping steeply beneath the town of Berwick and striking to the south-east across the mouth of the Tweed and along the Spittal coast. South of Scremerston the strike swings sharply to the south-west and the dip decreases; at Duddo, six miles to the south-west of Berwick, the strike reverts to a southerly direction. The outcrops of the succeeding groups conform to this structural pattern, the highest beds in the area forming a shallow syncline to the south-east, near Goswick.

The Lower Limestone Group forms a dominantly arenaceous phase below a typical Yoredale succession. A rhythmic sequence is already recognisable and a few marine horizons occur, but in most cases these are discontinuous as a result of contemporaneous erosion; this fact makes correlation difficult. Fortunately the lowest limestone, the Dun, is remarkably constant in both extent and character. The Woodend Limestone which succeeds the Dun is also widespread to the south of Berwick. Thin coals and a single oil-shale

band occur in this group.

The Middle Limestone Group includes the strata between the base of the Oxford Limestone and the base of the Dryburn Limestone. The lower beds of this group are well displayed on the coast at Berwick and again to the south of Spittal. The group contains many marine horizons of which the best known are the Oxford, Eelwell, Acre and Sandbanks Limestones; these contain a fauna which indicates that they are of D₂ age. The base of the Namurian is believed (Trotter, 1951) to lie between the Acre and Sandbanks Limestones (see page 90). The Dryburn Limestone and the beds above it are scarcely exposed in this area and they are not discussed in this thesis.

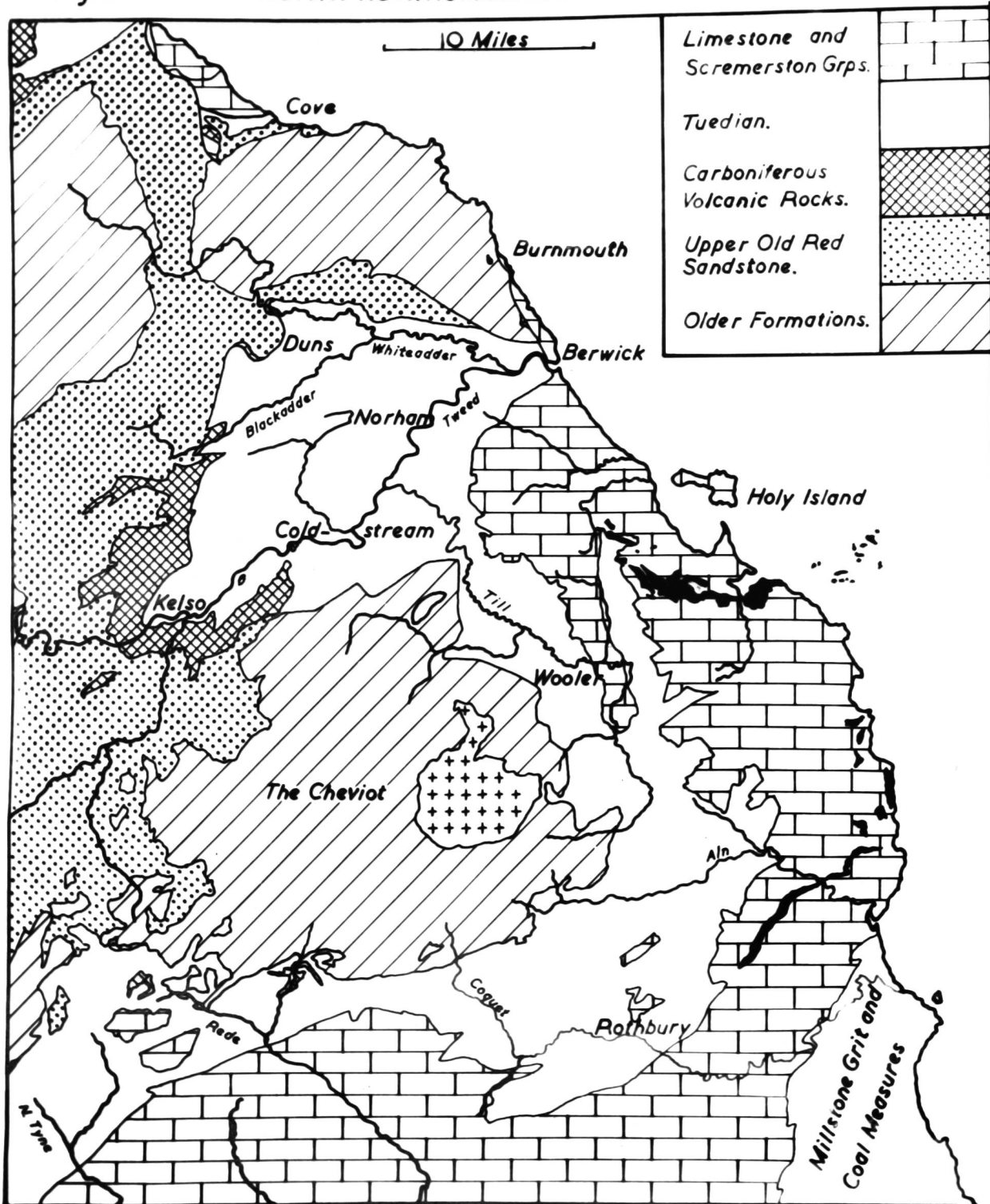
The Principal Horizons of the Lower Carboniferous Rocks in the Neighbourhood of Berwick upon Tweed.

<u>Subdivision.</u>	<u>Group.</u>	<u>Thickness.</u> (in feet)	<u>Principal Horizons.</u>
Bernician	Calcareous { Middle Limestones	820	Sandbanks Limestone Acre Limestone Eelwell Limestone Oxford Limestone
	{ Lower Limestones	740 - 830	Watchlaw Limestone Woodend Limestone Dun Limestone
Tuedian	Carbonaceous { Scremerston Coals	350?+ - 1000	Lamberton Marine Band =? Duddo Limestone
	{ Fell Sandstone	550?+ - 1100	Longridge Sandstones
	{ Cementstones	1600 - 3750	Norham Serpulid Bed Coldstream Shelly Beds

Upper Old Red sandstones and conglomerates.

Fig. 1.

NORTH NORTHUMBERLAND AND BERWICKSHIRE.



3) Previous Research.

Most of the area under consideration has been neglected by geologists in the past, partly because of its comparatively isolated position on the borders of England and Scotland, and partly because of the apparently unfossiliferous nature of the succession. The works of the few who have been patient enough to study the rocks of the area have been quoted by many later writers on Carboniferous stratigraphy.

No reliable records were made until the early part of the nineteenth century. At that time considerable doubt existed concerning the position of the red sandstones which had been observed in Berwickshire and north Northumberland. The sandstones were often seen to overlie typically Carbonaceous sediments, with apparent unconformity. It was suggested, therefore, that the red sandstones belonged to the New Red Sandstone formation, and that some of the dolomitic limestones associated with them were representatives of the Magnesian Limestone; this belief found expression in the early maps of Greenough (1820) and William Smith (1828).

The first geologists to interest themselves in the rocks of this area were Wood (1831, 1838), and Winch (1816, 1831) who believed that the red sandstones were coeval with the encrinal limestones and carbonaceous beds. Another who agreed with them was J. Witham (1831); meanwhile, T. Witham (1830, 1831) described "fossil vegetables" discovered in the

Cementstones at Lennel Braes, near Coldstream. Nevertheless, the view that the red sandstones were of New Red Sandstone age persisted for some time, finding support from Thomson (1831, 1835) and to a lesser extent from Milne-Home (1835, 1837, 1838).

The history of geological research in this area throughout the following thirty years is dominated by two local men. William Stevenson (1843 - 1864) an estate factor of Duns, confined his attention chiefly to the Upper Old Red Sandstone and Cementstone Group in the neighbourhood of his home town. Stevenson, however, must take second place to George Tate (1849 - 1871), an Alnwick man whose knowledge of the geology of north Northumberland was unsurpassed. Tate was by no means parochial in his studies and journeyed far and wide over Northumberland and Berwickshire, to the detriment of his home life. It is hard to find fault with Tate's factual accounts of the rocks of the Berwick district, and if they were ponderous, it was, after all, a characteristic of the age in which he lived. He named the lowest part of the Carboniferous succession (the Fell Sandstone and Cementstones), the Tuedian, (1856) a name which has persisted, despite the objections of later writers (e.g. Miller, 1887). The rocks above the Tuedian, which were at that time known as the Mountain Limestone (Phillips 1836), which Tate subdivided into a lower Carbonaceous Group (the Scremerston Coals) and an upper Calcareous Group (the Limestone Groups). An officer of the Berwick Naturalists Club, he was an assiduous leader of geological

excursions and it is in the club transactions that most of his papers are to be found.

Most of the subsequent research in the area has been carried out by officers of the Geological Survey. In 1864 Geikie published a memoir on the geology of Eastern Berwickshire, but it would seem that he knew little or nothing of Tate's work upon the Carboniferous rocks of the district.

Lebour (1875-1886) reclassified the Lower Carboniferous of north Northumberland, discarding Tate's Carbonaceous and Calcareous divisions, and substituting for them a single group, the Bernician, which he maintained could not be further subdivided. Miller (1887), despite his dislike of the word Tuedian, endorsed Tate's classification. The terms Bernician and Mountain Limestone are synonymous.

In the last decade of the century Clough and Gunn (1883) carried out a survey of the Cheviot and Berwick districts. Later, Gunn (1897) published a short description of the geology of Berwick upon Tweed and a year later attempted a correlation of the Lower Carboniferous rocks of northern England and Scotland. Goodchild (1900, 1903) contributed little of significance to the existing knowledge of the area; Smith (1910) made a comprehensive study of the fauna of the Limestone Groups; and Garwood (1910, 1912) related the Carboniferous of the extreme north-east to its equivalents in the south and west. In the period following the first World War, the district to the south of Berwick was

re-surveyed by the Geological Survey, (Fowler, 1926), and six years later a Memoir was published on the geology of the Cheviots (Carruthers et al., 1932). In succeeding years work in this area has been largely palaeontological, and perhaps the most notable contribution was the discovery of a new palaeoniscid fish fauna in the Cementstones at Foulden by a young local geologist, T. Ovens, who died shortly afterwards (White, 1927; Moy-Thomas, 1938).

Meanwhile, on the Scottish side of the Border no revision of Geikie's survey of 1864 has been published. There has been much fossil collecting, however, and the Cementstones of the Merse have yielded many plants, fish and crustacea to Macconochie and Tait of the Geological Survey; many of these were identified by Peach and Kidston.

A survey was commenced in the Kelso district before the recent war (Macgregor, 1937, 1938), but no map or memoir has yet been published.

4) Regional Problems.

The proximity of the Lower Carboniferous rocks of the Berwick district to those of the Midland Valley of Scotland is of obvious significance in any endeavour to compare or equate the successions or to assess the palaeogeography of the region.

Perhaps the most important influence affecting the sedimentary record of the Berwick area is the proximity of the

Southern Uplands axis (fig. 12).

The pre-Carboniferous palaeogeography is relatively clear. Red sandstones and conglomerates of continental facies were deposited under arid conditions upon the flanks of a ridge of considerable relief. The burial of the earlier rocks was probably complete in this area before changing conditions brought about a gradual change of sedimentary facies. The red sandstones were succeeded by conglstones and marls, and these in turn by cementstones with marls and shales; the change of facies is slight and the position of the boundary between the two groups is therefore uncertain. There is a faunal break, but the fauna is so scanty that it is of little help in the field; there is little evidence of a sedimentary break. The writer feels that attempts to fix the position of the boundary in the field can have little value as there is at present no means of dating the slight change in conditions which caused the faunal break; it is almost certainly not earlier than Z_1 — it may well be later, (fig. 4A).

In the Cementstone Group there is clear evidence of the existence between the Southern Uplands axis on the north-west and a subsidiary Cheviot axis to the south-east of a sedimentary basin within which rapid subsidence took place. In the Cementstones of the Tweed valley there are none of the diagnostic marine fossils which characterise the same group in Cumberland and south Northumberland. It seems probable

that the barrier formed by the Cheviot axis prevented the extension of marine conditions into the Tweed basin from the south, while the Southern Uplands axis acted in the same way to the north.

Both the upper and lower boundaries of the Tuedian division are difficult to define, as is the base of the Fell Sandstone, which subdivides it. In the north of the area there is a sedimentary break below the Fell Sandstone, but to the south there is interdigitation with beds of Cementstone facies. As a sandstone is a better marker in the field than a shale containing cementstones, and as the lower members of the Fell Sandstone have a distinctive lithology, the writer places the boundary locally at the point at which the lowest Fell-type sandstone is seen. The same difficulty arises in the case of the upper limit of the Fell Sandstone; here the writer has discarded the boundary used by earlier workers, a thin and probably discontinuous coal, in favour of the position at which the massive sandstones give way to shales with limestones and coals.

The Fell Sandstone and the Scremerston Coal Group show considerable variation in thickness, both becoming attenuated across the Cheviot axis to the south. It is doubtful whether these groups are represented to the north, but in the writer's opinion a greatly reduced succession is to be seen at Cove (see page 104). It is not certain

however whether any attenuation occurs northwards within the area of this survey.

In the highest part of the Scremerston group a marine horizon has been found which is correlated with the Lower Cove Marine Band to the north and the Redesdale Ironstone Shale to the south. From this level upwards in the succession numerous marine horizons occur, most of which can be traced to the south and some of which can be correlated with beds in the Scottish succession. During $D_1 - D_2$ times the rate of subsidence appears to have become more uniform, and the control of the Southern Uplands and Cheviot axes less marked; consequently the sediments show less variation throughout the region.

STRATIGRAPHY

1) The Lower Old Red Sandstone.

A confused series of andesitic lavas and tuffs, penetrated by vents filled with agglomerate, and pierced by intrusions of porphyrite, occurs on the Berwickshire coast between Eyemouth and St. Abb's Head. These rocks were first surveyed by A. Geikie (1864, also 1897), and later J. Geikie (1887) described the succession at St. Abb's Head; since then little or no work has been done in this area.

On the coast the succession consists predominantly of tuffs which appear to grade into, and are hard to differentiate from the porphyritic "lava-form" rocks; as the rocks are followed inland to the south-west the signs of vulcanicity rapidly diminish, and the tuffs give way to the feldspathic sandstones and shales from which Geikie obtained plant-remains and Pterygotus.

The series appears to be faulted against the Silurian to the south-east, along a line from Eyemouth to Millerton Hill; no outcrop was recorded by Geikie on the south-east side of the fault, and as the Upper Old Red Sandstones lie unconformably on these rocks to the north of Chirnside none was expected within the area surveyed.

The Geological Survey map (Sheet 34) shows a "felstone" intrusion in the Wheatlands Burn immediately above Mordington Bridge, but there is no mention of it in the explanation of the

sheet despite its exceptional position within the outcrop of the Upper Old Red Sandstone. 250 yards north of Mordington Bridge a cobble conglomerate is exposed in the bed of the burn and a few yards nearer the bridge is a very coarse unsorted breccia-conglomerate at a small waterfall beside which (in the left bank) is an outcrop of a compact red-stained igneous rock, (fig. 2).

The relationship of this igneous rock to the surrounding rocks is obscure. It appears to be faulted against the conglomerate along a line which strikes north 27° east; at its southern end it is truncated by another fault which strikes to the south-east, (see page 116). The rock, in common with the others at this locality, is much decomposed and it is not possible to give a satisfactory description of it. It has a fine-grained quartzose matrix containing small phenocrysts of biotite and highly altered feldspar; the orientation of the phenocrysts shows flow-texture which may indicate that the rock is a lava.

Lying against it, and exposed in the burn as far as Mordington Bridge is a purplish-red feldspathic agglomerate (Plate XV fig.ii) which consists of angular fragments of andesitic material in a soft decomposed ashy matrix; it is largely unbedded, but there are indications of a slight southerly dip. The composition of the fragments is similar to that of the porphyritic rock against which it is faulted, despite considerable variation in the texture of the groundmass, which

often encloses well-rounded grains of quartz with slight reaction rims and signs of resorption. Similar grains also occur in the groundmass itself which is of much finer grain and stained with abundant red iron oxide. It is clear from their angular shape and the projecting feldspars that the fragments have suffered little attrition; neither vesicular nor glassy material has been detected in the sections examined.

An andesitic lava, of a type not represented in the agglomerate, outcrops immediately to the south of Mordington Bridge. It contains similar phenocrysts of feldspar and biotite, and grains of quartz lying in a very fine groundmass predominantly composed of highly altered feldspar laths. At a point 40 yards south of the bridge the lava is faulted against red marls and mottled sandstones of Upper Old Red type.

At Blinkbonny quarry to the east of Nunlands there is a porphyritic rock of basaltic composition; the phenocrysts, which have been replaced by iron oxide, lie in a groundmass of feldspar laths. The rock, of more basic composition, is unlike any of the known Lower Old Red Sandstone lavas in this district.

There can be little doubt however that these rocks are representatives of the Eyemouth volcanic series. The northern outcrop appears to be the lowest in the succession, as the agglomerate is down-faulted against it; the fact that the fragments in the agglomerate are of a similar rock type bears out this suggestion. Although the position of the lava to the

south of the bridge remains obscure, the available evidence indicates that it overlies the agglomerate. The existence of these rocks is of interest in providing a further indication of the extent of the Eyemouth Lower Old Red Sandstone volcanic series.

2) The Upper Old Red Sandstone.

A thick series of sediments of continental facies was deposited upon rocks of Lower Old Red Sandstone and Silurian age in eastern Berwickshire. As the pre-Upper Old Red Sandstone land-surface was one of considerable relief, the outcrop of these rocks shows continual variation in thickness, and there can be little doubt that the oldest members of the group lie hidden beneath later sediments. Two lithological types are represented; (a) the marginal (locally basal) conglomerates or breccias and (b) the calcareous mottled sandstones and marls which were probably in part coeval with (a). It seems probable that these continental conditions prevailed from the Devonian into early Tournaisian times (George, 1948).

In this area there is little evidence of sedimentary discontinuity between the Upper Old Red Sandstone and the overlying Cementstone Group of the Lower Carboniferous. The criteria that have been used to distinguish these two groups are the change of sedimentary facies and the consequent differences in the fauna and flora. The best exposures in the eastern part of the county occur at Siccar Point and on the Whiteadder Water below Cockburn Mill, near Duns. To the east of Duns there are few exposures; Geikie (1864) described the rocks of this age which extend from Cockburn Mill to Mordington Church as resting at each end upon highly inclined Silurian strata, and in between upon the ashes of Lower Old Red Sandstone age, with a thickness

of "probably not more than 1000 feet". Scales of Holoptychius occur near the local base at Cockburn Mill and a specimen of Bothriolepis ornata was obtained from Harelaw quarry near Chirnside*.

The outcrops which lie within the area of this survey occur in two areas flanking the Silurian rocks and associated intrusions of Lamberton Moor. Geikie described outliers of conglomerate and coarse breccia-conglomerate at St. Abb's and at Eyemouth, and others in the neighbourhood of Burnmouth and Lamberton; of these, four lie to the south of Partanhall.

Geikie noted the presence of a small patch of breccia adhering to the cliff on the north side of Burnmouth Glen below the bend in the Partanhall road; the writer has examined this locality and considers the uncemented breccia seen there to consist of recent scree material.

The most striking of the outliers forms a prominent crag at Chester Hill, half a mile south of Burnmouth (Plate II fig. i). Little can be added to Geikie's description; the highest and coarsest part of this unsorted breccia-conglomerate lies 560 feet above sea level, within 150 feet of the summit of Lamberton Moor, and at a level close to its average height. A slight dip towards the hill is visible among some of the sandy beds in the lower part and these serve to show the steepness of the slope against which these sediments were deposited.

* On view at the Geological Museum, South Kensington.

Most of the boulders and cobbles are locally derived from the greywackes and intrusive porphyries of Lamberton Moor, but there are also less abundant fragments of fine-grained andesitic tuffs, and pebble-conglomerates containing igneous material of Lower Old Red Sandstone type. The angularity and great size of some of the boulders, and the composition of the conglomerate itself indicate that during its deposition the burial of the contemporary topography was by no means complete.

Further outcrops of marginal conglomerates are found at Hilton Bay (Plate VIII fig.ii) where the steep slope of the old land surface is again clearly seen. There are two outliers here; only the higher of these was noticed in the original survey, which was inaccurate in placing the position of the boundary fault at this point, (fig. 6).

Isolated outcrops of unsorted breccia-conglomerate occur in the cliff on the west side of the Bay from a point 30 feet above the beach to the level of the 200 foot contour, above which lies a covering of boulder-clay of very similar appearance. The clearest exposures (Plate II, fig.ii) are close to the Burnmouth Fault at the north side of the Bay where a dip of 35° towards the hill is visible in sandy pebble-conglomerate showing ripple-marks. Here, as at Chester Hill, the size of the fragments increases towards the top of the outcrop.

In the middle of the Bay (fig.6) another small exposure can be seen at low tide, close to the fault and separated from

the cliff exposure by a narrow outcrop of calcite-veined greywacke (Plate VIII fig. 17). The fragments here form a high proportion of the rock, being angular and more like a scree breccia than a conglomerate. If no fault intervenes between these outcrops and that at Chester Hill, at least 600 feet of marginal beds must have accumulated against a steep slope of the old land surface.

The remaining outlier of marginal conglomerate lies two miles to the south of Hilton Bay in the valley of the burn behind New East Farm, between 300 and 400 feet above sea level; it extends half a mile to the south-east past Scuddylaw. The steep dip to the east-north-east shewn on the original survey map appears to have been caused by contemporaneous slumping movements caused by a minor land-slip, and although there are few exposures, there is little to suggest that the beds are not in an approximately horizontal position, as in the other outliers.

The fragments of the Hilton Bay and New East Farm conglomerates are apparently entirely composed of greywackes or intrusive porphyries similar to the underlying rocks. The four outliers show that prior to the deposition of these conglomerates there was an escarpment, perhaps a fault-scarp, parallel to the trend of the present boundary fault. No further outliers occur to the north-east of Lamberton Moor, while all the rocks to the east of the main fault were believed by all previous workers to be of Carboniferous age, (Geikie, 1864; Gunn, 1897, etc.).

The oldest rocks in the vertical limb of the monoclinial fold at Burnmouth lie faulted against the Silurian to the west of the Harbour (fig.3).^{N²⁷} Between the fault at the Harbour (Plate III fig.1) and the base of the Fell Sandstone at Ross Point there is a succession of sandy shales and marls with ribs of cementstone, alternating with bands of sandstone, having a total thickness of 1865 feet. Previous workers have asserted that this succession represents only the upper part of the great development of the Cementstone Group of the Tweed valley. The writer has found, however, that beds which are undoubtedly of Upper Old Red Sandstone facies underlie the Carboniferous rocks close to the Burnmouth Fault.

A marked change in the sedimentary facies occurs at a position close to the angle of the west Harbour wall. The beds to the east of this point yield ostracods, lamellibranchs and plant debris and are typical of the Cementstone Group; to the west there are 250 feet of predominantly arenaceous unfossiliferous strata interbedded with a few bands of red sandy marl. The possibility that these basal sandstones may be faulted against the beds of typical Cementstone type cannot be discounted, but no evidence for such a fault has been found.

The character of the sandstones differs from those of the Cementstone Group; they are pink, yellowish-grey or mottled in colour, are poorly sorted and contain comparatively high percentages of microcline and calcite, the latter occurring both

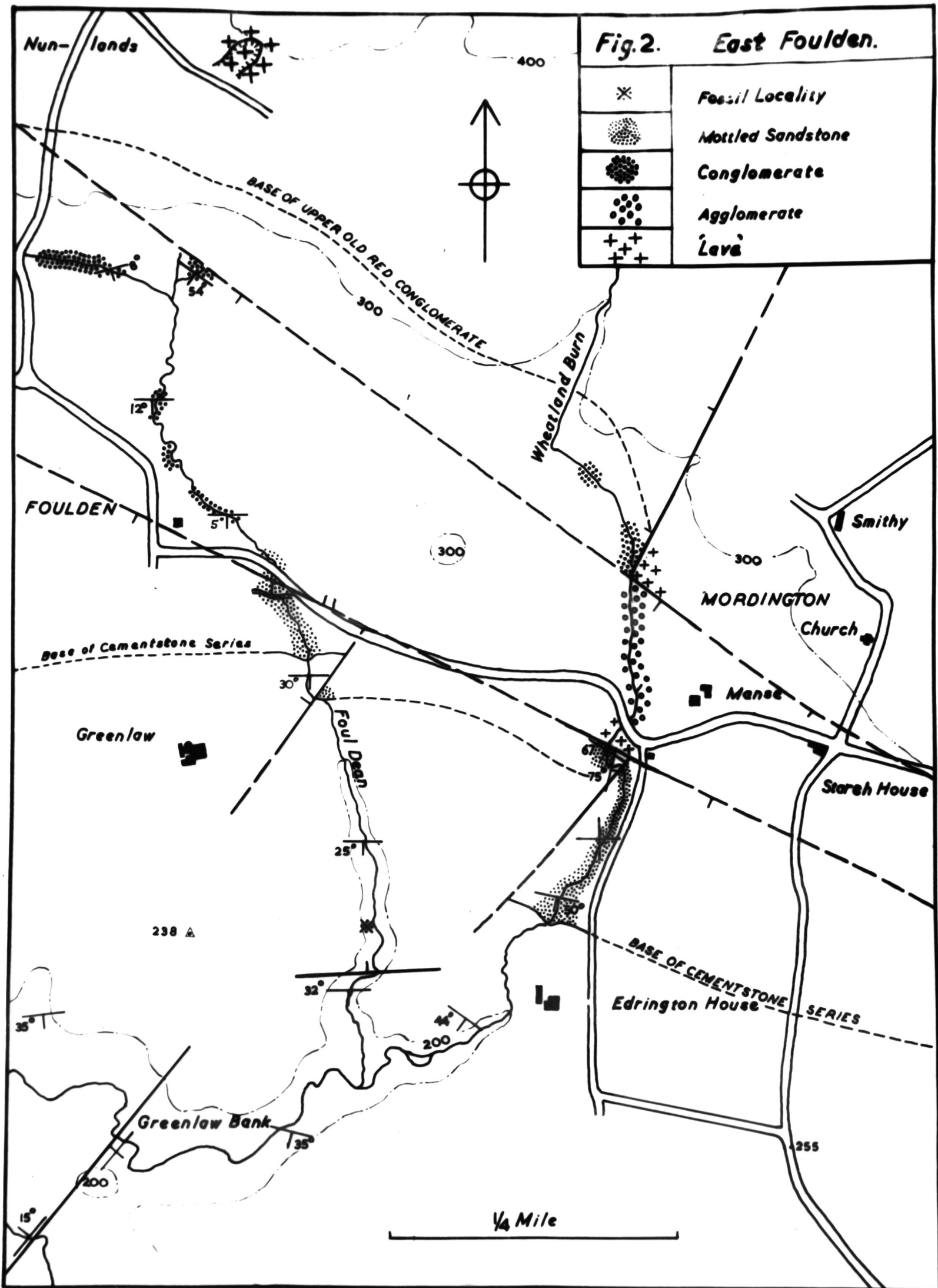
as a cement and as granules of calcareous rock; abraded millet-seed quartz grains and small fragments of fine-grained igneous rock are found in the lower members. A highly calcareous sandstone showing prominent nodular and carious weathering and containing thin lenticles of yellowish-white impure chert occurs 80 feet below the highest sandstone, while lower still there is a band of pebbly grit containing rounded quartz, "cornstone" pebbles, and fragments of decomposed porphyritic igneous rock. The lowest beds visible on the shore exhibit a series of small faults which cannot be traced into the overlying strata and may therefore be of contemporaneous origin.

Certain features of this succession closely resemble those of Upper Old Red Sandstone facies elsewhere, notably at Pease Bay near Cove. The resemblance of the highly calcareous cherty sandstone to Bed (e) at Pease Bay (Clough, 1909) is particularly striking, and it is interesting to note that there is also evidence of contemporaneous faulting at that point. (See note on Cove succession, page 104).

A further occurrence of rocks of Upper Old Red Sandstone facies was found in the ravine of the Catch-a-penny Burn, behind Ross village. Here 80 feet of deep red marls and calcareous siltstones alternating with mottled sandstones underlie a pebbly grit which is apparently faulted against beds low in the Cementstone Group, 200 feet above the basal sandstones of Burnmouth Harbour. They have a steep inverted dip which is conformable

with that of the Cementstone strata, against which they appear to have been thrown by a reversed fault; along the plane of the junction lie a number of large blocks of calcareous sandstone, some of which contain large quantities of brecciated chert. The highest bed is a pebbly grit containing chiefly vein quartz and quartzite, but also fragments of chert, and pebbles of fine-grained, sometimes porphyritic igneous rock. A feature of the underlying marls and calcareous siltstones is the presence of large numbers of rounded and polished millet-seed sand grains, which are clearly wind-blown particles deposited in various grades of sediment (Plate XVI figs. i, ii). At the west end of the section, mottled sandstones are faulted against an intrusive porphyry by the Burnmouth Fault, and greywacke is well exposed a few yards further up the burn. These beds clearly lie at a horizon below that of the basal sandstones at the Harbour. The composition of the pebble-beds is similar and since this shows that the materials were derived from a similar source it is probable that they are of similar age.

The rocks of Upper Old Red Sandstone facies which remain to be described lie to the south of Lamberton Moor in the parish of Foulden (fig.2). They lie at the east end of the outcrop which borders the older rocks to the north; the relations of the red sandstones and conglomerates here are obscure owing to faulting and the great thickness of drift which covers the lower slopes of Lamberton Moor.



The largest number of outcrops is seen in the burn below the bridge on the Nunlands road. Beds of pebble-conglomerate and breccia-conglomerate are interbedded with lenses of red sandstone and marls. At the north-east corner of the wood, 300 yards to the east of the bridge, a coarse conglomerate overlain by a thin band of marl is seen dipping steeply to the south-west. Elsewhere, to the north of Foulden Bridge, the dip of the rocks is lower than those of Carboniferous age to the south, a feature also noticed further to the west, which led earlier workers to believe that these red rocks were of Permian age, lying unconformably upon the Cementstone Group. Close to Foulden Bridge the conglomerates appear to be overlain by mottled sandstones, which closely resemble some of the basal sandstones at Burnmouth.

Rocks of Upper Old Red Sandstone facies are well exposed for 120 yards to the south of Foulden Bridge; they are followed conformably by grey sandy shales with cementstone ribs. Within this section the dip increases abruptly from 12° to 25° or 30° , and there is some evidence of the existence of a fault down-throwing to the south immediately below Foulden Bridge. Twenty yards to the south of the bridge and 100 feet below the top of these sandstones there is a five-foot bed of a character which is unique in this district; it contains small angular fragments of white and grey cornstone, together with well-rounded soft chloritic argillaceous granules and red sandstone pebbles in a

poorly sorted calcareous matrix containing angular and millet-seed sand grains, microcline, and chert. Although no igneous material has been found in this bed, it nevertheless closely resembles the bed described by Phemister (1933) as a "coarse tuff or fine-grained agglomerate . . . without igneous material", which was found 36 feet above the highest of the Kelso lavas at Stonefold, near Greenlaw; the uniform unbedded nature of this rock and the angularity of the concretion particles are possible indications of its pyroclastic origin.

In contrast to the apparently uninterrupted sequence seen in the Foul Dean section, the Wheatlands Burn, only a quarter of a mile to the east (fig.2), exhibits a faulted section which throws little further light on this succession. A pebble-conglomerate of the Foul Dean type is seen to the west of Mordington Smithy, while the next exposures are breccia-conglomerates of the marginal type which appear to be faulted against Lower Old Red Sandstone volcanic rocks (see page 13). Although these are clearly local basal conglomerates, the nature of the junction with the volcanic rocks and the absence of fragments of similar material in the conglomerate indicate the presence of a fault.

Forty yards to the south of Mordington Bridge the upper lava is truncated by a fault, to the south of which red mottled sandstone is succeeded by a grey sandstone of Cementstone type which is steeply inclined against a tear-fault striking to the north-east. Downstream to the south-east of this fault are

approximately horizontal mottled sandstones whose dip increases progressively to the south-west until a point is reached 100 yards to the north of Edrington House where they are overlain by normal Cementstone-type sediments; the dip at this point is 50° . This sequence is similar to that above the tuff-like bed in the Foul Dean; if this correlation is correct, it is in contradiction to the evidence which indicates a south-easterly downthrow for the northern part of the Greenlaw Banks fault (see page 115).

Apart from red sandstones exposed near Foulden Bastle, there are no further exposures of rocks of Upper Old Red Sandstone facies.

From this scanty evidence certain inferences can be drawn. The outliers to the east of Lamberton Moor show that a thickness of at least 600 feet of conglomerates was deposited at the foot of an escarpment which lay parallel to the strike of the present boundary fault. There is evidence that by the time the higher sandstones of this group were being deposited the greater part of the north-east of the Southern Uplands ridge was already covered by sediments. Parts of this ridge must have reached a great elevation, (as shown by the size of the boulders in the Chester Hill conglomerate) and it follows that the sediments on its flanks may have reached very considerable thicknesses.

On the southern side of Lamberton Moor there is only a small thickness of red beds which are not seen to the east of Mordington

The original Geological Survey map (Sheet 34) showed that the Carboniferous rocks overlapped the Lower Palaeozoic at this point; although such an overlap does occur on the flanks of the Cheviot Hills, there does not appear to be any evidence for a similar occurrence here. It seems more probable that a number of faults (the Mordington faults, see page 116) border the Lamberton hills, downthrowing to the south and cutting out a considerable thickness of rocks. The latter probably include red marls of the Catch-a-penny type, and possibly developments of cornstones which although they are of common occurrence as fragments in the higher beds, have not been seen in this area.

There is no development of the Kelso volcanic series in the area, although the tuff-like bed in the Foul Dean is possibly of pyroclastic origin, and may therefore be contemporaneous; fragments in the Catch-a-penny and Burnmouth Harbour pebble-beds may have been derived from the recorded contemporaneous erosion of the lavas (Manson and Phemister, 1933, Macgregor, 1938). If this is the case the thick cornstones and red and green marls of the Carham and Kelso districts have been replaced by an arenaceous facies at Foulden and Burnmouth.

3) The Cementstone Group.

In the Berwick district, the Cementstone Group is represented by a great thickness of sediments of a distinctive facies. The group has been framed on lithological grounds and its limits are difficult to define with any precision. There are no reliable marker horizons within the group and it is not possible therefore, to make any useful comparisons of the Cementstone Group of Berwickshire with similar formations elsewhere, or to do more than speculate upon the age of the lowest member of the group.

The Cementstone Group covers an area of 200 square miles, in south Berwickshire and north Northumberland, but only a small part of the outcrop lies within the bounds of this survey. It has been found necessary, therefore, to examine the outcrops of this group throughout the area to the north and east of the Cheviot Hills (Plate I, fig.1), and reference will be made to some of the localities visited in this area. Inland, exposures are confined to the banks of the rivers and burns, and it is only on the coast that the complete succession is visible.

At Burnmouth, (figs.3, 4) the Cementstone Group is represented by 1,600 feet of rocks which are well displayed in the vertical limb of the monoclinal fold, close to the Burnmouth Fault. The succession is unbroken and within it is comprised the complete development of the Cementstone Group at this locality.

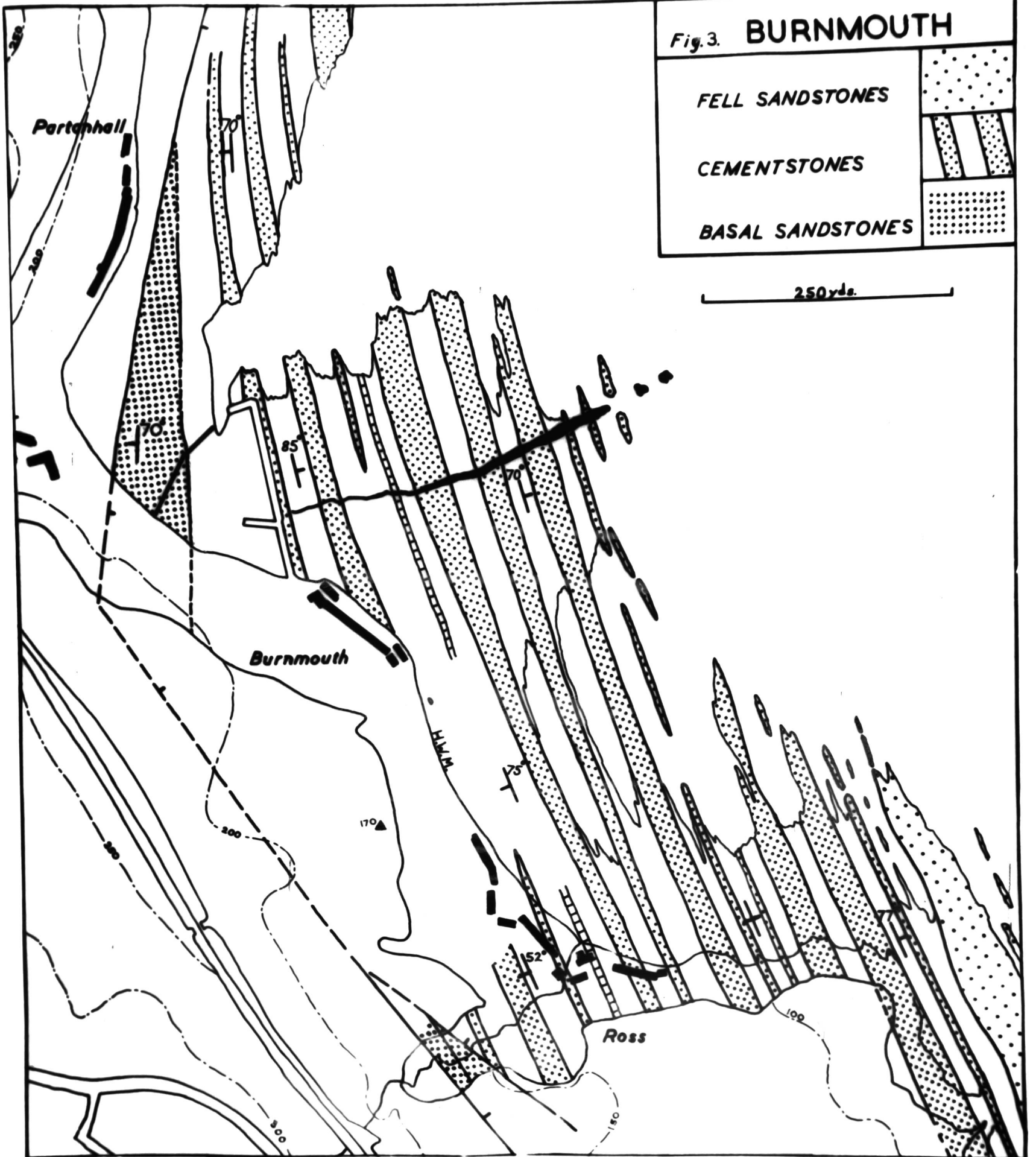
Fig. 3. BURNMOUTH

FELL SANDSTONES

CEMENTSTONES

BASAL SANDSTONES

250 yds.



The base of the group is clearly defined. At Burnmouth Harbour, the junction with the underlying Upper Old Red Sandstone (see page 20) is apparently unfaulted, and the discordance in strike may indicate a sedimentary break, although no erosion surface or basal conglomerate has been seen. At Catch-a-penny, above Ross, lower members of the group are faulted against red mudstones and sandstones of Upper Old Red Sandstone age.

To the east of Ross Point the Cementstone Group is succeeded by massive sandstones of the Fell Sandstone, at the base of which there is a pronounced disconformity (Plate V, fig. i, ii).

Throughout the succession grey sandy shales, with ribs of cementstone, alternate with bands of sandstone. The characters of the sediments change gradually towards the top of the group, but without essential change of facies.

The sandstones, which vary from dull red to grey in colour, may occur as thin ribs in the shales, or as massive current-bedded bands, up to 100 feet thick. The massive sandstones, of which there are twelve exceeding 25 feet in thickness, are red-stained in the higher part of the succession. They are fine- to medium-grained and well sorted; the quartz grains are angular and have a glassy, unetched surface. Microcline and mica are prominent constituents of the sandstones, some of which contain at least 10 per cent of feldspar; the heavy mineral assemblage is not distinctive and therefore gives little

indication of the nature of the source from which the sediment was derived. The sandstones are generally friable with little calcite cement, although hard calcareous bands and large oval concretions also occur.

Individual sandstone bands show rapid variation in thickness, and examples of lensing and splitting are frequently seen. Current-bedding is strongly developed, the dip of the foreset beds indicating a northerly derivation; evidence of contemporaneous slumping is rare. Coarse conglomeratic bands, which often yield fish scales and plant remains are commonly seen at the base of the thicker sandstones. In the higher part of the series, at Ross Point, a discontinuous band of conglomerate containing red mudstone pebbles occurs beneath a massive red sandstone. Lenses of cementstone-conglomerate (Plate III, fig.ii), which occur at two horizons lower down in the group, contain angular fragments of cementstone and sandstone, and it is probable that they are local desiccation breccias.

Sandy shales (fakes) and mudstones grading into marls predominate in the succession. The fakes, which are micaceous, are often unbedded and unsorted, indicating conditions of rapid deposition; they are very rarely fossiliferous. In the typical fake, a system of cleavages is developed which bears no relation to the original plane of deposition, and which gives rise to a characteristic "blocky" form of weathering.

Towards the top of the group at Ross Point the shales are

predominantly red, chocolate, or green in colour among the red sandstones; these beds in which cementstones are infrequent, have a higher carbonate content than the grey beds in the lower part of the series where cementstones are common. Gypsum occurs in shales and fakes throughout the group. Fine black shales are frequently found in association with the cementstone ribs.

The ribs of grey cementstone which characterise the group, consist of fine-grained argillaceous, sometimes sandy, magnesian limestones (Plate XV, fig.1); the carbonate content varies from 98 percent to as little as 60 percent, although the pure and impure cementstones differ little in appearance. The cementstone ribs, which vary from two to twelve inches in thickness, are often discontinuous and nodular, and typically their limits are sharply defined. The cementstones of this area are chemically precipitated magnesian limestones, which were deposited from shallow, lime-rich lagoonal waters, during periods of desiccation. Their nodular appearance and sharp contact with the surrounding shales suggest penecontemporaneous segregation of the lime-magnesium carbonates; in this respect they may be compared with the Hydraulic Limestones of the Lias (Kent, 1936), but it is not suggested that the cementstones are of purely epigenetic origin. Rhythmic sedimentation, as described by Robertson (1946), has not been recognised, although there is some evidence of less regular alternation of conditions;

a cementstone generally succeeds a dark grey shale or fake, but it may be followed by sandstone, shale or fake, and frequently by a parting of dark shale and another rib of cementstone.

Fossils are rare. Spirorbis, fish scales, ostracods and scolecodonts occur in the shales of the lower part of the Burnmouth succession. A few yards to the east of the Harbour wall a thin discontinuous coal is exposed, which contains pyritized plant stems and small lamellibranchs and gastropods; this seam, which is 250 feet above the base of the group, is the lowest horizon at which coal has been observed in the Berwick district.

The shales to the east of Burnmouth also seen in the cliff at Ross, contain numerous cementstone ribs, some of which are fossiliferous. Of these the most noteworthy is a one-foot band of shelly limestone at Ross, which was noted by Geikie (1864) who recorded Anthracomya and Edmondia. Lamellibranchs are too poorly preserved for identification; associated with them is a gastropod, Murchisonia cf. verneuilliana but no diagnostic marine fossils are found. The shelly limestone is of limited extent and at Burnmouth it is represented by three bands of cementstone in which fossils are rare. The remaining fossiliferous cementstones contain twisted elongate worm-tubes, (Serpulid, see page 131) which are similar to a form found in the southern part of the area. The upper half of the group

at Burnmouth has proved to be almost barren of fossils.

To the south-west, the lower part of the Cementstone Group is exposed along the valley of the Whiteadder Water and the basal members are seen in three burns in the parish of Foulden.

The most continuous section is seen in the Foul Dean (fig. 2). Here the red sandstones below Foulden Bridge are succeeded conformably by grey sandy shales with cementstones; the first major sandstone occurs some 300 feet above the base of the group and from the shales which overlie it ?Anthraconauta minima, Spirorbis, ostracods and cyprids were obtained.

A similar section in which the same abrupt change of facies is well marked can be seen in the Wheatland Burn to the north of Edrington House.

The lowest beds are seen again in the Foulden Burn, a mile to the west. Here the base of the group is not exposed, but the succession of cementstones in grey sandy shales is similar to that seen in the burns to the east. On the hillside immediately to the south of Newton Farm is the locality from which Ovens obtained the remarkable fauna of palaeoniscid fish, later described by White (1927) and Moy-Thomas (1938). Freshwater lamellibranchs, crustacea, ostracods and plants occur here, among typical grey sandy shales which lie some 400 feet above the base of the group.

The absence of thick sandstones from the lowest part of the group is not peculiar to the Foulden area. At Hutton Castle

Barns, two miles to the south-west, a boring passed through 450 feet of soft grey beds with gypsum before encountering sandstones; after penetrating a further 57 feet of transitional green beds with "cornstones", red sandstones were reached. Authracomya minima was recorded at several horizons between 300 feet and 450 feet above the base of the group, in an unpublished report of the Geological Survey.

Elsewhere within the area surveyed the base of the group is obscured by drift. At Cumledge and Preston Bridge, north of Duns, beds of Cementstone facies can be seen overlying the tuffs and lavas of the Kelso Traps, which in turn overlies beds of red sandstone facies (Geikie, 1864). In the Langton Burn, to the south-west of Duns a similar succession is seen in which a bed containing fish and plant remains was found near the base of the group (Stevenson, 1849). Thick dolomitic limestones and cornstones, such as the Carham Limestone, of the Kelso district are not represented in the north-east of the Merse.

The position of the lower limit of the group can be easily distinguished when argillaceous rocks of Cementstone facies succeed the red sandstones. In the Kelso district, however, the basal sandstones are succeeded by lagoonal sediments (see page 9) which may belong to the Upper Old Red Sandstone and which may be of the same age as the uppermost basal sandstones in the Berwick district. Alternatively, the lower members of the Cementstone Group may overlap the red sandstones,

but against this there is no indication of a break in the succession at Foulden, as there is at Burnmouth.

The remainder of the outcrops in the valley of the Whiteadder Water and its tributaries, between the Raven's Knowe and Allanton, are the lower members of the group, which closely resemble the lowest part of the succession at Burnmouth.

Anthraconauta minima has been found at several localities (see page 122); and ostracods, fish and plant debris are common, especially in the neighbourhood of Allanton.

Evidence of the conditions of deposition is abundant; ripple marks and desiccation cracks are common, and at Edington Mill the shales contain veins and nodules of white and orange gypsum. Clay pseudomorphs after rock salt also occur. In the neighbourhood of Hutton Castle Mill there are sandstone lenses representing contemporaneous wash-outs, and at Clarabad Mill flaggy sandstones showing large-scale false-bedding occur. Composite bands of cementstones, gently folded on axes parallel to the trend of the regional strike, are seen at two localities.

It is probable that parts of the succession are exposed many times in the Whiteadder Valley, but in spite of this, there is only one instance (see page 134) in which a sequence is recognisable at more than one locality, so variable is the nature of the rocks.

At Raven's Knowe, a shelly limestone occurs in association with cementstones containing serpulid tubes, similar to those

seen at Burnmouth; from the bend in the river at this locality the Whiteadder Water flows to the south. At Edrington Castle a massive sandstone, lying disconformably upon the underlying shales, is seen on both sides of the river. On the right bank close to the water's edge the sandstone becomes argillaceous, and in a few yards passes laterally into sandy shales. To the south, there is a succession of massive red and grey sandstones associated with soft red and grey shales that are poor in cementstones. The highest of these beds is seen at the point at which the course of the river swings to the north-east. However, it is probable that the same horizon is seen again in Paxton Glen and on this assumption the sequence can be followed from the Whiteadder to the Tweed valley.

Cementstones in grey shales with plant debris are seen in the lower part of Paxton Glen, and these are succeeded by red sandstones which outcrop along the shore of the Tweed and in the burn between Paxton House and Tweedhill. There is then no further exposure until the Union Bridge is reached; it is probable that the unexposed part of the succession is seen at West Ord and in Horndean Burn, where grey shales with numerous cementstones outcrop. The topography at Tweedhill indicates the presence of soft underlying strata.

A series of predominantly red sandstones follows. These beds are characterised by thin bands of conglomerate containing red mudstone pebbles, and they are similar to the higher

sandstones at Burnmouth. Beds of this nature can be traced as far as the lower reaches of the River Till to the south-west; to the north-east, however, they are absent from the banks of the Tweed at Ord, but similar red sandstones are seen at Castlehills on the north bank of the Tweed near Berwick.

Among the red sandstones, shales and cementstones occur and it is among these that distinctive faunal horizons have been found. Of these the most conspicuous occurs beneath a thick sandstone in the cliff which forms the right bank of the River Tweed 1200 yards north of Norham Castle, close to Upper Greenhill Shiel. The bed is exposed intermittently at the base of the sandstone cliff, for a distance of 60 yards; the lithology of the underlying sediments is very variable, even in this short distance, but the general succession is:-

Massive soft current-bedded yellow sandstone,	
Basal conglomerate.....	8" - 6".
Red sandstone.....	3" - 0".
Grey sandy micaceous shale with nodules.....	5" - 0".
Hard "splintery" cementstone.....	5" - 0".
Grey sandy marl with cone-in-cone structure...	1½" - 0".
Cementstone with brecciated appearance.....	2".
Red and grey argillaceous sand.....	2".
<u>Limestone</u> with serpulid tubes.....	1'6" - 8".
Dark grey or red calcareous sandstones,	
with soft partings.....	1'6" seen.

Remains of Crustacea occur in the sandy bed above the limestone, and Peach recorded Crangopsis eskdalensis, Peach, from this horizon. The Serpulid has been described as appearing to be a dwarfed form of Syringopora (Fowler, 1926) but upon examination it was found to have no affinity with tabulate corals (see page 126)

No other fossils were found in the limestone.

A mile to the north-east, 200 yards upstream from St. Thomas's Island, an exposure in the north bank shows the following succession:-

Red and grey sandy shales with thin sandstones...	3' 0"
Grey sandy shale with obscure fossil remains.....	$\frac{1}{4}$ "
Hard grey nodular <u>Limestone</u> with Serpulid.....	7 $\frac{1}{2}$ "
Soft greenish shaly sand, full of plant debris and containing a thin coal ($\frac{1}{4}$ ").....	1' 9", seen.

These beds lie between two major sandstones, and the top of the section is probably not more than ten feet below the base of the overlying sandstone. The worm tubes are similar in every respect to those seen in the Norham bed, and it is probable that the limestone in which they occur represents the same horizon as that at Norham.

To the north-east at Horncliffe House a red mudstone is found under a massive sandstone at the bend in the river. This mudstone contains scattered Serpulid tubes which are not in the position of growth. It is unlikely that the fragile tubes were transported far, and therefore this horizon may be close to that at which the Serpulid once grew.

At Heaton Mill, four miles to the south of Norham, a fault downthrowing to the south-west is clearly seen on the north bank of the River Till. On the north-east side of the fault a massive sandstone overlies a series of cementstones and shales:-

Massive sandstone, cutting out highest shale to east.	
Grey sandy shale.....	1' 2".
Thin cementstone with a number of shale partings; Serpulid and other fossils.....	1' 0 $\frac{1}{2}$ ".
Shale parting.....	$\frac{1}{2}$ ".
Thin cementstones, with shale parting.....	1' 1".
Dark shale.....	6".
Cementstone rib.....	6".
Grey sandy shale.....	6' seen.

The Serpulid found at this locality is similar to that seen at the Norham horizon and occurs with "Orthoceras" (two species), Sanguinolites abdenensis and Hypergonia elongata, an association which indicates a marine environment. A variety of the last-named species has been obtained from the Tweed at Coldstream (locality 17) in the lower part of the Cementstone Group (Donald 1892).

A quarter of a mile to the south a small burn flows into the river opposite Castle Heaton. A series of cementstones and shales is exposed near the head of this stream and has been described by Carruthers (1932); the measurements of this section given by Carruthers are inaccurate and differ considerably from those made by the writer:-

Soft faky sandstones.	
Cementstone conglomerate.....	2' 0".
Soft faky sandstone.....	2' 9".
Cementstone.....	10".
Grey fake and shale, poorly exposed.....	5' 3".
Cementstone with colonies of <u>Serpulid</u>	9".
Grey fake.....	1' 6".
Hard splintery cementstone.....	8".
fake, with thin sandstones.....	8' 9".
Cementstone with obscure worm-tubes.....	6".
Nodular cementstones in fake.....	1' 6".
Shales and mudstones.	

The Serpulid found at this locality, which was described by Carruthers as Syringopora, closely resembles the Heaton Mill form, and it is probable that they lie at the same horizon.

The highest beds in the group are seen in the banks of the Tweed near East Ord, in the Horncliffe Mill Burn, and to the south at Tindal House, on the River Till. At Ord, where the dip is notably low, the beds are typical of this series, being predominantly grey in colour with cementstones in sandy shales, associated with variable, sometimes lensing, grey-yellow sandstones. A shale containing Spirorbis occurs 400 yards north-east of the mouth of Ord Mill Burn.

In the Horncliffe Mill Burn, the rocks in the lower part have been disturbed, probably by faulting, and dip to the south-west, so that the lower part of the burn follows the strike. Though sandstones, some of which are red in colour, predominate, sandy shales with cementstones are still common. There is an interesting exposure below the Mill dam, where a sandstone overlies partially eroded cementstones and shales (Plate IV, fig. 11). The evidence here indicates that the cementstones were already fully consolidated before the sandstone was deposited. Above the mill are found alternations of sandstones with shales and cementstones. The upper limit of the group occurs midway between Slateford Bridge and the railway.

The uppermost beds are seen again five miles to the south

at Tindal House on the River Till. Here there are alternations of sandstones, and shales with cementstones, dipping to the north-east at this point under the overlying Fell Sandstone, which outcrops on the right bank below Tindal House.

The most fossiliferous strata in the Cementstone Group of this area are found in the lower part of the group at Coldstream, and along the banks of the Tweed as far as the mouth of the Till. On the right bank, a quarter of a mile below Coldstream Bridge, thin dark grey limestones occur, which are packed with lamellibranchs and tangled masses of Spirorbis. The condition of the fossils is such that accurate determination is not easy, but Modiola and Edmondia have been recorded and the writer has obtained "Orthoceras". The lithology of the rocks at this point resembles some parts of the marine succession in Liddesdale (Garwood, 1931).

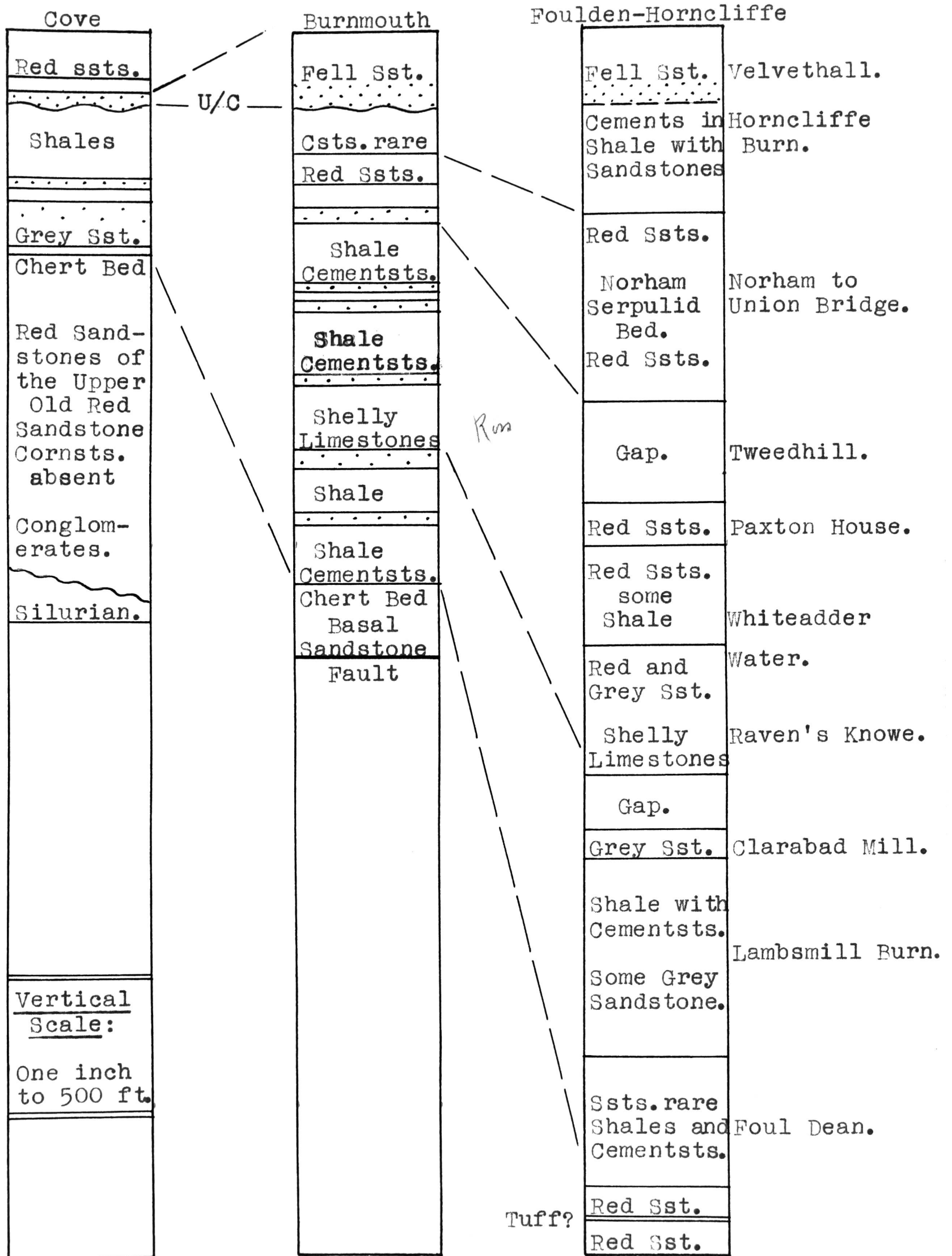
On the Scottish side of the river from Lennel to Tweedmill numerous fossils have been obtained, most of which are plants which were originally described by Witham in 1831. What is of more interest, however, is Tate's account of the discovery in 1856 of Orthocerata, "Pleurotomaria", and Modiola, at this locality. In the collection of the Geological Survey at Edinburgh are two specimens which were collected here by Macconochie in 1900; they are not well preserved, and are not named in the Survey collection, but there is no doubt that one is a Nautiloid and the other the cast of an Orthocerate. In

neither case is the exact locality recorded, but nevertheless there are some grounds for presuming the presence of quasi-marine horizons at these localities.

In spite of the absence of marker horizons within the Cementstone Group, there is positive evidence of great variation in thickness within the area (fig.4). Previous authors have stated that only the higher part of the group is seen at Burnmouth, on the grounds that the succession there amounts to less than 2000 feet, whereas the thickness in the Tweed Valley is considerably greater; (various estimates include: Geikie, 1863, 3000 feet for Calciferous Sandstone; Garwood, 1912, 2000 feet; Carruthers, 1932, 2000 feet; Pringle, 1935, 2500 - 3000 feet; Eastwood, 1946, 3000 feet). Between Foulden and Horndean Burn, the writer has measured a thickness of 3750 feet; it is possible that the true thickness is less, and that strike faults, downthrowing to the north-west, cause repetition, but there is no evidence to support this supposition.

To the south, near Alnwick, the estimated thickness is 2000 feet (Carruthers et al., 1930). In Liddesdale, forty miles to the south-west, a similar thickness is believed to occur (Chapman, 1951, unpublished). For the region to the north-west less information is available; at Cove, twelve miles away, 500 feet are exposed, but the succession is alleged to be faulted, (Clough, 1910; see note on Cove succession, page 104); while at Broxburn, south-east of Dunbar, 300 feet of beds

Fig.4 Variation of thickness within the Cementstone Group.



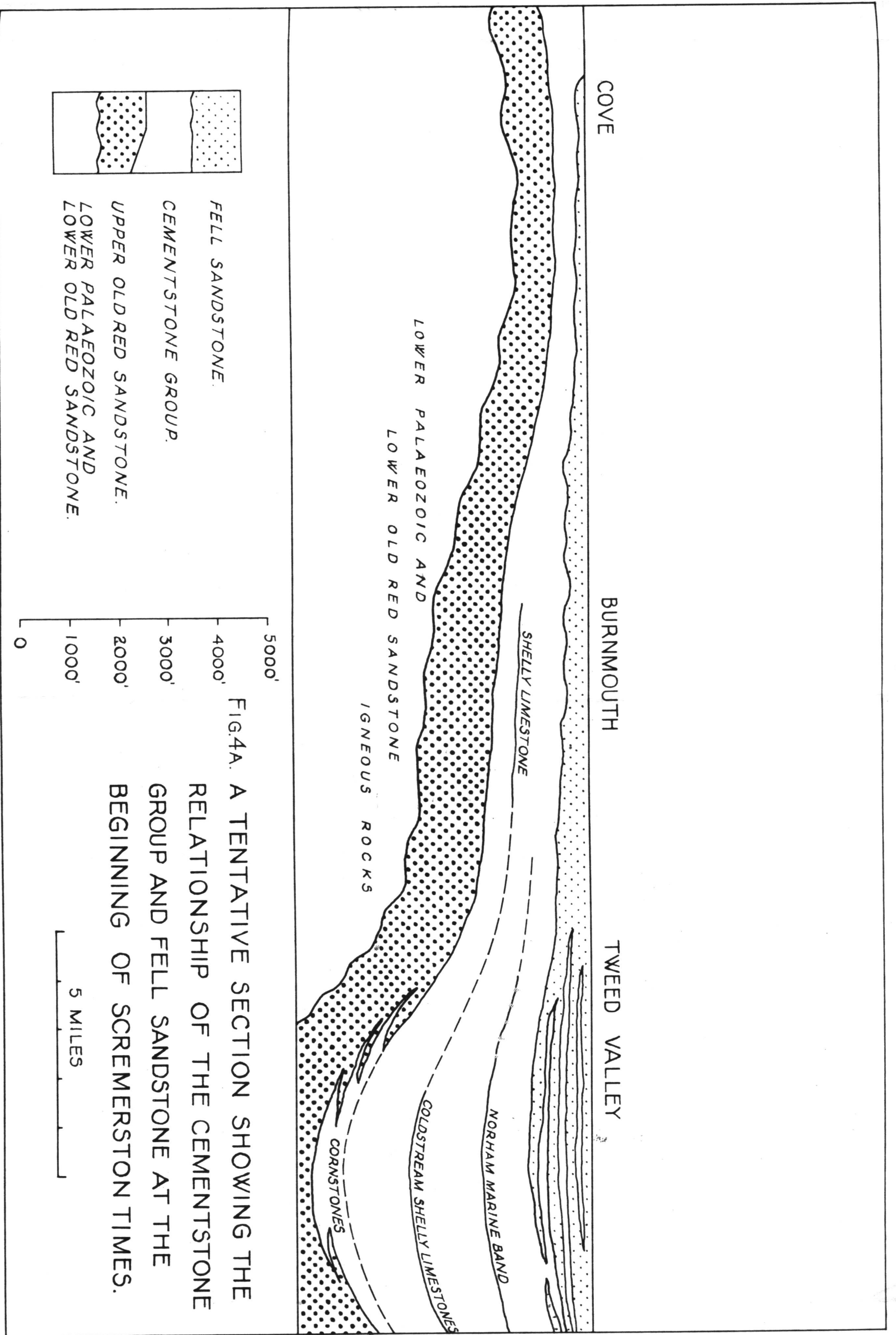


FIG.4A. A TENTATIVE SECTION SHOWING THE RELATIONSHIP OF THE CEMENTSTONE GROUP AND FELL SANDSTONE AT THE BEGINNING OF SCREMERSTON TIMES.

referable to this group contain an interbedded lava with tuff. Elsewhere in the Lothians volcanic rocks interrupt the succession, while on the Fife coast, only 36 miles from Burnmouth, 4000 feet of Calciferous Sandstone (rocks below the Oxford Limestone at Berwick) are exposed, but although these are probably in part coeval with the Berwick Cementstone Group, they are of so different a facies that no comparison is possible.

There are few reliable data for correlation within the area. The red sandstones near the top of the Burnmouth succession correspond well in character with those exposed in the Tweed valley, but the overlying strata differ - e.g. at Burnmouth cementstone ribs rarely occur in the uppermost part of the group. It is doubtful whether the Serpulids found at Burnmouth can be classed as a marine form and the only tentative correlation that can be advanced on fossil evidence is the assignment of the Ross Limestone and its associated beds to the horizon of the shelly limestones at Raven's Knowe and Coldstream. No similar limestone has been found in the higher parts of the succession in the Tweed valley. If this suggested correlation is correct, then the serpulid beds in the higher part of the group to the south are not represented at Burnmouth; their absence could be due to non-deposition, or to contemporaneous erosion which seems more probable, as at two localities the overlying sandstones show pronounced disconformity.

A slight unconformity is seen at the base of the overlying

Fell Sandstone Group at Ross Point, and within half a mile several beds are cut out to the south. There is no evidence of a similar unconformity to the south of the Tweed, where indeed it is found that sandstones of Fell-type alternate with beds of Cementstone facies; the writer has placed the boundary between the two groups at the point at which the lowest Fell-type sandstones are seen, (see page 10).

In the Midland Valley of Scotland it has been shewn that different areas subsided at different rates and that in general, the thicknesses decrease towards the Southern Uplands axis (Richey, 1935). These areas are separated by lines which lie parallel to the axis, and it is probable that they represent contemporaneous fault lines. Cove and Burnmouth lie on the northern and southern flanks of the Southern Uplands ridge and the writer suggests that the reduced thickness of the succession at these localities resulted from a relatively low rate of subsidence along and adjoining the Southern Uplands axis. It was across this relatively stable area that sediment was transported before being deposited in the Tweed basin (fig.12), which was an area of rapid subsidence. Further south the sediments thin again across the "Cheviot axis" (Hickling, 1949). At the top of the group at Burnmouth (and, according to the writer's interpretation, at Cove), there is conclusive evidence of uplift and erosion before the deposition of the Fell Sandstone (see note on Cove succession, page 104). The rapid increase in thickness between Burnmouth and Tweed valley (fig. 4a)

may, therefore, indicate the presence of a contemporaneous fault-line between these areas.

The conditions of deposition are clearly indicated by the nature of the sediments. Sun-cracks, ripple-marks, rain-pitting and the presence of seat-earths are evidence of shallow-water lagoonal deposition with frequent exposure of the sediments. The lack of bedding in the sandy shales, and the current-bedded lensing sandstones indicate rapid deposition in an estuarine environment. A copious, though intermittent supply of sediment was sufficient to maintain shallow-water conditions over an area in which varying rates of subsidence existed. In contrast to the rocks 35 miles to the north, and in those the same distance to the south, there is a marked absence of marine sediments and it is significant that it is in that part of the area where the succession is thickest, and therefore where the subsidence was greatest, that the only signs of marine incursions are found.

This rapid sedimentation was not continuous, however. It was interrupted frequently by lagoonal conditions, during which little or no sediment was introduced into the area and desiccation resulted in the formation of cementstones, associated with gypsum and occasionally rock salt.

Neither the lagoonal, nor the estuarine, conditions were favourable to animal life. The typical fauna of ?Anthraconauta, Spirorbis and ostracods probably existed in a brackish water environment. Serpulids, similar to those which occur in this

area, have been described by Garwood (1931) from the Cementstone Group of northern Cumberland and Roxburghshire; the serpulids, which he described as Serpula cf. advena Salter, are of common occurrence in the lower parts of the group, especially at the base of the Main Algal Series, and are frequently associated with algal bands. No algae have been obtained in the Tweed district, and unless further marine fossils are found it seems unlikely that any precise correlation with neighbouring areas can be made. The writer has reached the opinion that the Coldstream, and therefore the Ross, shelly limestones lie at about the position of the Main Algal Series of Liddesdale, but admits that it is a purely speculative conjecture.

There is no indication of the vulcanicity that interrupted the deposition of rocks of the same age in the Lothians and in Liddesdale.

4) Fell Sandstone.

The massive sandstones that succeed the Cementstone Group and represent the upper part of Tate's Tuedian sub-division, are generally called the Fell Sandstone. Locally they have been named the Longridge Sandstone after the locality in which they are most prominent three miles to the south-west of Berwick. There can be no doubt, however, that these sandstones, (sometimes referred to as "grits"), are part of the lithological group which shows its greatest development in the Rothbury Fells, the type area of the Fell Sandstone.

As with most lithological sub-divisions, the upper and lower boundaries of this formation are difficult to define; this fact, combined with the usual lack of inland exposures and borehole information, makes it impossible to give more than an approximation of the thickness at any point. At Burnmouth it is only the lower parts of the group that can be studied in detail; to the south, in the banks of the Tweed at Berwick, the sandstones are seen dipping steeply to the east; from that point only isolated exposures occur and these show that the formation strikes to the south-west for six miles, as far as the Salutation Inn, and that further south the strike assumes a southerly direction as far as the limit of the area surveyed.

There can be no doubt that the Fell Sandstone is genuinely represented at Burnmouth, although it has been stated that this formation does not occur there (Pringle, 1935). 500 feet of

sandstones are exposed between the Maiden's Stone, a stack to the east of Ross, and a point in the middle of Hilton Bay (figs. 3, 6; Plates V, VIII); but of these, only the lower 300 feet are definitely referable to the Fell Sandstone.

The lithology of these lower sandstones contrasts strongly with that of the upper members of the Cementstone Group; whereas the latter are of fine- to medium-grain, reddish-brown to grey in colour and contain much argillaceous material, the Fell Sandstone is coarser in grain, of yellowish-white or pink colour and has a clean, granular, "sugary" appearance. It is this distinctive lithology combined with the evidence of a sedimentary break, which makes the position of the base of the Fell Sandstone certain at this point.

The base of the sandstone, which succeeds the Cementstone Group with slight unconformity, is characterised by the presence of a continuous limonitic layer, locally as much as three inches thick; there is no basal conglomerate. Above the basal limonite layer there are a number of thick current-bedded sandstones, separated by lenticular bands of red and grey sandy micaceous marls not unlike the uppermost beds of the underlying group.

To the east of Ross Point (Plate V, figs. i, ii) the sandstones are well exposed at low water for over 150 yards, although the marls are not seen. The sandstones are yellow or orange, while some of the bands show a salmon-pink, and others

occasionally a greenish colour. The thickness at this point is about 440 feet.

At Heathery Carrs (Plate V, fig.ii), half a mile to the south, the Fell Sandstone has transgressed on to beds nearly 100 feet lower in the Cementstone Group. Here a similar succession is exposed, with the addition that the intervening beds of red marl are also seen: it is of interest to note that a limonitic band occurs at the base of the sandstone overlying these marls. Red-stained beds occur here, and also a lenticular conglomerate containing occasional rounded pebbles of vein quartz together with larger sub-angular fragments of fine-grained white sandy marl in a coarse red matrix. The highest bed in this complete section is the lateral equivalent of the highest seen half a mile to the north, but here the total thickness is only 300 feet. It is clear that this sandstone is lensing out rapidly towards the south.

The upper part of the same group of sandstones can be seen in the headland to the north of Hilton Bay (Plate VIII, fig.ii). The lowest beds here are of Cementstone facies, probably within the Fell Sandstone, and are thrown by the Burnmouth Fault against the Upper Old Red Sandstone breccias lying unconformably upon the Silurian. The sandstones at this point are deeply stained and so much indurated that the bedding-planes can scarcely be discerned.

The shattered nature of the rocks makes it difficult to

find an explanation for the apparent discordance in the dips of the individual sandstone bands, which appear to thin out down the dip towards the fault (Plate VIII, fig.ii). The phenomena might be ascribed to some tectonic cause, such as the squeezing out of the incompetent soft marls between the sandstones, but this would not account for the thinning of the sandstones themselves and it seems more likely that the whole group forms a lens, particularly as there is definite lensing in the horizontal plane within the same rocks, to the north. If this explanation is correct, then it is clear that this group of sandstones became thicker to the west as well as to the north.

The sandstones described above belong to a distinct group, which includes all the rocks exposed to the east of the Maiden's Stone, with the exception of the Brisset, and includes the East and West Carr rocks to the north, and the Heathery Carrs to the south. As far as this the rocks are well exposed and, taking into consideration their stratigraphical position and their lithology, there can be little doubt that they represent the Fell Sandstone of Northumberland. The apparent succession above this group however, differs so greatly from the typical succession in the district south of the Tweed, that it is necessary to describe that area before returning to the problems of Hilton Bay.

In the left bank of the Tweed at Berwick 350 feet of rocks are exposed which belong to the Fell Sandstone. They dip

steeply (50° - 65°) N. 75° E. and are to be seen on the shore and in the cliff between the Royal Border Bridge and the Conqueror's Well. The lowest bed seen in this section is a dessication breccia similar to those occurring in the Cementstone Group, with fragments of sandstone and sandy marls. A white sandstone of Fell-type in which the foreset dips are to the west and north-west, is followed, close to the entrance to the Castle Vale gardens, by a band of greyish-white hard siliceous marl. Above this is a series of white, brown and pinkish sandstones, some with very hard cemented bands, separated by sandy shales or marls of various colours from grey to red in which thin red ribs of hard sandstone are prominent.

At the Conqueror's Well the succession is cut by a small fault which downthrows to the south-east; the lowest bed seen on the downthrow side of the fault is a sandstone of Fell type, which is probably the top of the one cut by the fault; above, a thin coal overlies twenty feet of soft sandy shales. The boundary between the Fell Sandstone and the Scremerston Coal Group has been placed at a thin coal which was met in a single boring 140 feet below the Wester Coal, the lowest workable seam; this was the lowest coal seen in this boring (Scremerston No.3.), and 35 feet below it the bore passed into sandstones of Fell type of which 225 feet were proved.

This boundary is clearly a most unsatisfactory one; a coal seam which may only extend over a small area is perhaps the

worst type of horizon to adopt as the boundary between two formations. The fundamental difference between these two groups is one of sedimentary facies; it would seem logical therefore to place the boundary at the point where the facies changes; in this case, where the massive sandstones give way to strata consisting of shales and marls, with thin fresh-water limestones and coals, in which sandstones constitute only a small fraction of the total thickness. This boundary may be diachronous over a wide area, but it does demarcate the position at which the change of facies occurs. At Conqueror's Well it is proposed to place the top limit of the series at the top of the Fell type sandstone on the south-east side of the fault.

The Fell Sandstones strike southwards across the Tweed; during the building of the Royal Tweed Bridge and in a boring in Tweedmouth a conglomerate was encountered which is probably at the same horizon as that seen at the foot of the railway viaduct. On the Spittal road near Berwick Water Works, and in the hill behind, massive pink and white sandstones are seen, still dipping north of east; at the water works a boring proved 350 feet of thick sandstones with intervening "clays". Similar sandstones are seen in the cutting of the dock railway where the strike is beginning to swing to the west. The foreset dips in these rocks are generally to the south-west.

Where the Fell Sandstone is next exposed it strikes to the west-south-west. At Tweedmouth Cemetery a massive sandstone was quarried, but is not now exposed; the coal which is seen at the top of the old quarry is probably that which was taken as the base of the Scremerston Coal Group in the No.3 bore, 600 yards to the south; the sandstone in the quarry is therefore taken to be the highest member of the Fell Sandstone. At no other place to the south-west can the top of the group be accurately determined.

At East Ord the base of the Fell Sandstone lies midway between the railway and the river, but the nature of the junction is not seen. Higher up the burn there are a number of exposures of sandstone and at one place, west of the village, a grey marl containing cementstone nodules was found. On the south side of the village a large quarry has been worked in a thick sandstone of the usual type.

To the south of Longridge a dry valley, a glacial drainage channel, can be followed almost as far as East Ord; it runs parallel to the strike and it is only in this part of the area that the topography bears any simple relation to the underlying rocks. The alternating soft-beds and sandstones form a series of dip-slopes and scarps, along which exposures are frequent. The usual inclination of the foreset dips is to the west, and contortion resulting from contemporaneous slumping can be seen in the higher beds.

The lowest sandstones can be seen in the burn on the north west side of the railway at Velvet Hall, but again the actual base is not seen. A boring at Royalty, a mile to the south-west, passed from massive sandstone into 100 feet of marls and shales without cementstones at 96 feet; these argillaceous beds probably lie within the Fell Sandstone, as cementstone ribs are common at Slateford Bridge only 40 feet below the lowest member of the series. The sandstones are seen in quarries at Shoreswood and the Salutation Inn where the strike is still to the west-south-west.

In a burn half a mile north of Grieve Stead the strike is still to the west-south-west, but the beds are disturbed by the Ancroft fault, and to the south of this the features show clearly that the sandstones are dipping to the east. A boring midway between Grieve Stead and Grindon passed through 200 feet of shales and marls with "limestones" up to 1 foot 6 inches in thickness; it would appear to have passed into the sediments of Cementstone facies, although this position was previously mapped (Carruthers, 1932) in the middle of the Fell Sandstone outcrop.

To the south there are few exposures until the Duddo Mill Burn is reached. A series of fairly distinct dip-slopes and scarps show the general strike of the rocks. At Grindonrigg there is a disused pit from which the local inhabitants allege that limestone was obtained for burning;

this locality is again above the base of the Fell Sandstone as previously mapped by Carruthers (loc. cit.). In the Duddo Mill Burn the massive sandstones are exposed for half a mile as far as the mouth of the burn, but the soft beds are not seen.

The Fell Sandstone has been described as having a thickness of 600 - 800 feet and as "a mass of sandstones,..... with very little shale" (Fowler, 1926). Between Ord Mill Burn, where the base is seen, and a point 150 yards to the north of South Ord, the estimated position of the top of the group, is a horizontal distance of one mile; therefore, the minimum thickness at this point is 1100 feet and the formation may well be thicker, as there are several faults at Spittal downthrowing to the south-east. At Velvet Hall where the base is seen again, the outcrop is over a mile wide, and a similar thickness can be inferred.

The Fell Sandstone in this part of the area consists of thick sandstones interbedded with bands of marl. There is evidence that the marls thicken at the expense of the sandstones within the Tweed basin, but it is only a local facies-change and the sandstones are well developed again to the south in the area of the Cheviot axis. Various borings have been made within the outcrop of this group and the thicknesses of the sandstones expressed as percentages of the total thickness are as follows:-

<u>Locality</u>	<u>Percentage of sandstone</u>
Berwick Water Works.....	60
South Ord.....	32
Ord Mains.....	55
Middle Ord.....	57
Longridge Towers.....	42
Royalty.....	38

These figures are quoted in order to shew that argillaceous beds account for a large proportion of the total thickness; in the boring at Grindon the percentage of sandstone is even smaller, while in contrast, the figure for the lower sandstones at Burnmouth is 89 per cent (fig. 4A).

The only fossils so far obtained from this group were found in the borings; plant remains were seen at Ord Mains and a two-inch ostracodal band at Grindonrigg. The occurrence of "limestones" at Grindon and possibly in the old pit at Grindonrigg, may indicate a continuation or a recurrence of the Cementstone conditions.

To the south and south-west of Berwick the Fell Sandstone is succeeded by 1000 feet of coal-bearing strata, the Scremerston Coal Group; the top of this group is placed at the base of the Dun Limestone, a marine horizon which is constant and widespread. The two groups therefore comprise over 2000 feet of rocks.

The apparent succession at Hilton Bay is strikingly different, for here a thickness of only 600 feet is exposed.

At Heathery Carrs (fig.6) there are few exposures above the lower group of sandstones; fifty yards to the east are two prominent bands of massive sandstone whose strike is noticeably more to the east than that of the lower sandstones; these are known as the Catcairn Bushes and they can be followed to the south as far as the north side of Hilton Bay (Plate VIII, fig.1).

On the north side of Hilton Bay the succession can be followed from a point at the foot of the cliff adjacent to the fault to the top of the outer Catcairn sandstone. There are three gaps in the sandstone succession exposed here, the greatest being 15 feet. The lowest bed seen here cannot be more than 20 feet above the top of the lower group; there is no evidence to suggest that the beds which are not exposed are anything but red-stained sandstone or red sandy marl. The lowest sandstones are very shattered and appear to dip at about 60° to the west, while only twenty yards to the east the degree of inversion seems to increase suddenly to give a dip of 26° , beyond which the dip increases again. The succession consists of soft red sandstones with a few bands of yellow or mottled colour and close-grained texture of which the highest are the Catcairn sandstones; with the probable exception of the highest sandstone, all these rocks are cut out to the south by the Burnmouth Fault which runs in a south-easterly direction towards the middle of the Bay.

In the middle of the Bay, 85 yards from the shore, the fault changes its direction abruptly, striking from there to the south; as if in prolongation of the main fault, a small fault downthrowing to the south-west runs towards the south headland from the centre of the Bay, but dies out before it reaches it.

The lowest bed seen on the south side of the bay is a hard indurated sandstone, 16 feet in thickness. This may be the equivalent of the upper Catcairn sandstone which has been slightly displaced to the east by the small fault. The outcrop of this bed narrows towards the south side of the Bay, a point of some significance, as the attenuation does not appear to be due to the normal lensing, but to faulting. The lower face of the sandstone displays a sheared surface which dips at 40° to the west, while the top of the sandstone is truncated by a vertical fault, the throw of which is not known, (see page 119).

Fifty feet above the sandstone, is the Dun Limestone which forms the upper limit of the Scremerston Coal Group, and the rocks between it and the Catcairn sandstone are typical of the highest part of that group.

It is clear therefore that the apparent thickness of rocks exposed here between the base of the Fell Sandstone and the Dun Limestone is much less than it is in the area to the south of Berwick. There is a reduction in thickness of

1500 feet; the strata which are not represented at Hilton Bay include 950 feet of the Scremerston Coal Group, with several coals of economic value, in the area south of Berwick.

The absence of this part of the succession was first noted by Gunn (1898) who estimated that "at least 1000 feet of strata" were missing, but did not attempt any explanation. Goodchild (1903-1) stated that the boundary faults "cause so much confusion that it is almost useless to try to make out the succession". Later (1903-11), he says, "the fishery station is upon the Dun Limestone,.....while rocks just to the north are near the base of the Fell Sandstone. Hence a fault of considerable magnitude, cutting across the Berwickshire coast fault, must come in there".

There are three possible answers to this problem. The missing part of the succession may have been "faulted out"; this was Goodchild's explanation, but he did not give any indication of the whereabouts, or the nature of the hypothetical fault or faults. It is interesting to note that the same reason is given for the abbreviated succession at Cove, where the problem is analogous. An alternative explanation is that the "missing" rocks do not occur at Hilton Bay at all; that is, either that they were never deposited, or that they were removed by erosion before the deposition of the uppermost Scremerston beds.

This problem cannot be discussed fully at this stage,

but certain points can be made clear. If the reduced thickness is due to faulting, the fault or faults must be strike faults. One such fault is seen above the lowest sandstone on the south side of the Bay and there are indications of similar vertical faults both above and below the upper Catcairn sandstone; the amount of displacement caused by these faults is not known. There is no sign of strong unconformity among the upper sandstones; evidence of non-sequence would be difficult to detect among such indurated rocks. The presence of great thicknesses of marls and shales among the lower Fell Sandstone in the south-west of the area is at least an indication that this part of the group thickens in the Tweed Basin, (fig. 4A).

The base of the Fell Sandstone has been taken at the point at which the lowest sandstones of Fell type are seen. It is probable that some of the lowest beds which have been mapped by the writer as Fell Sandstone to the south, are intercalated with rocks of Cementstone facies; the presence of "limestones" in the boring at Grindon is strong evidence that this is the case. The predominantly arenaceous succession lying unconformably on the upper members of the Cementstone Group at Burnmouth, is a further indication of the differing rates of subsidence which prevailed during Lower Carboniferous times in this area.

5) The Scremerston Coal Group.

This group of rocks derives its name from the mining village of Scremerston, two miles to the south of Berwick. In the neighbourhood coal has been obtained from at least ten named horizons within a thickness of 1000 feet of rocks; most of the seams are now worked out and only one colliery is in operation at the present time. The coals have been worked to the north-east as far as the outskirts of Spittal where the steepness of the dip prevented further workings; the thickness of the coal seams was said to increase in that direction (Fowler, 1926). There have been many workings in the vicinity of Thornton and Shoreswood, but to the south, towards Duddo, the total thickness is much reduced, although most of the workable coals are still represented.

Most of the information concerning the Scremerston Coal Group has been obtained from the records of mine-shafts and bore-holes. More or less accurate descriptions of the strata encountered have been published (Fowler, 1926; Carruthers, 1932, etc.) and it is unnecessary to repeat them in this thesis. It is unfortunate that the greater part of the group is not exposed, and thus it is largely upon such second-hand information that the description of its geological characteristics must be based.

Tate (1856 - 1868) named these rocks the Carbonaceous group, which succeeded the Tuedian, and was followed in turn

by the Calcareous group. They form a natural lithological group, characterised by the presence of coals and by the absence of thick marine limestones. The Scremerston Coal Group which is generally supposed to be coeval with the Lower Oil-Shale Group of the Midland Valley of Scotland (Gunn, 1898) contains the oldest coals of economic importance in the British Isles.

The succession is one of alternating sandstones and sandy marls and shales. The massive sandstones, which are as much as 100 feet in thickness, are red in colour and often coarse in grain, but the thinner beds and seat-earths, which are often associated with *stigmaria* and other plant debris, are grey. The argillaceous rocks are red, grey or green, and calcareous sandstones (kingles) and thin limestones, not dissimilar from the cementstones of the Tuedian, occur among them.

Thin limestones occur in association with the coals, and often form a good roof to the workings; they are fine-grained and dark in colour, rarely more than two feet thick and usually contain a fauna of entomostraca, gastropods and fresh-water lamellibranchs, while fish remains have also been reported. They are most numerous in the lower part of the group, between the Cooper Eye and Wester Coals (fig. 5), and there is some evidence of the occurrence of marine horizons at this level. N.J.Winch (1830) recorded a dark

grey encrinal limestone at the north end of the Sunnyside cutting close to the base of the group; the authenticity of this record has been doubted (Fowler, 1926), attention being drawn to the absence of such a rock in the Scremerston No.3 bore nearby. Nevertheless, the recorded occurrence of such forms as Lingula, from the boring, and Schizodus pentlandicus from the roof of the Cooper Eye Coal, shows little cause for doubting Winch's original observation. Examination of the bings of disused coal mines and of the small section now visible above and below the Blackhill (Main) seam in the present colliery, has shewn that the rocks of the middle part of the group are predominantly of non-marine origin. To the south, at Fordmoss, Carruthers (1922) reported the occurrence of a marine fauna in bing material from the middle or lower part of the group. The only undoubted marine horizons occur not far below the Dun Limestone and yield a D₁ fauna.

The lowest beds of the Scremerston Coal Group are seen at Berwick, between the Conqueror's Well and the Rowing Club boathouse; here a thick red sandstone is underlain by red and grey marls with thin bands of calcareous sandstone and sandy limestone containing plant debris and ostracods; a 3-inch seam of coal lies a few feet above the base of the group (see pages 50, 51).

The lower part of the group was at one time exposed on

the shore of the river immediately to the north-west of Spittal near the Carr Rock, but most of the outcrops are now covered. On the shore by the Carr Rock Pier the following typical section is seen:-

Hard grey cementstone.....	3"
Grey shale, with coal-streak.....	5"
Hard brown carbonaceous shale.....	3"
Soft grey shale.....	9"
Hard grey sandstone with plant-debris...	1'6"
Soft grey sandy shale.....	6"
Coal.....	1"
Soft purplish-grey sandy shale.....	5'6"
Massive red sandstone.	

On each side of the railway bridge there are further exposures, which must lie close below the above section:-

Massive fine-grained red sandstone.	
Grey sandy shales with sandy ribs.....	15'
Gap.....	10'
Grey shale with iron-stone nodules and plant debris.....	4'
Red sandstone: fine-grained.....	14'
Yellow sandstone of 'Fell' type.....	14'
Shale, purple-grey with nodules.....	5'

These exposures lie close to the bottom of the group, probably at about the horizon of the Wester Coal.

At Gamesgreen Plantation, half a mile south of Middle Ord, massive reddish-brown sandstones outcrop and have been quarried. In these rocks the current-bedding shows slumping which characterises the rocks of this group to the south of Berwick; foreset dips are to the south and south-east; they lie close to the top of the Fell Sandstone, but differ

from them in colour, grain size and degree of sorting. They overlie a thin coal which is seen at the south-west end of the plantation. At Billylaw, red-brown sandstones occur which are close above the outcrop of the Cooper Eye Coal.

Rocks of the lower part of the group are exposed again at Springhill cutting on the North Road one and a half miles south of Berwick. The section here exposed lies between the Bulman and Cooper Eye horizons, and is notable for the slumping in the sandstones all of which have foreset dips to the south:-

Grey-yellow sandstone, slumped.....	11'	seen
Yellow sandstone, current-bedded.....	1'6"	
Coal.....	1'6"	
Seat-earth.....	9"	
Sandstone.....	1'	
Brown sandy shale, sandstone ribs, and rootlets.....	10'	
Limestone, impure.....	9"	
Grey shale and thin coals.....	6'	
Coal, with parting.....	1'6"	
Grey sandy shales.....	6'	
Massive red-grey slumped sandstone....	40'	seen

A few coals are poorly exposed in the sides of the Sunnyside cut; these are probably at the horizon of the Wester Coal, as the Cooper Eye was reached at a depth of only 60 feet in the Scremerston No.3 bore at the road junction at the top of the hill (Fowler, 1926).

With the exception of a few shallow pits in sandstone, such as those seen at Catchlaw Crag west of Scremerston and at Seaview above Spittal, the beds of the middle part of

the group between those in the Springhill cutting and the horizon of the Caldside Coal are not exposed.

The existence of a marine horizon in the upper part of the group at three localities near Duddo was first recorded by Gunn in 1880, while in 1921 Carruthers described its position within the Scremerston Coal Group as unique in North Northumberland. Evidence has been found during the course of the present work which indicates that the Duddo Limestone may be the local equivalent of a marine horizon characterised by a distinctive fauna, which extends from East Lothian to the southern part of Northumberland (see page 144).

The outcrops of the Duddo Limestone at Duddo Tile Works, Mattilees Quarry and on the right bank of Duddo Mill Burn, which were described in the surveys of 1880 and 1921, are no longer exposed. However, excavations at the two latter localities have yielded some material. At Duddo Mill Burn, the southern locality, the following section was seen:-

Massive sandstone, shaly at base.	
Grey shale, sandy with ironstone nodules at top, with brachiopods, lamellibranchs, bryozoa.....	8' 0"
<u>Limestone</u> , hard dark, crinoidal.....	2' 6"
<u>Shale</u> , black, calcareous with <u>Lithostrotion</u> sp.....	1' 10"
<u>Coal</u>	1"
Fire-clay, grey with plant debris.	

Most of the fossils obtained from this locality (see page 138) were found in the shale four feet above the limestone. At Mattilees Quarry where the beds lie adjacent to the Cornhill

dolerite dyke the succession is:-

Grey shale, ironstone nodules at top.....	8' 0"	seen
<u>Limestone</u> , compact, very crinoidal.....	6"	
Dark shale, very fossiliferous (<u>Lithostrotion</u> sp.)..	9"	
<u>Limestone</u> , hard dark crinoidal.....	2' 0"	
Black calcareous shale, very fossiliferous.....	2' 9"	
Fire-clay.....	3"	seen

The sedimentary and faunal characteristics of the sequence at these localities closely resemble those of the Limestone Groups, and it would perhaps be logical to place the base of the Lower Limestone Group at this level and not below the Dun Limestone. However, the Dun, in view of its constant thickness and lithology forms a more practical marker-horizon.

The Duddo Limestone was encountered in a boring at Hetton 115 feet below the top of the group (Geological Survey; unpublished report). It is almost certainly the lateral equivalent of the Stocking Burn Limestone at Alnwick, which contains a similar fauna and lies 66 feet below the Dun Limestone. It has not been previously recorded to the north of Duddo.

The Jack Tar Pit, by the third milestone south of Berwick, reached the Scremerston Main Coal at a depth of 660 feet and was the deepest pit in this field. In the cutting of the colliery railway which led to this mine some of the higher beds in the group are exposed; a coal which was worked in this cutting immediately to the east of

Richardson's Stead (Robie's Coal) (fig. 5), is succeeded by at least 90 feet of reddish-brown sandstone, and overlies some thinner sandstones and sandy shales. No limestones were seen in this section or in the shaft of the Jack Tar Pit, where a very similar sequence was recorded; the massive sandstone which is such a prominent feature in these sections is split by shales containing coals in the No.2 Bore only 600 yards away, while in the Ancroft borings two miles to the south-east, it has been almost completely replaced by fire-clays and shales. Again there is no report of limestones or marine fossils, except at the bottom of the Ancroft No.1 Bore where a "dark limestone with white spar" three feet six inches in thickness, was encountered 223 feet below the Dun Limestone; there is no record of the fossil content of this limestone, which lies below the horizon of the Caldside Coal. The Caldside Coal (Fowler, 1926) is said to be the equivalent of the Fawcett seam which overlies the Duddo Limestone to the south, and thus the dark limestone at the foot of Ancroft No.1 Bore could be at the horizon of the Duddo Limestone.

The highest part of this formation is well exposed on the shore between Hud's Head and Spittal. At this point (Plate VI, fig.1) the succession beneath the Dun Limestone is:-

Coal.....	1' 6"
Seat-earth over nodular sandy shale.....	12' 9"
Sandstone, hard grey-green, quartz veins.	6' 0"
Marl, soft grey.....	6' 0"
Shale, sandy with plant fragments.....	14' 9"
Coal.....	3"
Shale, grey sandy with small ironstone nodules and plant fragments.....	11' 6"
Gap, Coal ?.....	1' 0"
Seat-earth over sandy shale as above.....	11' 6"
Sandstone, massive yellow-grey.....	16' 6"
Shale, grey with ironstone nodules.....	2' 8"
Gap.....	6' 0"
Sandstone, yellow-brown, false-bedded....	8' 6"
Shale sandy with sandstone ribs.....	4' 4"
Gap.....	17' 6"
Coal (Robie's) at least.....	1' 0"
Seat-earth, hard grey-brown, rootlets....	3' 8"
Shale grey sandy, plant debris, nodules..	1' 2"
Sandstone, brown-grey, plant debris.....	1' 7"
Shale grey sandy, plant debris, nodules..	5' 6" seen.
Total thickness.....	<u>133' 8"</u>

The above section is taken from a number of outcrops which are separated by a series of small faults downthrowing to the south-east, while Robie's Coal can only be seen some distance up the level which drains the Scremerston pits and which debouches close to the shiel at Hud's Head.

Grey sandy shales with numerous ironstone nodules, stigmaria and comminuted plant remains characterise this part of the succession. The massive yellow sandstone 65 feet below the Dun Limestone is strongly current-bedded and the foreset dips vary between south-west and north-west; the underlying sandstone exhibits the most spectacular large-scale false-bedding (Plate VI, fig.1) and its upper surface

is covered by a thin limonitic layer similar to that seen on the lower surface of the Fell Sandstone at Burnmouth. No limestone is seen here, and no marine fossils have been obtained from the shales, which are, however, not fully exposed.

Half a mile to the north-west, at Berwick Gasworks, a bore passed through 350 feet of steeply dipping rocks; it reached the Dun Limestone at 143 feet and after passing through an estimated thickness of 90 feet of sandstones and shales, met two feet six inches of coal. This was probably Robie's Coal. Seven feet six inches below the coal a three foot limestone was reported, although no such horizon can be seen at Hud's Head.

The remaining exposures of the upper part of this formation occur in the faulted coastal strip to the north of Berwick. The Dun Limestone outcrops on the shore just south of St. John's Haven, and is seen to rise in the cliff to the north-west as far as the axis of the fold, 300 yards south of the Lamberton Salmon Fishery (Plate VI, fig.ii) where it is inverted and strikes inland parallel to the fault; at that point it is 215 feet above sea level (fig. 6).

The rocks beneath the limestone in these cliffs show great lateral variation. At the north end of the outcrop, 55 feet below the Dun Limestone the top of an orange-coloured micaceous sandstone containing Punctospirifer, "Orthotetes"

and lamellibranchs, is exposed; the writer has named this horizon the "Lamberton Marine Band". It is seen again at the north-west side of Marshall Meadows Bay underlying a discontinuous coal, perhaps Robie's, where it consists of seven feet of sandy grey shale containing large ironstone nodules above a lenticular greenish marl with cone-in-cone structure; Tate (1863) first recorded marine fossils from this horizon but its significance was not realised and no references have been made to it by later workers. At Marshall Meadows it contains a rich fauna of brachiopods, lamellibranchs, gastropods and bryozoa (see page 137).

At the north end of the section a thin cement-limestone lies 14 feet below the Lamberton Marine Band and 23 feet lower is a massive yellow-grey and pink sandstone, over 70 feet in thickness. This sandstone forms a prominent feature to the south of the Salmon Fishery where it is inverted against the Lamberton Fault, and it forms the higher of the two inverted sandstones which outcrop close to the Lamberton bore; along the cliff to the south-east it thins out rapidly, and is replaced by sandy shales.

The beds immediately below the massive sandstone contain a series of thin coals with associated seat-earths, fire-clays, and thin sandstones, while not far beneath these must lie a massive red sandstone, which is seen in the vertical limb of the fold. In the Lamb's Burn some 68 feet

of sheared and inverted rocks are seen close to the Lamberton
Fault:-

Red sandstone, with thin shales at top...	33' 2"
Fault?	
Grey shale.....	7"
Coal.....	4"
Grey shale, sheared.....	2' 2"
Coal.....	8"
Grey shale, with ostracods.....	2' 9"
Limestone, sandy, pyritous, with fish- teeth, ostracods and lamellibranchs.....	1' 0"
Marl grey.....	1' 8"
Coal.....	7½"
Sandstone, red-grey with thin shales.....	7' 9"
Brown and grey sandy shales partly exposed.....	9' 10"
Red sandstone.....	5' 0"
Fault breccia.	

The red sandstone at the top of this sequence is probably that which lies below the coals at the foot of the cliff and which is seen inverted against the fault 70 yards to the south, and again at the Lamberton bore (fig.6); if this is so, the lowest of the beds in the Lamb's Burn section must lie at least 290 feet below the Dun Limestone.

Further information concerning the structure and the sequence at this point has been obtained from the records of a water-bore (Unpublished, 1948) close to the Lamberton Fault and 500 yards south of the Lamb's Burn section. This boring was made a few yards to the east of the position of the fault, and on the assumption that the fault was of the normal type (as previously mapped), the bore was intended to reach the

water-bearing fault-plane at no great depth. In fact, the fault was not encountered, and after passing through steeply inclined beds the bore entered horizontal sandstones at sea level. As the rocks at the bottom of the boring, like those exposed on the shore to the east, are horizontal, all the strata seen in the bore should outcrop in the cliff (fig.6).

The bore appears to have passed through the lower of the two inverted sandstones into the soft beds which overlie it; here, among thin coals and sandy shales, a "grey and brownish-grey limestone,.....with encrinite and shell fragments" was encountered at a depth of 175 feet (Unpublished report); this is 45 feet below the level of the Lamberton Marine Band in the cliff, and moreover below the 70 foot sandstone. The bore then reached the axis of the fold at 200 feet where "signs of smash" were seen, below which it passed back into the horizontal limb of the lower sandstone. The recorded crinoidal band lies between the two sandstones, but it has not been found in the cliff below the 70 foot sandstone.

Rocks belonging to the Scremerston Coal Group are exposed on the south of Hilton Bay (Plate VIII, fig.i). Here, there is an inverted succession below the Dun Limestone, similar to that seen in the cliff a quarter of a mile to the south, but the Lamberton Marine Band, which at this point is

represented by four feet of dark calcareous sandstone, is faulted against the Upper Catcairn sandstone which appears to be the highest of the 550 feet of rocks which have been assigned to the Fell Sandstone. The lower surface of the Catcairn sandstone at this point is sheared and its thickness reduced by the Lamberton Fault (fig. 6); two small faults downthrowing to the north, shift the outcrops a few yards to the west above the high-water mark. A few yards to the south, on the hillside, are several outcrops of a hard pure limestone containing crinoid ossicles, foraminifera, ostracods and shell fragments. These blocks of limestone are not in situ, and it is possible that they owe their presence to faulting and may represent a considerably lower horizon.

Many problems arise in connection with the Scremerston Coal Group in the Berwick area (fig. 5). The thickness of the group increases rapidly to the north-east of Duddo and the maximum development is seen in the type area, immediately south of Berwick. To the north only the upper part of the group is seen and at Hilton Bay a minimum thickness of 250 feet has been cut out by the fault which throws the Lamberton Marine Band against the Fell Sandstone. How much more of the succession has been cut out by this fault is dependent upon the attenuation which may have occurred within the group between Scremerston and Lamberton. To assess the degree of attenuation, if any, it is necessary to compare the succession

at Lamberton with that seen and recorded to the south.

The Lamberton Marine Band occurs 55 feet below the Dun Limestone, and there is some evidence of the existence of another marine band at least 160 feet lower (see page 72). There is a striking similarity between the fauna of the Lamberton Marine Band and that of the Duddo Limestone, which does not, however, constitute conclusive evidence that they represent a single horizon.

A. Evidence for correlation:-

- 1) Similarity of faunas despite variation of lithology.
- 2) Similarity of lithology of overlying strata.
- 3) At only one point (Lamberton) is there evidence of the existence of more than one marine horizon in the upper part of the group.

B. Evidence against correlation:-

- 1) The greater thickness of strata between the Duddo Limestone and the top of the group.
- 2) The Duddo Limestone lies below the Fawcett Coal which is believed to be the equivalent of the Caldside Coal.
- 3) The Lamberton Marine Band is apparently associated with Robie's Coal which lies more than 80 feet above the Caldside seam in the type area.

If the correlation (A) were in fact correct, there would be considerable evidence of attenuation within the group. The thickness between the Caldside Coal and the Dun Limestone has been reduced from 210 feet to 50 feet in a distance of seven miles. Similar attenuation in the underlying strata

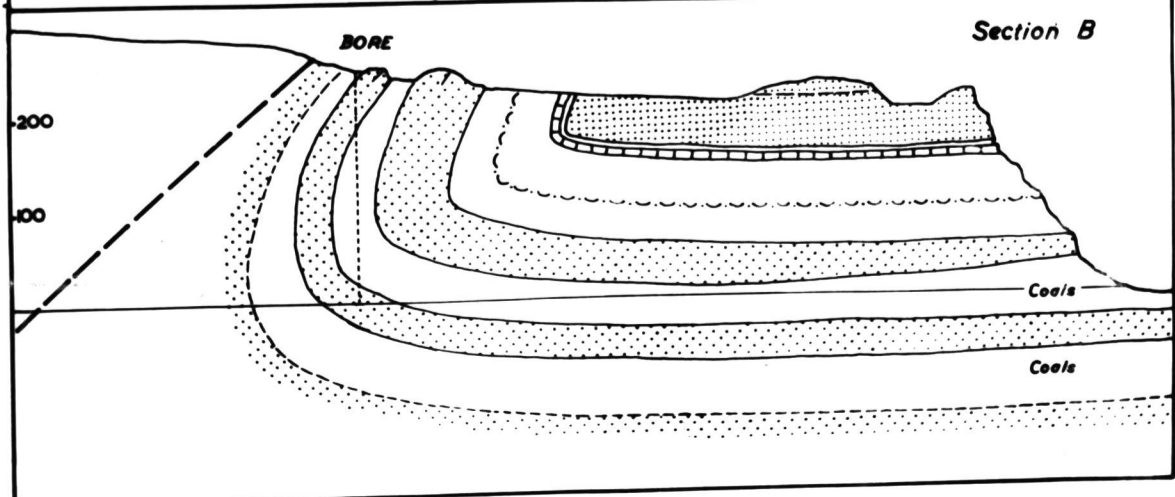
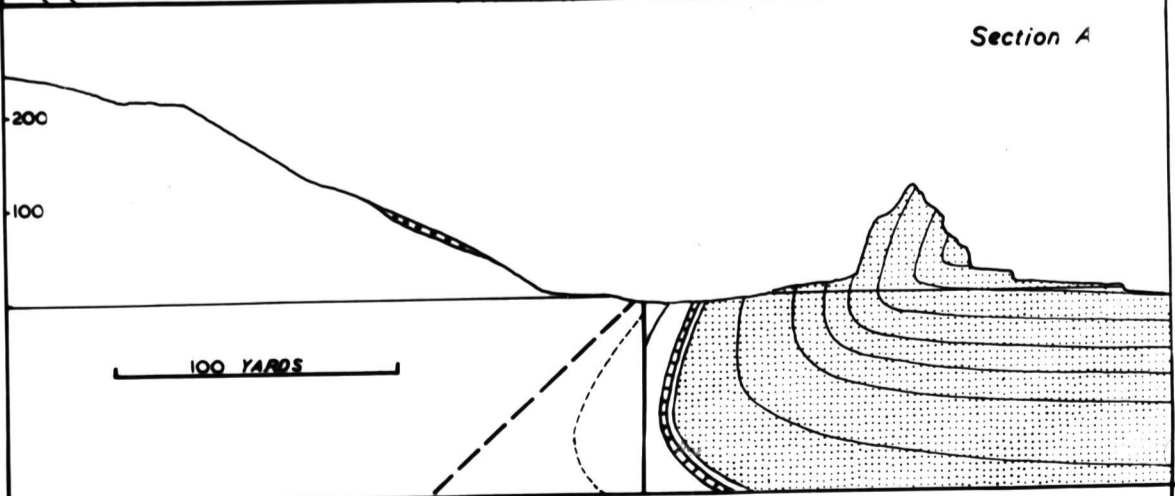
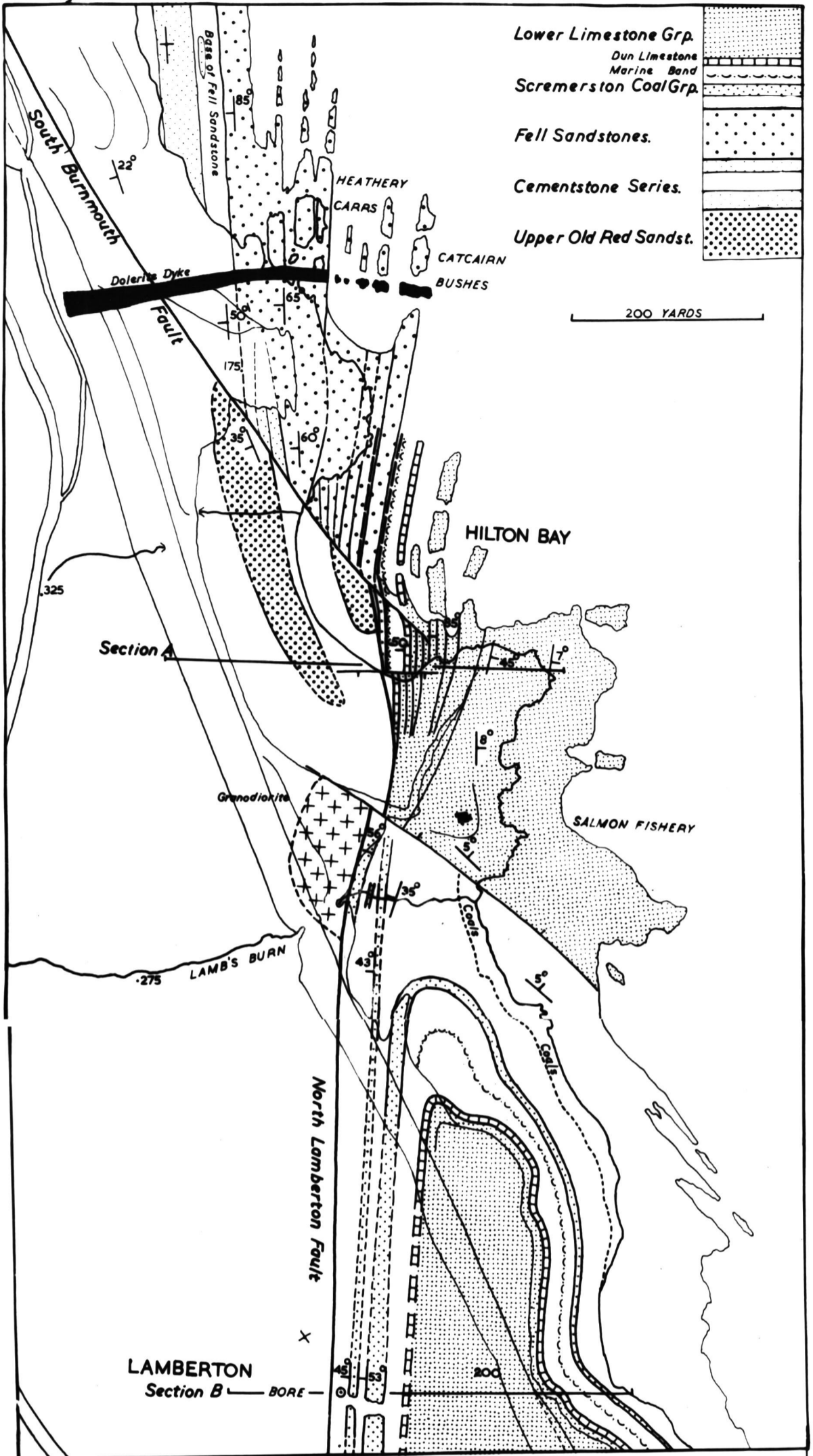
would mean that the succession at Lamberton represents the greater part of the group, and the throw of the vertical fault at Hilton Bay would not be great. Such thinning is by no means improbable in rocks of this age; in this case, it is unlikely that an important development of the Scremerston Coal Group lies to the north of Berwick. Considerable northward attenuation is known to occur in the Cementstone Group (fig.4) and the Lower Limestone Group (fig.7).

If it is considered that there is no case for the correlation of the Duddo and Lamberton horizons and that they are in fact distinct, there is then no indication of northerly attenuation within the group. The Lamberton Marine Band lies at the horizon of Robie's Coal, while the Duddo Limestone occurs below the Caldside. At Lamberton, the coals seen at the foot of the cliff represent the Caldside seam, and the crinoidal band reported in the boring, may represent the horizon of the Duddo Limestone. Great attenuation of the lower parts of the group is improbable and a considerable extension of the Scremerston coalfield to the north of Berwick is possible. A great thickness of strata is excluded by the faulting at Hilton Bay. The evidence is therefore inconclusive.

The area to the south of Berwick was undergoing rapid subsidence with the formation of a trough into which sediments were washed from the north. At Duddo the thickness of the

group is halved and to the south towards Alnwick it is represented by a mere 250 feet. In northern Berwickshire only 370 feet of strata separate the Kip Carle Sandstone, a rock of Fell Sandstone type, from the Cove Upper Marine Band which lies at the horizon of the Dun Limestone. Attenuation may be expected across the Southern Uplands axis, but whether this affects the group at Lamberton is uncertain (see note on Cove succession, page 104).

Fig 6 HILTON BAY.



6) The Lower Limestone Group.

The Lower Limestone Group in the Berwick area consists of 650 to 850 feet of rocks between the Oxford and Dun Limestones (fig.7), and is a continuation of the arenaceous Yoredale facies initiated by the deposition of the Duddo Limestone in late Scremerston times. Rhythmic sedimentation is usually discernable, but many of the rhythmic units are incomplete, often as a result of contemporary erosion. There is considerable northward attenuation within the group in the Berwick district, accompanied by an increase in the proportion of arenaceous sediments. Three thick marine limestones occur in the southern part of the area, two at Berwick, and only one to the north. The coral-brachiopod fauna of the marine horizons is characteristic of the Lower Dibunophyllum (D_1) zone; no identifiable goniatites have been obtained from the Lower Limestone Group in north Northumberland, but the discovery of Beyrichoceras redesdalensis from the Lower Cove Marine Band (= Lamberton Marine Band) (Wilson, 1952 i) indicates that the group is of B_2 age.

The Lower Limestone Group occupies a flat drift-covered tract of country to the north-east of Duddo. The dip in this area varies from 15° to 30° , to the south-east. Three miles south of Berwick, the outcrop extends across the Scremerston Anticline, beyond which the rocks strike to the north-north-west, and the dip increases from 30° to 60° , towards the north. The lower members of the group are exposed

in a tract of horizontal strata to the north-west of Berwick as far as Lamberton, and again in the inverted limb of the monoclinial fold at Hilton Bay.

The basal member of this group, the Dun Limestone, is a persistent and widespread horizon; it is the equivalent of the Redesdale Limestone to the south and of the Upper Cove Marine Band to the north-west. It is the only marine horizon in the Lower Limestone Group which is known to be represented to the north of the Southern Uplands axis. It should not be correlated with the Lower Cove Marine Band (see page 144) as suggested by earlier writers, (e.g. Gunn, 1898, Wilson, 1952) for the Lamberton Marine Band clearly lies at that horizon (see note on Cove succession, page 106).

The characteristic fauna of the Dun Limestone includes Girvanella, Lithostrotion junceum, L. cf. clavatum, Gigantoproductus, and several tabulate corals. The occurrence of Girvanella is of interest, as elsewhere this alga is confined to a horizon at the base of D₂. The shale which succeeds the limestone yields a small Chonetes and Estheria.

The Dun Limestone rarely exceeds six feet in thickness and thins northwards. There is always a coal immediately beneath the limestone, which is succeeded by a dark grey shale containing small ironstone nodules. The shale may be thick, (12 feet to 17 feet) and grade into the overlying sandstone, as at Hud's Head and Hilton Bay, or a reduced

thickness of the shale may be followed abruptly by conglomeratic red sandstones, indicating contemporary erosion, as in the cliffs at Lamberton.

The succession above the Dun Limestone shows considerable lateral variation. At Hud's Head (Plate IX, fig.1) the shale is followed by yellow-grey slumped sandstones, with shale partings, rootlets, ripple-markings and thin coals, one of which, the Biteabout, has been mined to the south of the Berwick area. These beds are overlain by the second limestone, the Woodend.

The sandstones which succeed the Dun Limestone north of Berwick, are of quite a different nature. They are red in colour, coarse in grain, free from argillaceous material and devoid of plant-remains; the shales which separate the massive sandstones are sandy and often purplish-red in colour. It is clear that these sandstones and those at Hud's Head, were deposited in quite different environments.

The Woodend Limestone is also of widespread occurrence to the south of Berwick, and has been worked within the area as a source of lime. Its lateral equivalent in south Northumberland is the Fournalms Limestone, but it does not extend far to the north of Berwick; it does not appear to be represented at Cove, and on the basis of the correlation of the Lower Cove Marine Band with the Lamberton Marine Band, is not the equivalent of the Upper Cove Marine Band

(Wilson, 1952), which is represented by the Dun Limestone in this area.

At Hud's Head the Woodend Limestone is seven feet in thickness, and contains an abundant coral-brachiopod fauna; the base of the overlying shale is rich in Pustula, productids, and Fenestrellina. The sequence is:-

Shale, with marine fossils at base becoming sandy upwards.....	65' 0"
Woodend Limestone, with <u>Lithostrotion</u> <u>junceum</u> , <u>L.cf. portlocki</u> , productids, etc.....	7' 3"
Shale, with marine fossils at top.....	11' 0"
Hard calcareous sandstone, rootlets at top.....	6' 0"

To the north of Berwick the succession above the Dun Limestone consists predominantly of thick red sandstones. At a small cove, locally known as Sandy Beds, a four foot sandy limestone is seen below a massive red sandstone; the succession is:-

Massive current-bedded red sandstone.	
Grey sandy shale, purple near top.....	4' 6"
Sandy limestone with <u>Lithostrotion</u> <u>junceum</u> , <u>L.cf. martini</u>	4' 0"
Grey sandy shale.....	3' 0" seen
Massive current-bedded red sandstones.	

This limestone has been correlated with the Woodend (Gunn, 1898). At the north side of the cove the limestone is obscured by fallen rocks; where the horizon is seen again to the north, only sandy shales occur. There is no

evidence of disconformity at the base of the overlying sandstones, and it is evident that this represents the local limit of the depositional area of the Woodend Limestone. The shale, when traced northwards in the cliffs, is found to lie 125 feet above the Dun Limestone at St. John's Haven. At the south end of Sandy Beds Cove the limestone does not "die out" as stated by Fowler (1926), but is cut out by a fault which downthrows to the south. A discontinuous band of limestone (four feet) was worked to the north of Marshall Meadows (Geikie, 1864), which was probably another northward extension of the Woodend Limestone.

The shales which succeed the Woodend Limestone at Hud's Head, have been replaced by red sandstones at Sandy Beds Cove. There are 260 feet of red sandstones above the Dun Limestone in the inverted limb of the monocline at Hilton Bay (fig.6), which must, therefore, include the horizon of the Woodend Limestone.

Red sandstones (110 feet) with sandy mottled marls follow the shale above the Woodend Limestone at Hud's Head, showing that the conditions which controlled the deposition of the red sandstones north of Berwick, had spread southwards.

The next horizon of significance is the Doupster Oil-shale, which is known throughout the northern part of Northumberland. It may also represent the horizon of the Cove Oil-shale and if this is the case, the horizon of the

Woodend Limestone at Cove, is occupied by sandstones, as at Hilton Bay. The sequence at Red Shin Cove is:-

Dark grey shale, unfossiliferous.....	16' 6"
<u>Doupster Oil-shale</u> , impure below.....	3' 7"
Green marl with " <u>Somphospongia</u> ".....	6' 0"
Hard, fine-grained magnesian limestone, (two bands).....	2' 9"

The oil-shale contains fish-scales and entomostraca; the green marl, with "Somphospongia" (Anderson, 1950), is a remarkable sight with thousands of algal nodules projecting from its weathered surface (Plate X, fig.1). The same beds, reduced in thickness and more arenaceous in composition, are among the lowest members of the succession visible at Calot Shad (fig.8), to the north of Berwick Harbour. There are no published records of the occurrence of "Somphospongia" elsewhere in Great Britain. The succession between the Oil-shale horizon and the Oxford Limestone is much attenuated at Calot Shad; Fowler (1926) noted this attenuation, (although his section exaggerates the actual thickness) and he states that it may be the result of strike-faulting. There is no evidence for strike-faulting and study of the structure of the area has shewn that the existence of such a fault, is improbable.

Above the Doupster Oil-shale, there are further red sandstones and marls reminiscent of the upper parts of the Cementstone Group. Some of these beds have been eroded to

the north, and they are overlain with disconformity by a seat-earth, which transgresses onto lower beds to the north (Plate IX, fig.1).

The seat-earth is followed by nine feet of marine shale, with thin bands of limestone, exposed in the cliff at Red Shin Cove; the shale contains Lithostrotion, productids and spiriferids. This marine band is probably at the horizon of the Watchlaw Limestone at its type locality, but it is probable that the name Watchlaw has been applied to more than one thick limestone in the middle of the group in other parts of the area to the south.

The Red Shin Marine Band has not been seen at Calot Shad, but it occurs in the railway cutting 600 yards to the south of Red Shin Cove, where a sandy crinoidal limestone is developed.

A six-foot crinoidal limestone has been discovered by the writer in the Slateford Burn, south-west of Scremerston, a short distance south-east of the position at which the Woodend Limestone is said to occur (Fowler, 1926). It seems probable to the writer that the limestone is, in fact, the Woodend horizon, for no thick limestone was encountered above the Woodend in either of the bores at Ancroft. A marine shale with bryozoa, which was recorded from the Ancroft No.2 bore, below 60 feet of shales, appears to represent the Red Shin Marine Band.

At Dodd's Well at the north side of Burgess' Cove, which is defined by faults downthrowing to the south, a calcareous marine shale with Lithostrotion junceum and crushed clysiophyllid corals, is seen at the foot of the cliff; this may be at the horizon of the Red Shin Marine Band. The overlying strata are unlike any seen in the Lower Limestone Group of the Berwick district; they are pale-grey shales interbedded with thin calcareous sandstone bands, which somewhat resemble cementstones and may consequently have led Geikie to ascribe these beds to the Cementstone Group.

At Red Shin Cove, the marine band is followed by another seat-earth and coal; these, in turn, are succeeded by 33 feet of red sandstone, the Red Shin Sandstone, which Fowler believed to lie unconformably upon the underlying rocks (Plate IX, fig.1). Fowler ascribed the absence of the Watchlaw Limestone in the Berwick area to this unconformity. While there can be little doubt that the Red Shin Sandstone, like many others, was deposited after a period of localised erosion, it seems unwarranted to attach regional importance to this sedimentary break. In fact, the apparent unconformity at Red Shin is due to variation in the thickness of the underlying beds; it is the writer's experience that these phenomena are of local significance only, and are characteristic of the conditions which obtained in the Berwick area

throughout D₁ times. The Red Shin Sandstone is coeval with the shales which overlie the Red Shin Marine Band at Ancroft and Dodd's Well; therefore, it cannot properly be said that there is unconformity.

After the deposition of the Red Shin Sandstone, another marine limestone was laid down and this may be the equivalent of one of the higher limestones to the south, which have been incorrectly correlated with the Watchlaw. In the Berwick district, however, its depositional areas were limited, and later erosion removed any shales that may have succeeded it. The partially dolomitized remains of this limestone occur at two previously unrecorded localities, lying above the Red Shin Sandstone.

At the foot of Red Shin cliff, the sandstone is followed by current-bedded, slumped, purple and grey sandy shales. Scattered blocks of yellow dolomitized limestone were noticed, and a search towards the north revealed a band of marine limestone, three to four feet thick, above the Red Shin Sandstone, and terminating abruptly against the sandy shales (Plate X, fig.ii). The limestone thickens northwards, but it is not seen at Calot Shad; a quarter of a mile to the south the limestone outcrops again for a short distance at Maiden Kirk. The sandy shale lies disconformably upon the limestone, even penetrating beneath it at the end of the outcrop.

The remainder of the succession, both at Calot Shad and Maiden-kirk (Plate IX, fig.ii) is of current-bedded, often reddish, sandstones such as the thick Maidenkirk Sandstone, alternating with sandy shales interrupted by occasional thin seams of coal. Sandstones predominate at Calot Shad where the thickness of the group above the Doupster Oil-shale is 390 feet, compared with 495 feet to the south of Spittal, and 530 feet at Ancroft (No.1 bore); the increase in total thickness is accompanied by a reduction in the number and thickness of the sandstones in the succession.

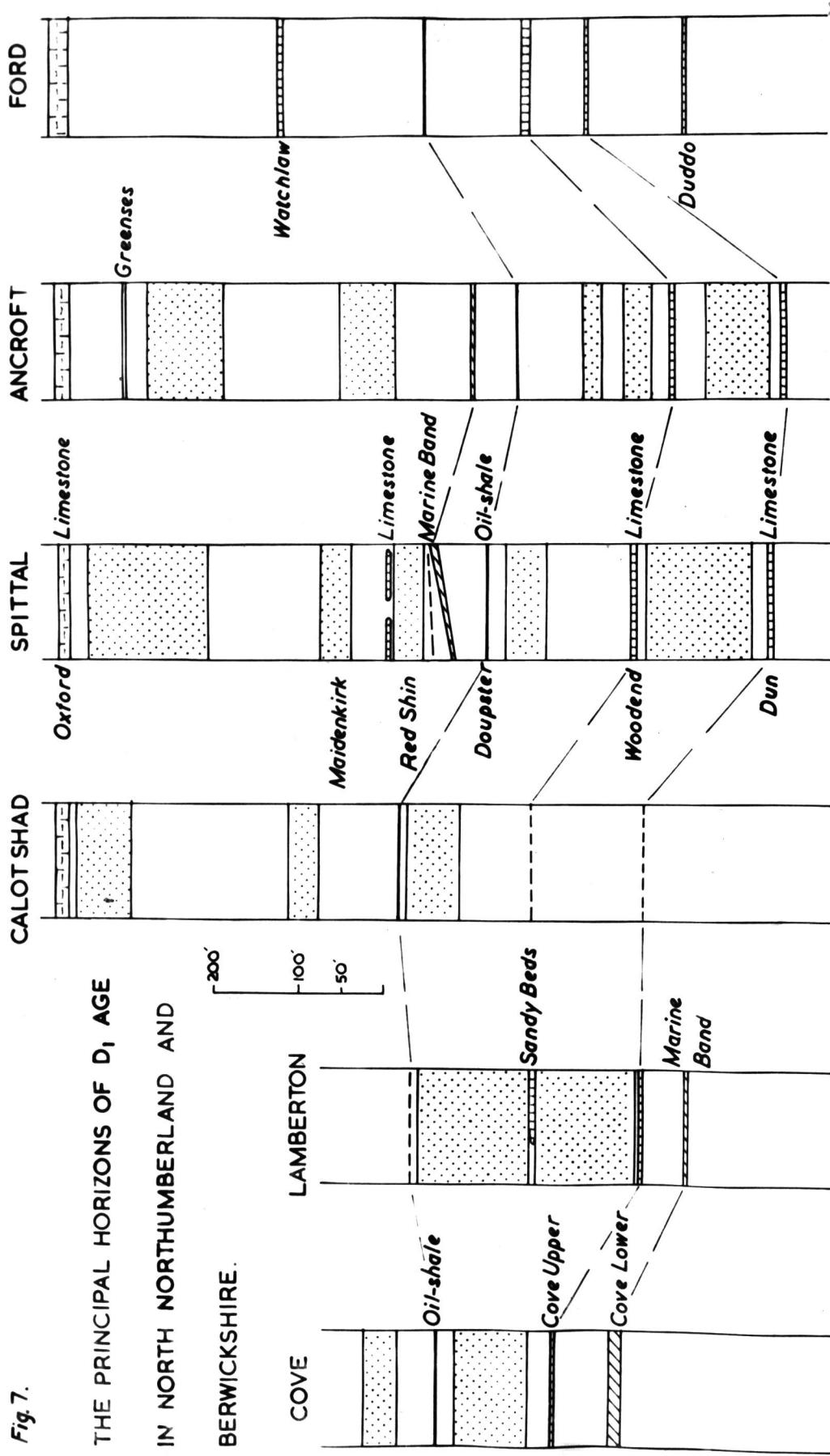
Greenses Coal, a seam which has been worked in association with the quarrying of the Oxford Limestone, lies about 70 feet below the top of the Group. It is not seen at Calot Shad or to the south of Spittal; it does occur, however, in the Doupster Burn, where it is succeeded by a thin crinoidal limestone (1' 2"). The limestone is exposed again in the burn at Ancroft Greens, where the coal (2' 6") has been worked in recent years; several further outcrops of limestone containing large productids and bryozoa have been noted in the Haydon Dean, north-west of Berringtonlaw.

The succession in the Lower Limestone Group, more than any other, exhibits features which show the controlling influence of the Southern Uplands axis upon sedimentation in the Berwick area; the attenuation of the group itself, and of the individual members within it; the increase in

the proportion of arenaceous sediments to the north, and the reduction in the number of marine horizons in that direction, are all results of this control. With the exception of the Dun Limestone, no marine horizon is known to have extended far to the north of Berwick; evidence shows that at least two other marine limestones interdigitate with deltaic sandstones at the limit of their area of deposition. To the south, lack of exposures preclude the accurate determination of the thickness of the group, but from the evidence of borings to the south of the area, it is known that the thickness of the group is reduced across the Cheviot axis.

At Gallowmoor, seven miles north of Alnwick, a boring passed through 220 feet of beds of shale facies below the Oxford Limestone, in which eight marine limestones were encountered (Burnett, 1946). Burnett admitted failure to correlate this succession with that at Spittal and Ancroft, and states that the beds in the Gallowmoor Bore (342 feet) must be above the horizon of the Watchlaw Limestone; obviously, attempts at detailed correlation based only on thickness and lithology must be valueless in such variable rocks. The eight limestones yielded a typical D_1 fauna, and the lowest contained Girvanella nodules. The writer has observed seven incomplete rhythmic units at Spittal, and this fact combined with the occurrence of Girvanella (see page 78) indicates that the lowest limestone was, in fact, the Dun,

and it follows therefore that the Lower Limestone Group at Alnwick is represented by less than 220 feet of beds of limestone-shale facies.



7) The Middle Limestone Group.

The extension of conditions which gave rise to a true Yoredale limestone-shale facies was slow and probably localised, and although such conditions prevailed in areas to the south (e.g. at Gallowmoor) in D_1 times, it was not until the deposition of the Oxford Limestone that they became established in the Berwick area.

The Middle Limestone Group (fig. 9) is represented by approximately 820 feet of rocks of Yoredale facies lying between the Oxford Limestone and the base of the Great or Dryburn Limestone. The principal horizons above the Oxford Limestone are the Eelwell, Acre and Sandbanks Limestones; a complete succession of 600 feet below the Acre Limestone is seen at Seahouse and Calot Shad, while the upper part is exposed in the shallow folds to the south-east of Green's Haven (fig.8; Plate XII, fig.1). Few of the members of the higher part of the group are exposed to the south of Seahouse, and inland, only flooded and overgrown quarries show where the thicker limestones have been worked in the past.

The coral-brachiopod fauna of the Oxford Limestone and of the marine horizons above it are characteristic of the Upper Dibunophyllum (D_2) zone; the base of the obsolete D_3 zone was placed at the base of the Eelwell Limestone by earlier workers (e.g. Garwood, 1929). Sudeticeras adeps has been obtained from the shales above the Acre Limestone

at Ancroft Steads and Holy Island (Trotter, 1951): as this species is characteristic of the P_{2c} subzone, it is probable that the base of the Namurian lies between the Sandbanks and Acre Limestones. The Middle Limestone Group of Northumberland is the equivalent of the Lower Limestone Group of the Midland Valley of Scotland.

Rhythmic sedimentation is strikingly displayed in the succession between the Oxford and Acre Limestones. In contrast to the variable arenaceous sediments of the Lower Limestone Group, the succession exhibits great regularity, both in thickness and lithology. The complete rhythmic sequence (a to j), as seen in the Berwick district (fig.9)* is:-

- b. Limestone
- a. Marine Shale
- j. Sandy grey fake
- i. Coal
- h. Seat-earth
- g. Sandstone
- f. Sandy shale
- e. Black shale with ironstone nodules
- d. Dark grey shale with normal shale fauna
- c. Dark grey shale with modified limestone fauna
- b. Limestone
- a. Marine shale

* j is omitted in fig.9.

- j. Sandy grey fake
- i. Coal

The sequence is rarely complete; the marine shale (a) which occurs above the only sedimentary break is not always present, and the sandy fake (j), the highest known member of the unit is also uncommon. The absence of the marine shale (a) may be attributed to non-deposition, while it is more probable that the absence of the beds (j) and (i) below the break is the result of contemporaneous erosion. Bed (c) is generally present, which indicates that there was little, if any, erosion following the deposition of the limestone; in this respect the succession shows a closer resemblance to that of the Scottish Lower Limestone Group, than to the type succession in the Wensleydale district. The sequence is not identical with the Scottish type as described by Robertson (1945); beds (a) and (j) are not represented in the typical Scottish unit, while the shale beneath the seat-earth in Scotland is not usually seen in the Berwick development. The proportion of arenaceous beds is greater in the Scottish unit and the transition from shale to sandstone more abrupt.

The group, as a whole, shows little variation in thickness or lithology between Berwick and Seahouse, or in the area to the south. In the Dunbar district, however, the succession is replaced by a non-marine arenaceous facies below

the Eelwell horizon, and further to the north-west the beds of equivalent age are not sufficiently well-known to permit a detailed correlation.

The Oxford Limestone is the local representative of an important stratigraphical horizon - the Girvanella Band. This algal bed is of great extent, being found at the base of the D₂ zone at Pen-y-ghent in Yorkshire, 110 miles to the south, and it is, perhaps, the most important marker horizon in the north of England. It is represented by the Smiddy Limestone of the Alston district and the Bankhouse Limestone, in south-west Northumberland and north-east Cumberland; it is not known at Dunbar, and is probably not represented there, but in the Midland valley of Scotland it is believed (Gunn, 1898, Macgregor M. 1929) to be the equivalent of the Hurlet or Main Limestone, although the characteristic Girvanella has not been found.

Although the Oxford limestone is by no means the thickest of the limestones in the Berwick district it has been extensively quarried. It appears to thicken northwards, increasing from 10 feet at Beadnell to 17 feet 6 inches at Calot Shad. Apart from the reddish-coloured Girvanella nodules, which are larger than those occurring in the Dun Limestone, and which are usually encrusted about a small shell or crinoid fragment, the fossil-content is poor; crinoid debris is more abundant than in any other limestone in the area, crushed Dibunophyllid corals, Lithostrotion,

and Giganto-productus sp. being the most common forms. Beyrichoceratoides truncatum has been obtained from the overlying shales at a locality to the south of the area (Dunham, 1948).

In the south of the area, the Oxford Limestone outcrops around the anticlinal area between the Berrington and Ancroft Faults (see page 110). On the north (or downthrow) side of the Ancroft Fault it is seen again near Ancroft Greens, and has been worked from there to Ancroft North Farm, where it is displaced to the south-east by another fault. It has been quarried continuously for a mile at Oxford, as far as the North Road, but apart from a small exposure near Scremerston Farm it is not seen again until the shore section is reached at Seahouse. At both Seahouse and Calot Shad the overlying shale contains many crushed corals and it is clear that this limestone was not eroded prior to the deposition of the shale.

The succession between the Oxford and Eelwell limestones is a perfect example of rhythmic sedimentation; previous workers have dealt only cursorily with this part of the group. The present writer feels that the six thin limestones found within the succession may prove to be as useful for purposes of correlation as the thicker limestones lying immediately above and below. The thickness is 460 feet; nine rhythmic units have been recognised, and there are seven marine horizons above the Oxford Limestone; the second and third

units are arenaceous and no marine horizon is seen at the base of the third. The thickness of the units varies from a few feet to over 90 feet and it is noticeable that the total thickness bears a direct relationship to that of the marine horizon which forms the basal member.

There are few inland exposures of this part of the succession. The sandy shales which succeed the Oxford Limestone (Plate IX, fig.ii) are exposed in many of the old quarries in which the limestone itself is no longer seen. The extent of the six thin limestones in the area to the south is uncertain, and although six similar limestones are seen in the shore section at Beadnell (fig.9), the writer feels no assurance that this coincidence alone constitutes a basis for direct correlation. The writer has numbered the limestones of the Middle Limestone Group in ascending order above the Oxford Limestone (fig.9). This nomenclature is of only local significance, but is considered to be more logical than that used by Carruthers at Beadnell, which is a reversal of the order of deposition and infers a relationship between the major and minor limestones which probably does not exist. In attempting to correlate such a succession, in which few of the marine beds carry a distinctive fauna, the writer considers that the rhythmic nature of the sequence forms a sound basis for short-distance correlation. Working upon this basis, it is probable that

the Beadnell limestones 4c and 4e (fig.9) are not represented (as limestones) at Berwick; similarly, the 4th and 5th limestones at Seahouse, do not occur at Beadnell where the higher part of the succession is arenaceous.

The Oxford Limestone is not seen in the Doupster Burn, but its position is certain as both Greenses and the 1st limestone occur there; in the lower part of the burn the 2nd to 5th limestones are poorly exposed, but the 6th is not seen. The successions at Calot Shad and Seahouse are similar. Fowler (1926) stated that only five limestones were seen at Calot Shad but did not state which one was absent; from his section it is clear that he failed to recognise the 2nd limestone, which is reddish-brown and sandy at that locality.

The 1st limestone is 4'4" thick at Seahouse, where it contains the D₂ fossil Lonsdaleia floriformis, which occurs in the Oxford Limestone elsewhere; other fossils include Lithostrotion, Pustula, and Punctospirifer, while the papery shale above contains crushed productids. At Calot Shad the limestone is 3' 9" in thickness; it is the local representative of the 4f limestone at Beadnell.

On the basis of the rhythmic succession, the 2nd limestone in the Berwick district (fig.9) should represent limestone 4d - the Budle Limestone, as there is no marine horizon at the base of the third unit. The limestone is

sandy at Seahouse and 7'3" in thickness; its fauna is not prolific and only Lithostrotion and Gigantoproductus have been recognised. At Calot Shad it is reduced to 4'3" of reddish sandy limestone. The shales which succeed the limestone at both localities have yielded Posidonia becheri and Goniatites crenistria to the present writer (Plate XXIII, fig. ii) fossils which are known to be associated only in the shale above the Budle Limestone in north Northumberland. The tentative correlation based on the rhythmic sequence is thus given additional support.

Below the 3rd limestone at Seahouse, the succession is:-

Marine Limestone (3rd).....	2' 6"
Black, Carbonaceous shale.....	1' 4"
Sandstone with plant remains at top...	3' 4"
Grey sandy shale.....	10"
Dark shale with ironstone nodules and marine fossils.....	9"
Carbonaceous shale, sandy and grey below.....	13' 0"

This appears to represent a condensed rhythmic sequence and the previously unrecorded marine shale, which contains Posidonia becheri, Pinna mutica and fragments of other lamellibranchs and Brachiopods, is tentatively correlated with the 4c limestone at Beadnell (fig. 9) which lies only eleven feet below the 4b limestone.

The 3rd marine limestone at Seahouse (Scremerston, fig.9) the thinnest of the group, has been correlated with the Budle Limestone (4d) (Burnett, 1927) on account of its position, and the fact that the shales above it yield Posidonia becheri. The limestone itself is practically unfossiliferous, but the overlying shale yields Eomarginifera, orthotetids and other lamellibranchs. Although orthotetids occur with P. becheri above the Budle Limestone, the writer feels inclined to attach more significance to the combined faunal and sedimentary evidence for the correlation of the 2nd (Scremerston) and Budle (4d, Beadnell) limestones. The 3rd limestone is the lowest limestone exposed in the middle of the Ladies Skerrs anticline, south of Green's Haven (fig.8).

The 4th limestone is around 7 feet in thickness at the three localities. It contains a fasciculate Lithostrotion and Syringopora, but few other recognisable fossils. At Seahouse the overlying shale contains Productus longispinus and large dibunophyllid corals. This limestone is not believed to be represented at Beadnell.

The 5th limestone includes two limestones with an intermediate band of marine shale; the whole is considered to form a part of a single rhythmic unit as there is no evidence of the existence of non-marine conditions before the deposition of the second limestone. The thickness of the upper limestone at Berwick is 8' 9" and at Seahouse is

5' 9"; the shale and the lower limestone combined are 8' - 9' at Berwick and 5' at Seahouse. The lower limestone which often passes laterally into shale, contains Gigantoproductus. The shale contains lenticles of limestone packed with "Orthotetes", Rhynchonella and small productids including Eomarginifera. The upper limestone, however, contains few fossils. This horizon is not represented at Beadnell (fig.9).

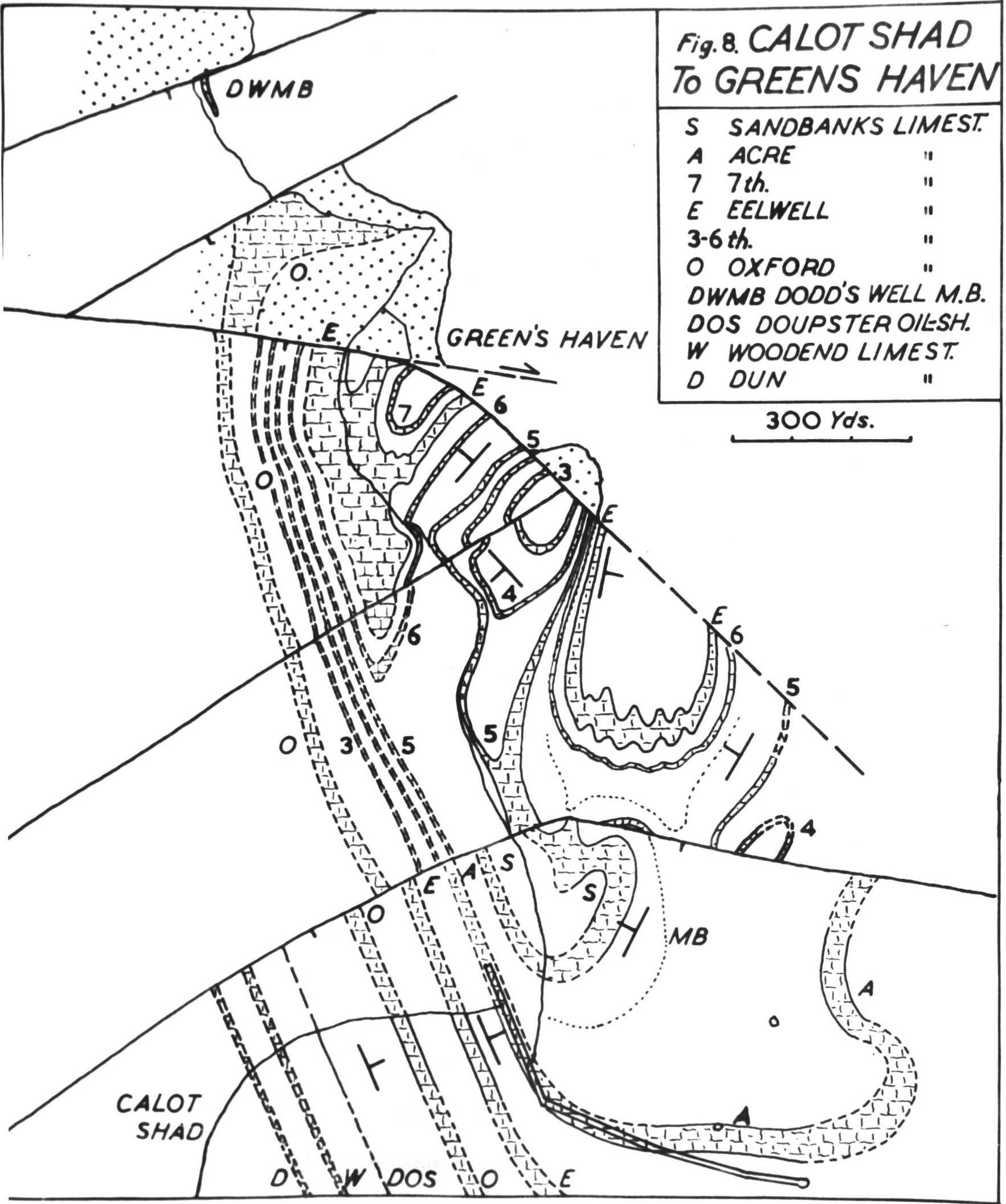
The 6th marine limestone lies from 13 - 20 feet below the Eelwell Limestone. It varies in thickness from 3'10" at Green's Haven to 5' at Seahouse, and is sandy at the northern outcrops. It is sparsely fossiliferous, but the shale beneath it contains many large spiriferids and productids. It is the equivalent of the 4a limestone at Beadnell.

The Eelwell (7th) Limestone (Plate XII, fig.1; Plate XIII; Plate XIV, fig.1) does not contain a distinctive fauna and correlation is thereby rendered difficult. It probably represents the Upper Long Craig Limestone at Dunbar and may represent the Gilmerton Limestone of the Lothians. To the south of Berwick, it has been correlated both with the Tynebottom (Trotter, 1951) and the Scar Limestone (Rayner, 1952, and Gunn, 1898), but the divergence of opinion is due to doubt concerning the correct correlation of the Acre Limestone.

Fig. 8. CALOT SHAD
To GREENS HAVEN

S	SANDBANKS LIMEST.	
A	ACRE	"
7	7th.	"
E	EELWELL	"
3-6th.		"
O	OXFORD	"
DWMB	DODD'S WELL M.B.	
DOS	DOUPSTER OIL-SH.	
W	WOODEND LIMEST.	
D	DUN	"

300 Yds.



The Eelwell Limestone is 28 feet thick at Green's Haven, where it is partially dolomitised, and as elsewhere, contorted; Gigantoproductus and Syringopora are common at this locality. It is seen again in the syncline, to the south-east, where it is intensely folded (fig. 8). At Seahouse it exhibits drag-folding and thrusting (see page 112) and is again partially dolomitised; Lithostrotion and spiriferids occur at the top of the limestone. To the south-west, the Eelwell has been worked on both sides of the railway as far as the fault, and is seen again in the Doupster Burn. Limestone outcrops, which are probably at the Eelwell horizon, have been observed during the course of this survey near Nabhill Bridge, and north-west of Ancroft, on the north side of the Ancroft Fault.

The 8th marine limestone is the last of the series of marine beds which were deposited in the Berwick area in D₂ times. The limestone, which is invariably found above the Eelwell Limestone, is 4 feet in thickness, and contains large colonies of Syringopora (Plate XI); at Seahouse, large concretionary mounds are seen on the upper surface of the limestone. It is seen in the quarry on the east side of the railway, but, owing to the lack of workings in the Eelwell Limestone, it is not seen elsewhere inland.

The beds between the 8th limestone and the Acre are arenaceous, showing a change of sedimentary facies which also

characterises this part of the succession at Beadnell; four thin coals occur in these beds.

The Acre Limestone is the lowest horizon at which Saccamminopsis carteri is known in north Northumberland, although this fossil is found at lower horizons (such as the Jew Limestone), in the south of the county. The overlying shale contains a distinctive zaphrentid fauna and has, at one locality, yielded Sudeticeras adeps.

There has been some controversy as to the correlation of the Acre Limestone. There is general agreement on its correlation with the Middle Skateraw Limestone at Dunbar, which contains S. carteri and Cyathaxonia cornu in the succeeding shales. Further to the west, in the Glasgow district, the horizon is correlated with the Burnhall Limestone, which is succeeded by shales containing a similar zaphrentid fauna, while Sudeticeras newtonense, a late P₂ goniatite, occurs in the overlying Neilson Shell Bed. Trotter (loc. cit.) correlates the Burnhall, Skateraw, Acre horizon with the Scar Limestone, and Middle Limestone of the Alston area, on the basis of the occurrence of S. carteri, and the presence of a C. cornu fauna in the succeeding shale. Rayner (1952), who doubts the validity of long-range correlation on the basis of the zaphrentid fauna, correlates the Acre with the Five-yard Limestone of the north Pennine area. It is clear that the occurrence of S. carteri is of

little significance.

In the Berwick district, the Acre Limestone is nowhere fully exposed, but a thickness of at least 25 feet is known to occur. In the south of the area, the upper part of the limestone, which is reputed to be only 15 feet thick, is seen in the disused quarry at Ancroft Limeworks, to the south-east of Ancroft; a thin (10") shelly limestone lies in the marine shales above the main limestone. It is from these shales that Sudeticeras adeps, a late P₂ zone fossil, has been obtained.

All the remaining exposures of the Acre Limestone in this area are on the coast. At Seahouse, where it is underlain by a thin coal, the limestone is at least 26 feet in thickness and contains abundant S. carteri and Gigantoproductus; the succession above the limestone is not seen at this point. At Berwick, the Acre forms the foundation for the greater part of the Pier, as it outcrops around the shallow synclinal basin at Meadow Haven. Above the limestone, there is a gap in the succession, which can be little more than half Fowler's (1926) estimate of 50 feet.

The upper part of the succession between the Acre and Sandbanks Limestones is exposed to the north of Berwick Pier. The lowest bed seen is a sandy calcareous marine shale containing "Orthoceras" crinoid ossicles, crushed corals and fragments of productids and spiriferids. The beds

which succeed the marine band are arenaceous with indications of coal.

The Sandbanks Limestone (Plate XII, fig.ii), 28 feet in thickness, lies in the centre of the syncline to the north of Berwick Pier; it is also seen to the south and east of Seahouse, where it lies in a number of shallow folds. It is generally agreed that the Sandbanks Limestone is the equivalent of the Four Fathom of the Alston area, and the Undersett Limestone of Wensleydale. At Dunbar it is apparently represented by the Chapel Limestone; in the west of Scotland it has been correlated with the Middle Hosie (Trotter, 1951) on the assumption that the Upper Hosie represents the Great Limestone. If this correlation is correct there is no limestone at the horizon of the Main Hosie, in the Berwick district, nor is there a representative of the Three-yard - or Five-yard, if one assumes the Acre to represent the Scar Limestone; the occurrence of an undoubted marine horizon between the Sandbanks and Acre Limestones is of interest, as it may well be the local representative of the limestones mentioned above.

In the neighbourhood of Scremerston Limeworks (Sandbanks) to the south of Seahouse the limestone has been extensively worked, although no complete section is visible there now. The section seen at the base of the limestone on the coast is:-

Sandbanks Limestone.....	28' 0"
Marine Shale.....	4' 0"
Limestone.....	3' 3"
Marine shale, carbonaceous at base...	4' 0"
Sandstone with rootlets.	

The shales above and below the thin limestone, and above the main limestone contain a prolific coral-brachiopod fauna, including abundant Productus (Homarginifera) longispinus.

To the south-west the Sandbanks Limestone outcrops in the Allerdeanmill Burn close to East Ancroft, where it is contorted, and is seen again close to the workings in the Acre Limestone at Ancroft Limeworks.

The succession between the Sandbanks Limestone and the top of the group has been well described by Fowler (1926). Two marine horizons are seen; the lower, a 6 foot sandy limestone (the 11th); and the higher, a sandstone with crinoid debris. A similar crinoidal sandstone occurs at the same position in the Beadnell succession: the 11th limestone and the crinoidal sandstone also correspond in position with the Barness Limestone and the overlying Lingula Bed at Dunbar.

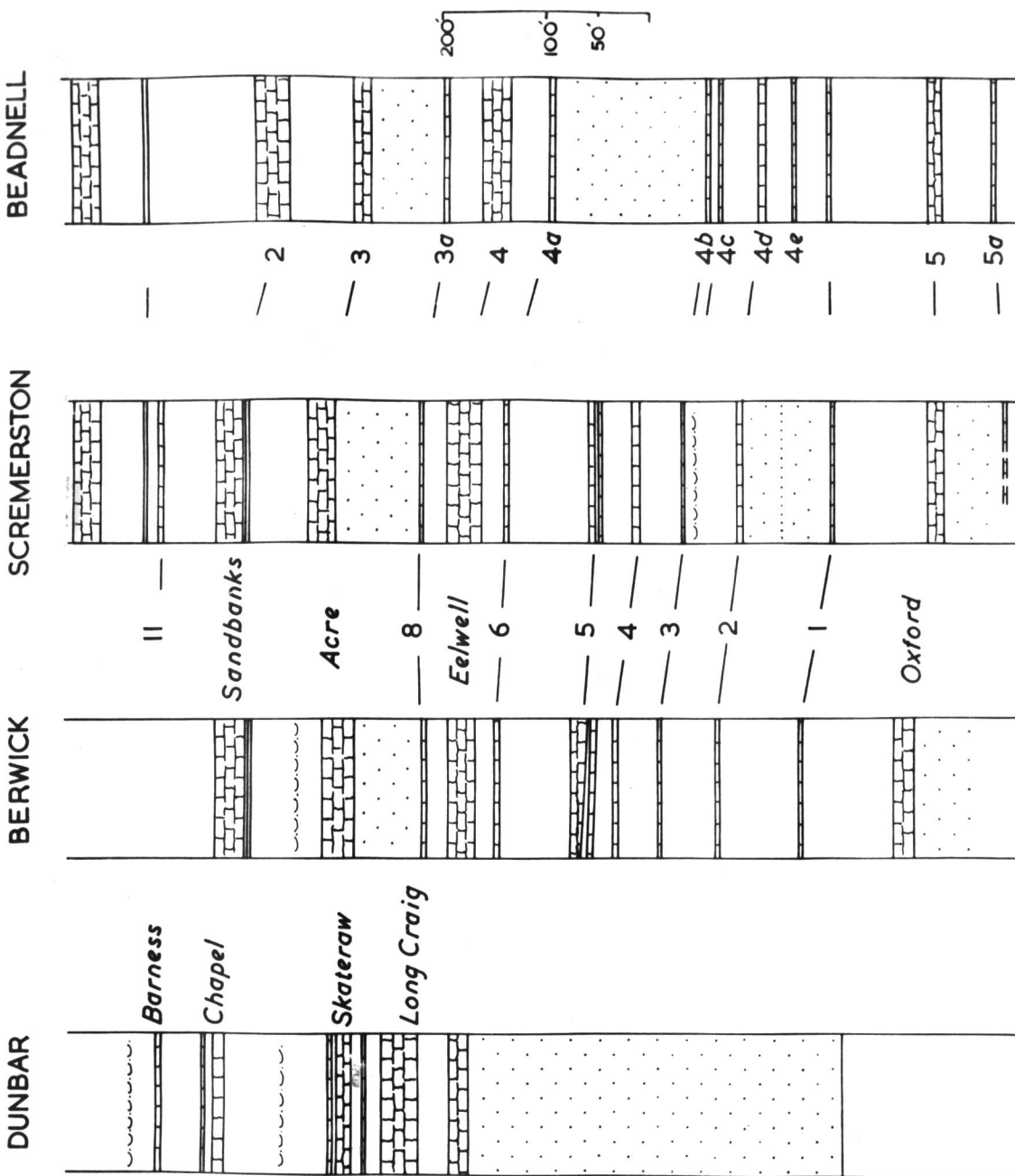
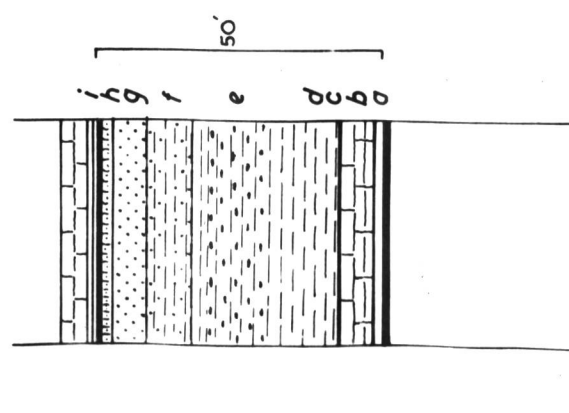


Fig. 9.
 THE MIDDLE LIMESTONE
 GROUP AT DUNBAR, AND IN
 NORTH NORTHUMBERLAND.



A Typical Rhythmic Unit.

8) Note on the Succession at Cove, Berwickshire.

Numerous references have been made throughout the preceding pages to the succession at Cove, a study of which casts much light on the geology of the area as a whole. The Upper Old Red Sandstone and Lower Carboniferous rocks at Cove were deposited over the northern flank of the Southern Uplands ridge. The conditions of sedimentation were consequently likely to be analogous to those that obtained in the Burnmouth and Lamberton areas. With this idea in mind the writer made many visits to the Cove area during the course of this investigation.

The succession at Cove extends from the base of the Cementstone Group to the Bilsdean Sandstone, which lies at or near the horizon of the Red Shin Sandstone of the Lower Limestone Group at Berwick. The lower members of the Cementstone Group lie conformably upon the Upper Old Red Sandstone at Pease Bay (fig. 4), to the south of Cove.

The higher members of the Upper Old Red Sandstone at Pease Bay closely resemble the basal sandstones at Burnmouth (see page 20), thus providing evidence supporting the view that the basal sandstones at Burnmouth are of Upper Old Red Sandstone age.

The apparent thickness of the Cementstone Group at Cove is 500 feet but it has been stated that this thickness represents only the lower part of the Group, and that the

upper part, together with most of the Fell Sandstone, has been cut out by the action of strike faulting at the Cove Fault (Clough, 1910; Wilson, 1952 ii). It is of interest to note that earlier workers (Tate, 1856; Geikie, 1866) considered that the succession at Cove was unbroken.

The Kip Carle Sandstone, lying on the downthrown side of the alleged Cove Fault, has a thickness of some 50 feet. It has been correlated with the Fell Sandstone at Berwick by Clough and Wilson (loc. cit.), who maintain that its limited thickness is due to truncation by the Cove Fault. The writer has examined the Kip Carle Sandstone and finds it to be finer grained than the Fell Sandstone at Burnmouth, but otherwise similar in appearance and composition. It is a hard greyish-white sandstone (Plate XVII), quite unlike the friable red and brown sandstones of the Scremerston Group in the Berwick district. For these reasons the writer considers it probable that Clough's correlation is correct.

The sequence above the Kip Carle Sandstone contains a few thin coals in shales followed by a massive red sandstone. This in turn is succeeded by a series of sandstones and shales in which there are two marine horizons. The Lower Cove Marine Band contains few fossils at Cove, but in Thornton Burn it has yielded a remarkable ironstone-shale fauna. This horizon was correlated with the Dun Limestone at Berwick, and the Redesdale Ironstone Shale by Wilson (1952).

Many of the species of brachiopods, lamellibranchs and cephalopods which occur in the Redesdale Ironstone Shale are also found in the Lower Cove Marine Band, but very few are common to the Dun Limestone, which carries a typical coral-brachiopod limestone fauna. The Lamberton Marine Band in the upper part of the Scremerston Group at Berwick is an ironstone-shale containing many of the forms typical of the Redesdale horizon.

The Upper Cove Marine Band yields a limestone fauna, which includes Lithostrotion junceum and Gigantoproductus, characteristic fossils of the Dun Limestone at Berwick. This horizon was correlated with the Woodend Limestone by Clough and Wilson (loc. cit.). The Woodend Limestone does not extend far to the north of Berwick, and it is therefore considered that the true correlation is:-

<u>Cove</u>	<u>Berwick</u>
-----	Woodend Limestone
Upper Marine Band	Dun Limestone
Lower Marine Band	Lamberton Marine Band (?=Duddo Limestone)

The Upper Cove Marine Band is followed by a thick, lensing red sandstone which may well be coeval with the red sandstones above the Dun Limestone at Lamberton, and the oil-shale which occurs in the succeeding shales may tentatively be correlated with the Doupster horizon at Scremerston. It is probable that the overlying Bilsdean Sandstone lies close

to the horizon of the Red Shin Sandstone. In their discussions of the stratigraphical position of the Cove succession, Clough and Wilson (loc. cit.) draw attention to the thicknesses of the equivalent formations in north Northumberland.

	<u>Cove</u>	<u>Lamberton- Burnmouth</u>	<u>North Northumberland</u>
Bilsdean Sandstone to Upper Cove Marine Band	220'	---	450'
Scremerston Coal Group	380'	300' ?+	1000'
Fell Sandstone (Kip Carle Sandstone)	50' ?+	500' ?+	1100'
Cementstone Group	500' ?+	1600'	3500'

The greatly reduced thicknesses of the Cementstone Group and Fell Sandstone were attributed by them to the effect of the Cove Fault. But no faulting is observed in the upper parts of the succession - where there is also attenuation - and in the light of this and other evidence the present writer considers the reduced thickness of the entire succession at Cove to be entirely consistent with the position of the area on the northern flank of the Southern Uplands geanticlinal axis. The lensing of the sandstones in a predominantly arenaceous succession, and the paucity of marine horizons are also features which lend support to this view, (fig. 4A).

The evidence for the existence of the Cove Fault is

unconvincing. Nowhere else in the Dunbar-Cockburnspath area is there known to be a greater thickness of Tuedian beds. The dip is steep at the position of the alleged fault, which Wilson (1952, unpublished) considered to have a throw of 850 feet. Moreover, Wilson believed the plane of the fault to be vertical, and he inferred that tangential movement had occurred. Slickensides are common in the Kip Carle Sandstone, but none have been seen which could indicate the presence of either a vertical fault-plane or a transcurrent movement. The present writer believes the slickensides, which hade at low angles, to be indications of small differential movements within the Sandstone during the development of a monoclinial fold. At the base of the Kip Carle Sandstone neither slickensiding nor brecciation is seen and the writer is unable to accept the view that there is a fault at this point.

The base of the Kip Carle Sandstone very closely resembles the base of the Fell Sandstone at Ross Point. There is a similar basal limonitic layer and also a strong indication of disconformity, the Sandstone transgressing on to lower horizons to the north-east; in addition, the beds underlying the beds underlying the Sandstone closely resemble the seat-earths of the Lower and Middle Limestone Groups. Thus there is evidence of non-sequence at the base of the Kip Carle Sandstone, and it is probable that the latter rests

unconformably upon the Cementstone Group. Such a break in the sequence would be comparable to the unconformity at Ross, but it is probable that the extent of the stratigraphical break at Cove is the greater. At the point in the cliff at which the Kip Carle Sandstone is said to be truncated by the fault (Clough, 1910) there is again no evidence of faulting. It is more probable that the sandstone lenses out at this point, and that to the west, the lowest Scremerston beds succeed the Cementstone Group unconformably: this would explain the absence of the Kip Carle Sandstone in that direction, (fig. 4A).

The writer supports the view of the earlier workers, who saw no reason to believe that the succession at Cove was incomplete. To him there would seem to be no necessity to postulate the existence of a large fault at Cove. On the contrary, there is evidence suggesting that the deposition of the Fell or Kip Carle Sandstone followed a period of uplift and erosion in the areas flanking the Southern Uplands axis (fig. 12). The Fell Sandstone is a deltaic formation of variable thickness and extent, which was derived from the north and north-east. Thus the Kip Carle Sandstone at Cove may represent the north-western limit of the Fell Sandstone to the north of the Southern Uplands axis.

TECTONICS1) Introduction.






The regional dip in the greater part of north Northumberland is to the east, but in the neighbourhood of Berwick, where there has been little previous structural research, the disposition of the Lower Carboniferous rocks is variable. The tectonic disturbance can be related to the presence of the stable area of the Southern Uplands ridge, against which east-west compressive forces were exerted, during the period of the Carbo-Permian orogeny.

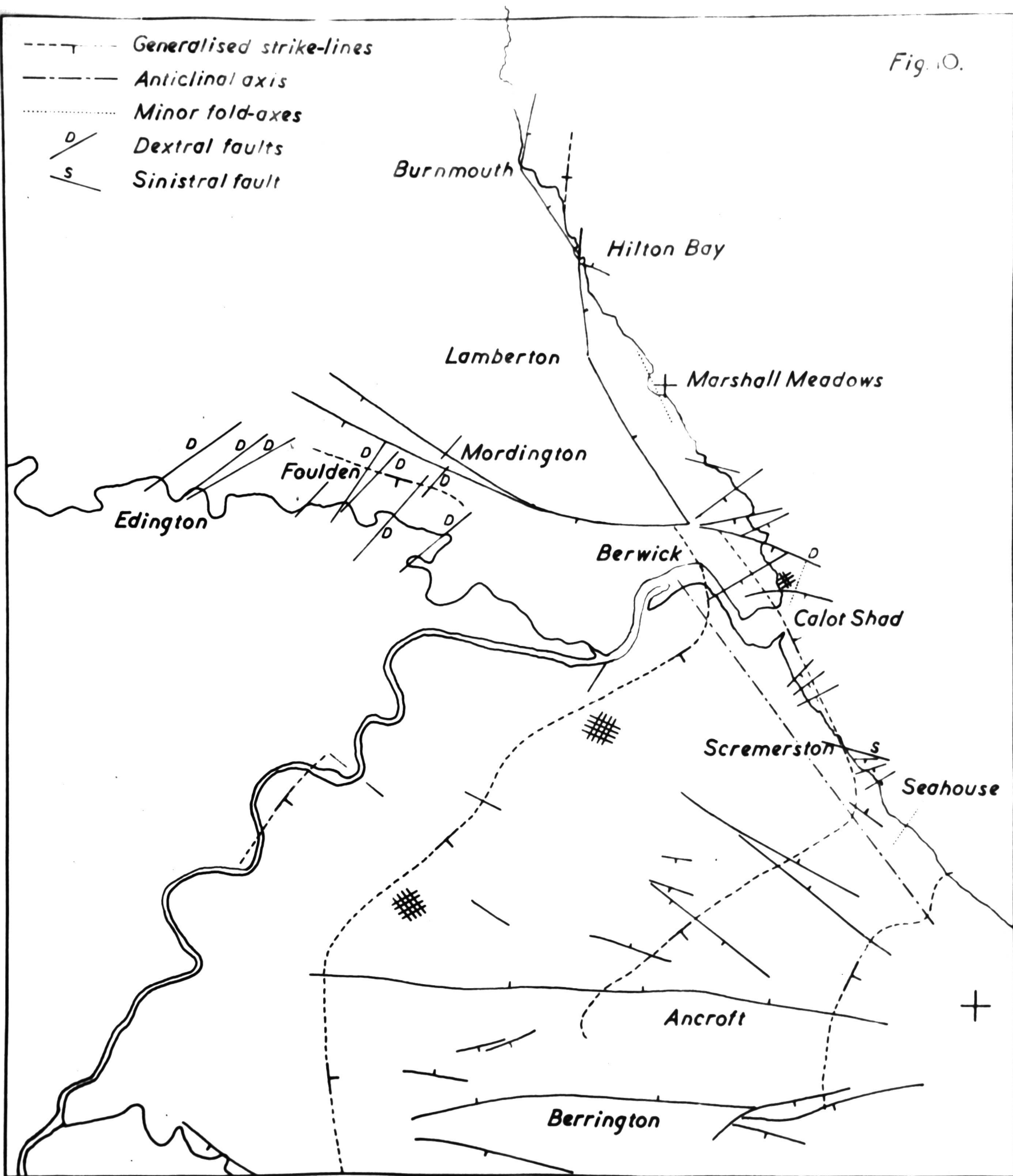
The Lower Palaeozoic rocks of Lamberton Moor (fig. 10) form a faulted outlier of the main Southern Uplands ridge and it is about this outlier that the less competent Carboniferous rocks are disposed. The chief structural problems in the Berwick district are concerned with the fault, or faults, which form the eastern boundary of the Lamberton Moor outlier: they may be referred to as the Burnmouth-Lamberton faults, and their trend (fig. 11) varies between north 6° east and north 36° west. The structures in the surrounding rocks are complementary to this axis.

2) The Ancroft and Berrington Faults.

A number of faults occur in north Northumberland which have an east-west trend, and downthrow to the north: of these,

Fig. 10.

-  Generalised strike-lines
-  Anticlinal axis
-  Minor fold-axes
-  Dextral faults
-  Sinistral fault



the Ancroft and Berrington faults are the most important within the area of this survey. They are the northern representatives of a group of faults which are structurally related to the Cheviot axis; the Ancroft Fault forms the boundary between two tectonic areas; to the north, the structure has been influenced by Southern Uplands axis. The positions of the Ancroft and Berrington faults correspond with the area in which attenuation of the Lower Carboniferous sediments takes place, and it is possible that these Carboniferous-Permian faults resulted from a renewal of movement along pre-existing fault-lines which were initiated in early Carboniferous or even pre-Carboniferous times.

3) The Scremerston Anticline.

The axis of an asymmetrical anticline extends to the south south-east of Berwick; the anticline, which plunges at 15° to the south-east, is the most important structural feature in the southern part of the Berwick district, and its axis coincides with the line of the Burnmouth-Lamberton Faults.

The south-west limb of the Scremerston Anticline shows few features of interest. The south-easterly dip of the rocks is low, and the strike is the result of the influence of the forces which gave rise to the Scremerston Anticline, upon the regional strike of the area, to the south. There are numerous normal

or tear-faults in this area which trend east-south-east; their precise nature is not known, however, as their presence has been recorded only in disused coal-mines and limestone workings. The apparent downthrow is to the south in most cases. Minor drag-folds occur in the workings of the Blackhill Colliery. Jointing, which is displayed at several localities in the Fell Sandstone, conforms with the trends of the faults in the district.

The Scremerston Anticline plunges to the south-south-east and its influence diminishes among the highest members of the succession, which lie in a shallow syncline in the neighbourhood of Cheswick. The Sandbanks Limestone is the highest horizon seen to the north-east of the Anticline, which it flanks in a number of shallow folds trending north-east.

The Eelwell Limestone is exposed at Seahouse in the steeply dipping north-east limb of the Anticline. The limestone, which is overlain by 22 feet of soft shale, exhibits a number of striking drag-folds and minor thrusts (Plates XIII, XIV) which were attributed by Goodchild (1903 ii) to the action of sea-ice. The drag-folds, some of which are overturned (in relation to the undisturbed bedding-plane), plunge at 10° to 15° to the north; the folding occurs largely in the upper part of the limestone, resulting in decollement. The limestone above the Eelwell is not affected, although the shales between the limestones

are violently contorted.

Between Seahouse and Spittal, the dip increases in the north-east limb of the anticline, which is cut by a number of small gravity faults which downthrow to the south. An exception, however, is the Maidenkirk Fault, a sinistral tear fault which displaces the Oxford Limestone on the shore, and against which the Maidenkirk Sandstone is truncated in the cliff (Plate IX, fig.ii).

To the north, the Scremerston Anticline underlies the town of Berwick and its steeply inclined limb can be seen in the banks of the Tweed, and at Calot Shad (fig. 8) by the Pier road. The dip between the Border Bridge and Berwick Pier is 50° - 60° ; as at Seahouse, the Acre Limestone is the highest bed flanking the Anticline, and to the north and east only minor structures are observed in horizontal strata flanking the Lamberton Faults as far as Hilton Bay.

4) The "Foreland".

A relatively stable area or "foreland," in which the rocks are horizontal or gently folded lies to the east of the steeply dipping formations associated with the Burnmouth-Lamberton Faults and their southern extension, the Scremerston Anticline. The visible extent of this region is from Hilton Bay to the southern limit of the area; it may extend for a considerable distance to the east.

In the northern part of this region the arenaceous rocks of the Lower Limestone Group and the uppermost members of the Scremerston Coal Group flank the Burnmouth-Lamberton Faults; minor structures are uncommon in arenaceous rocks, and the only example which has been recorded is a low anticline at Marshall Meadows, the axis of which is parallel to the line of the South Lamberton Fault.

To the east of Berwick a number of faults downthrow 1000 feet to the south, bringing in rocks of the Middle Limestone Group, which are of limestone-shale facies. These relatively incompetent rocks exhibit a number of shallow folds between Green's Haven and Berwick Pier whose axes trend north 15° - 30° east. The Eelwell Limestone lies in the synclines at Green's Haven (fig.8; Plate XII, fig.i) and Bucket Rocks; at Green's Haven, it exhibits drag-folding, although not to the extent seen at Seahouse; in the syncline at Bucket Rocks the limestone is folded into a number of sharp isoclines trending parallel to the axis of the syncline. A third syncline in which the Sandbanks Limestone is the highest horizon, lies to the south of a fault which has a throw of 400 feet to the south (Plate XII, fig.ii).

5) The Foulden and Edington Faults.

The writer has examined a number of hitherto unrecorded faults in the neighbourhood of Foulden and Edington. The

absence of marker horizons in the Cementstone Group makes it impossible to assess the displacement of the faults; their chief interest lies in their transcurrent nature, and uniform trend.

The Greenlaw Banks Fault is seen on the north side of the Whiteadder valley, and at two localities near Greenlaw Banks (fig. 2). At the two southern exposures there are indications of downthrow to the north-west and slickensides show that the final movements were transcurrent. At Greenlaw Banks, however, shales and cementstones are vertical against the south-east side of the fault indicating downthrow in that direction. The Greenlaw Banks Fault is not seen again to the north-east, but a number of associated faults have been observed, all of which have an apparent downthrow to the south-west. At the fault to the south of Mordington Bridge the dip of the adjacent rocks indicates a downthrow to the south-east, as at Greenlaw Banks, but horizontal slickensides indicate transcurrent movement. The writer concludes that the north-east to south-west faults at Foulden are primarily tear-faults, with a dextral movement which masks a lesser vertical component downthrowing to the south-east.

Indications of other tear-faults are seen along the valley of the Whiteadder; at Edington Mill there is a fault, trending to the north-east, which is a dextral tear-fault with considerable displacement.

6) The Mordington Faults.

The evidence for the existence of the previously unrecorded Mordington Faults is found in the vicinity of Mordington Bridge. The faults throw down to the south but horizontal slickensides are seen indicating that the final movement was tangential; it is not possible to estimate their combined displacement, which increases to the east, but as only a small thickness of the Upper Old Red Sandstone is represented, it may well be considerable. The relative age of the two sets of faults at Foulden and Mordington is not known. The Mordington Faults, which probably coalesce to the east, form the Halidon Hill fault-scarp which extends to the north-east outskirts of Berwick.

7) The Burnmouth and Lamberton Faults.

The Burnmouth and Lamberton Faults are not normal faults, as suggested by Geikie (1864). Their complex nature was recognised by Gunn (1898) and Goodchild (1903), but neither put forward any interpretation of the nature of the faults.

It is clear from a study of the structures of the area to the south that the rocks were subjected to compressional forces acting in an east-west direction. This has resulted in the formation of a system of faults, some of which are proved to be tear-faults, lying oblique to the direction of compression in accord with Navier's principle. The

predominance of dextral tear-faults may be explained by the relief of stress on the flanks of the rigid block formed by the Lower Palaeozoic rocks of Lamberton Moor; however, one complementary sinistral tear-fault has been observed on the coast, and it is probable that faults which have a recorded downthrow to the north-east may, in fact, prove to be sinistral tear-faults.

The Burnmouth-Lamberton Faults and the Scremerston Anticline are perpendicular to the bisectrix of the fault systems (fig. 11), and therefore perpendicular to the direction of compression. The axes of the minor structures in the "foreland" area become progressively more oblique to the Lamberton line, towards the south-east, and form another illustration of the moulding of the Carboniferous sediments around the more rigid Lower Palaeozoic rocks.

In the light of these facts, it is clear that the fault, or faults, of the Burnmouth-Lamberton fault-zone are unlikely to be of the normal type, as suggested by Geikie, and the field evidence supports this view.

The Burnmouth-Lamberton fault-zone is divided into two parts, one north and the other south of Hilton Bay. Each shows two trends. The subdivision of the fault-line into four units, is made according to the trends of the faults, and it is not inferred that there are, in fact, four distinct faults.

The Burnmouth Fault extends north 35° west from Hilton Bay to Burnmouth, and then changes its direction and strikes seawards at Partanhall (fig. 3) to the north 6° east. The throw of this fault exceeds 3000 feet and against it lie over 2000 feet of Upper Old Red Sandstone and Carboniferous sediments which are in an approximately vertical position. These rocks form a northern extension of the north-east limb of the Scremerston Anticline and it is clear that the folding occurred before the initiation of the fault, which lies oblique to the strike. The fault plane is apparently vertical, but fault-breccia and lack of exposures preclude accurate determination of the angle of hade. There is a notable absence of slickensides and distortion in the rocks adjacent to the fault; the increase in the degree of inversion is gradual and the average dip of the rocks at the fault is high. At Catch-a-penny Burn there is an associated reverse fault, which brings in a wedge of Upper Old Red Sandstone rocks.

The southern part of the Lamberton Fault, which has a throw of over 5000 feet, is completely hidden by glacial drift, but it may be of significance that its trend coincides with that of the South Burnmouth Fault.

The northern part of the Lamberton Fault extends north 5° west from near Lamberton Farm to Hilton Bay. The rocks adjacent to the fault are shattered and have suffered a high

degree of inversion; in the higher part of the Lamb's Burn, the dips are variable and numerous small thrusts are seen in shales, dipping 30° - 50° towards the fault. A shear-surface, dipping 40° west, is seen on the lowest sandstone on the south side of Hilton Bay. The thickness of rocks inverted against this fault is small, and the Lamberton Bore (fig. 6 Sect.B.), which was put down close to the outcrop of the fault, entered the horizontal limb of the fold at sea-level. The evidence suggests to the writer that the high degree of inversion, and the features at Hilton Bay and Lamb's Burn are related directly to the fault, thereby indicating that it is either a low-angle reverse-fault, or a high-angle thrust.

At Hilton Bay, there is an abbreviated succession which is due, at least in part (see pages 57, 72), to faulting. The vertical plane of the South Burnmouth Fault can be seen in the cliff to the north, and it extends across the Bay towards the south headland. At a point in the middle of the Bay the two faults converge; a small fault, which downthrows a few feet to the south-west, continues towards the south headland, on the line of the Burnmouth Fault. The presence of this small fault may be an indication that the Burnmouth Fault is truncated by another fault; its direction of throw, which shows a reversal of the movement of the Burnmouth Fault, clearly indicates the reverse nature of the latter. Either the North Lamberton Fault is younger than the Burnmouth Fault,

which it truncates, or they are in fact continuous. No indication of the Lamberton Fault has been found to the north, but the sandstones there are imperfectly exposed.

To the east of the lowest sandstone on the south side of the Bay, a vertical strike fault (fig. 6 sect.A) cuts out an unknown thickness of rocks below the Lamberton Marine Band; there is no indication of the direction of throw, but if this fault cuts out the great thickness of rocks which would account for the abbreviated succession, it must downthrow to the west. This does not appear to be a probable explanation and the complete absence of fault-breccia indicates that the displacement is not great. Vertical slickensides are seen on both faces of the Catcairn Sandstone on the north side of the bay, and together with slickensides on the sandstones of the north headland, may be associated with the northern extension of the vertical strike-fault.

An alternative explanation of the abbreviated succession at Hilton Bay is dependent upon the assumption that the North Lamberton Fault hades at a low angle to the west and truncates the Burnmouth Fault. If this is so, the Fell Sandstone has been faulted or thrust over the Scremerston Group, so that the Fell Sandstone apparently underlies the Lamberton Marine Band. Such a low-angle reverse fault could have been initiated by an increase in the forces which first caused the formation of the anticline and later gave rise to the Burnmouth and South

Lamberton Faults. No horizontal displacement in the meridional axis is known to occur, but dextral movement of the Mordington fault is likely, and this is supported by the dextral movement of the fault at Green's Haven.

8) Comparison with the Cockburnspath District.

The similarity between the Innerwick Fault and the Burnmouth-Lamberton Fault-zone is striking. The Innerwick Fault is reversed and it is known to have at as low an angle as 45° to the west (Wilson, 1952 ii). The area of Lower Carboniferous rocks to the east of the Innerwick Fault is analogous with the "foreland" at Berwick, and the stability of these areas must be attributed to the rigidity of the underlying Lower Palaeozoic rocks. The alignment of the tear-faults east of the Innerwick fault is similar to the fault system at Berwick, but, as might be expected from the position of the area in relation to the Southern Uplands ridge, sinistral movement of the associated tear-faults predominates.

PALAEONTOLOGY1) Fauna of the Cementstone Group in the Neighbourhood of Berwick.

		<u>Localities</u>
Annelida:-	Scolecodonts	1,2,3,19.
	Serpulid gen. et sp. nov.	13,14,15,18,19, 20,21,23.
	Spirorbis (Microconchus) pusillus Martin	} Common } throughout } the group.
	Spirorbis helicteres Salter	
Brachiopoda:-	?Rhynchonella (Pugnax) fawcettensis Garwood	22.
	?Lingula sp.	23.
	Lamellibranchia:-	
	Sanguinolites abdenensis Eth.	19.
	?Anthraconauta minima s.l. Ludwig	1,2,3,4,5,6,7, 8,9,11,16.
	Naiadites sp.	*
	Modiola sp.	2,17,16?
	Edmondia sp.	2,16?
	Modiola lata Portlock	22.
Gasteropoda:-	Hypergonia elongata Portlock	19.
	"Pleurotomaria" sp.	16.
	Murchisonia cf. verneuilliana de Kon.	2.
	Cephalopoda:-	
	Nautiloid	16*.
	"Orthoceras" sp.	16*,17,19 (two species)
Arthropoda:-	Paraparchites okeni (Münster)	11.
	Paraparchites scotoburdi- galensis (Hibbert)	11.
	Tribolbina gigantea (Jones, Kirby and Brady)	11.
	Cytherella sp.	11.
	Crangopsis eskdalensis (Peach)	6,11,15.
	Crangopsis elegans (Peach)	11.
	Teallicaris robusta (Peach)	11.

* See page 136.

Localities

	<i>Teallicaris tarrasiana</i>	
	(Peach)	11.
	<i>Anthracophausia dunsiana</i>	
	(Peach)	11.
	<i>Anthracophausia dunsiana</i>	
	var. <i>obesa</i> (Peach)	11.
	<i>Anthrapalaemon</i> sp.	11.
	? <i>Eurypterus stevensoni</i> Eth.	11.
	<i>Glyptoscorpius caledonicus</i>	
	Salter	16.
	<i>Eoscorpius</i> sp.	11.
	<i>Archidesmus</i> sp.	11.
	<i>Archiulus</i> sp.	11.
	<i>Eupoberia</i> sp.	11.
Fish:-	<i>Rhizodus hibberti</i> Ag. and	
	Hib.	4, 8, 11.
	<i>Strepsodus</i> sp.	11, 16.
	<i>Gyracanthus</i> sp.	11, 16.
	<i>Rhizodopsis</i> sp.	11.
	<i>Ctenodont</i> ribs	11.
	Palaeoniscid scales	11.
Foulden Burn Fauna:-	<i>Styracopterus ottadinicus</i>	
	White	4.
	<i>Carboveles ovensi</i> White	4.
	<i>Aetheretmon valenticum</i>	
	White	4.
	<i>A. valenticum</i> var. <i>ovensis</i>	
	White	4.
	<i>A. whitei</i> Moy-Thomas	4.
	<i>Aetheretmon</i> sp.	11.
	<i>Strepheoschema fouldenensis</i>	
	White	4.
	<i>Acanthodes ovensi</i> White	4.
	<i>Gyracanthus</i> sp.	4.
	<i>Callopristodus pectinatus</i> Ag.	4.
	<i>Strepsodus</i> cf. <i>sulcidens</i>	4.
	<i>S. striatulus</i>	4.
	<i>Styrocopterus ischipterus</i>	
	(Traquair)	17.

2) Flora of the Cementstone Group in the Neighbourhood of Berwick.

	<u>Localities</u>
Marchantites sp.	11, 24.
Aneimites sp.	10, 11.
Aneimites acadica Dawson	4.
Aleicomopteris convoluta Kidston	11, 16, 24.
Sphenopteris patentissima Ett. sp.	16.
S. elegans Brongt	11, 24.
Sphenopteris (Telangium) affine Lind. and Hutt.	4.
Aphlebia sp.	11, 24.
Lepidodendron spitsbergense Nath.	11, 26.
L. veltheimianum Sternb.	11, 24.
Lepidodendron sp.	4, 16.
Lepidostrobos sp.	11.
Cardiocarpus bicaudatus Kid.	11, 24.
Astero calamites scrobiculatus Sch. sp.	25.
Stigmara ficoides Sternb.	6, 11, 16, 24
S. ficoides var. undulata Gopp.	11, 16.
Ootheca globosa Kid.	4.
Carpolithus sp.	4.
Calymmatotheca kidstoni Calder	26.
Kalymma tuediana Calder	24, 25, 26.
Samaropsis scotica Calder	24, 26

The following species were obtained from rocks of the Cementstone Group in Berwickshire, but their localities are unknown (Kidston, 1923):-

Zygopteris kidstoni Bert.
 Rhetinangium cf. arberi Gordon.
 Stenomyelon tuedianum K. and G-V (= S. tripartitum Kid).
 Lyginorachis papilio Kid.
 Cladoxylon kidstoni Solms.
 Rachiopteris multifascicula Kid.
 Eristophyton (Calamopitys) beinertiana Gopp. sp.
 Pitys antiqua Witham.
 P. withami L. and H. sp.
 P. primoeva Witham.

List of Fossiliferous Localities.

1.	Catch-a-penny Burn, Burnmouth.	36/961606
2.	Ross Cliff, Burnmouth.	36/962606
3.	Burnmouth Shore.	36/960610
4.	Newton Farm, (Foulden Burn), Foulden.	36/939551
5.	Foul Dean Quarry, Foulden.	36/551939
6.	Raven's Knowe, Foulden.	36/944538
7.	Clarabad Mill, Paxton.	36/930545
8.	North bank of Whiteadder Water 300 yards east-north-east of Hutton Bridge.	36/923547
9.	Edington Mill, Chirnside.	36/894548
10.	Bluestones Ford, Chirnside.	36/876550
11.	Whiteadder Water, near Allanton. ⁺	36/864545
12.	Burn, near Paxton House.	36/924516
13.	Horncliffe House.	36/934505
14.	Tweed (north bank), near Fishwick Mains.	36/917497
15.	Tweed (right bank), one mile north-north- east of Norham Cross.	36/908486
16.	Lennel Braes, near Coldstream.	36/864426
17.	Tweed (right bank), below Coldstream Bridge.	36/852403
18.	Brownridge, Cornhill on Tweed.	36/865416
19.	Heaton Mill, (100 yards north of).	36/901424
20.	Stream north-east of Castle (Old) Heaton.	36/905421
21.	Brownridge ("Broomridge") Dean, Kimmerston.	36/970363
22.	Tweed, below Kelso Bridge. (M. MacGregor, 1938).	
23.	Tuparee Burn, Howtel.	36/899338
24.	Whiteadder, below Edrom Church.	36/827560
25.	Norham Bridge, Ladykirk.	36/889474
26.	Langton Burn, one mile south-west of Duns.	36/780520

+ Many specimens have been recorded from the "Whiteadder Water" with no specific locality, and these have been included under this locality number.

3) Notes on the Fauna of the Cementstone Group.

- A. Serpulid gen. et sp. nov. (Plate XVIII, figs. iv, v, vi;
(Plate XIX, figs. i, ii, iii, v, vi)

A tubicolar fossil which occurs in association with a marine fauna at a number of localities in north Northumberland, and in Berwickshire (see pages 36 - 39) has been assigned tentatively to the Order Tubicola of the Annelids. The first record of this fossil was made by Carruthers (1921) who recorded that Syringopora had been collected by Marsden at three localities (18, 20, 21) in the area to the north-east of the Cheviot Hills. In 1922 specimens were collected from a further locality (19) by Tait of the Scottish Survey, and these were also named Syringopora. Fowler (1926) described the occurrence of "a dwarfed form of Syringopora" from the banks of the Tweed near Norham Castle. Carruthers (1932) mentions only one locality (20) in "The Geology of the Cheviot Hills" at which "a true Syringopora..... of dwarfed habit" was recorded. The writer has obtained specimens of this fossil from a further three localities (13, 14, 17), and a similar Annelid, hitherto unrecorded, occurs at Burnmouth and is described on pages 131 - 132.

Diagnosis

More or less compact spreading colonies of narrow flexuous calcareous tubes. Tubes circular or sub-hexagonal showing great variation in size, average diameter 1 mm.

External walls show prominent transverse rugae and fine longitudinal striae. Tubes are "tabulate", the partitions being concave upwards, often oblique, perforate centrally, and widely spaced. In the nepionic stage the tube forms a single spiral coil cemented to a fully developed tube; no communication between the tubes has been observed at any point.

The Serpulid occurs typically as more or less compact colonies, which sometimes become confluent, and even massive; at other times the colonies are rare, and detached tubes are found scattered throughout the rock. Well developed colonies reach a height of 6 - 7 inches, with a maximum diameter of at least 12 inches.

The tubes are round in section, though where they are very closely packed they assume a sub-hexagonal form. A prominent feature is their variable size (0.1 - 1.25 mm. diameter), specimens with small diameter being common. The tubes increase in diameter rapidly in the early stages of growth and are parallel-sided thereafter. They show transverse growth wrinkles some of which project to form distinct cusps; in a few of the specimens very faint fine longitudinal striae are seen.

The tubes are chambered, each chamber being separated from the next by cross-partitions or "tabulae" which are

spaced 2 - 3 mm. apart throughout the tube. These partitions are invariably concave upwards, and are often oblique to the axis of the tube. In specimens which have broken immediately below the partition, as is often the case, a small indentation may be seen near its centre (Plate XVIII, fig.v; Plate XIX, fig.v).

Thin sections have revealed that the development of the walls and the partitions shows some variation; where the colonies are most compact these parts show their strongest development although in other respects the forms are similar. When best developed the walls are clearly defined, consisting of fibrous calcite bounded by a thin layer of grey material internally and a brown layer externally. There is a marked line of weakness along the centre-line of the wall along which it is frequently fractured. Where two tubes are in contact, the walls generally become fused, the combined thickness being equal to the thickness of a single wall.

The microscopic structure of the partitions is similar to that of the walls. Two partitions may occur close together and in some cases are seen to divide; they frequently occur at the same level in adjacent tubes. There is evidence that the partition is often perforated at the small central indentation, but it cannot be stated positively that this is invariably the case.

There is no form of communication between adjacent tubes.

In its nepionic stage the tube is in the form of a single spirorbiform coil cemented to an adult tube (Plate XIX, figs. v, vi). The initial growth is horizontal, then downwards and finally in an upward direction. In its neanic stage it increases rapidly in diameter and becomes detached from its "parent" tube. There is no evidence of any connection with the tube to which the serpulid in its nepionic stage is cemented. Numerous young individuals occur at the same level throughout a colony.

The identification of this fossil as Syringopora appears to have been based upon the concavity of the "tabulae". The characteristics of the walls, and "tabulae", and the mode of growth are strongly suggestive of the sub-class Tabulata of the Anthozoa, but other features such as the lack of septa and mural pores and, in particular, the method of reproduction must exclude this fossil from that class. On the other hand, the serpulid appearance of the individual tubes and the spirorbi-form coiling in the nepionic stage are strong indications of annelid affinities.

An Ordovician tubicolar annelid Cornulites flexuosus (Hall) possesses concave "septa", while a Silurian member of the same family, Cornulites bellistriatus Hall shows fine longitudinal striae, and another Ortonia minor Nich. shows coiling in the nepionic stage. Other cases of chambered tubicolar annelids are Serpula melitensis described by

Daudin and "segmented" examples of Spirorbis (Microconchus) helicteres Salter, noted by Young (1878) in the Cementstone group of Ayrshire. Of the living serpulids two genera (Pomatoceras and Mercierella) are known to be capable of producing a calcareous partition posterior to the body when the tube is damaged, but none normally produce a chambered tube. The partitions appear to have been formed by secretion of lime posterior to the body of the worm. The occurrence of many partitions at the same level indicates that upward movement, initiated by one individual, resulted in similar movement by neighbouring individuals. The perforation of the partition in this fossil species is apparently unique.

The fossil has been collected by the author from the following localities:- 13, 14, 15, 17, 19 and 20. Carruthers (1921) recorded "Syringopora" at two further localities, 18 and 21, but he did not mention these in the Memoir (1932), and the writer was not able to find the fossil at either of these points. All these localities, with the exception of numbers 17 and 18, lie in the upper part of the Cementstone Group, about 1000 feet below the base of the Fell Sandstones, and it seems probable that they are restricted to a single horizon. A similar form has been collected from the Calciferosus Sandstone Group in Dumfriesshire (Plate XIX, fig. iv).

B. Serpulid gen. et sp. nov. (Plate XVIII, figs. i, ii, iii)

A tubicolar annelid occurs in profusion in three cementstone ribs which lie near the middle of the Cementstone succession at Burnmouth (see page 31). In spite of its prominence this fossil has remained unrecorded and Spirorbis is the only annelid to be noted at this locality.

The best examples have been obtained from two horizons below the "shelly limestone". They do not differ sufficiently from the Norham and Heaton specimens to merit a full description, but certain differences may be noted.

At the higher horizon (CM356) the tubes are generally short, small in diameter (less than 1 mm), flexuous, with a tendency to form closely entwined colonies, but it is doubtful whether these are now in the position of growth. The walls are almost free of tranverse rugae, and are of moderate thickness. Well developed "tabulae" are common though widely-spaced and may be straight or concave. This fossil shows a closer resemblance to the Heaton form (locs. 19, 20), than to that found at Norham (locs. 14, 15).

The lower horizon (CM340) occurs 47 feet below that described above. The tubes are long, around 1.25 mm. in diameter and covered in tranverse rugae which often form strong cusps. There is no indication of a colonial habit and the tubes all lie in the vertical plane (Plate XVIII, fig. iii). The walls are thin, and "tabulae", which are rare,

poorly developed; it is probable that only a small proportion of the tubes are tabulate. This form closely resembles Serpula advena, Salter, in external appearance, and is thus similar to S.cf.advena noted by Garwood (1931) at several horizons in the Liddesdale district.

The method of reproduction is obscure in both of the Burnmouth forms, but their association with small spirorbiform tubes indicates that it may be similar to that seen in the Heaton specimens. Both horizons at Burnmouth are characterised by the presence of numerous very small tubes, of about 0.25 mm. diameter (Plate XVIII, fig.1); the wall structure of these tubes is identical to that of the larger ones to which they are often cemented. They show little variation in diameter although they appear to grow to at least one inch in length; this fact, and the fact that intermediate diameters are rare, indicate that the smaller form is a distinct genus, living in association with the larger Serpulid.

The remains of tubicolar Annelids occur in several other Cementstone ribs at Burnmouth, and elsewhere, but the state of preservation is such that few features can be described.

C. ?Rhynchonella (Pugnax) fawcettensis Garwood, was recorded from shales near the base of the Cementstone Group at Kelso (M. Macgregor, 1938). "Shells resembling Lingula" were

recorded from the Cementstones of the Howtel outlier (Carruthers, 1932). The writer has searched in vain for further specimens at these localities and elsewhere. The record of the occurrence of Pustula spinulosa (J. Sow) from Lennel Braes (loc. 16) (Ivor Thomas, 1914) is apparently an error, as neither the specimen quoted, nor any other material from that locality contains any brachiopod.

D. ?Anthraconauta minima s.l. (Hind) (Plates XX, XXI)

Geikie (1865) recorded Anthracomya at two localities, the Burnmouth "shelly limestone" and at Raven's Knowe on the Whiteadder Water (loc. 6). Specimens collected by Macconchie from near Cairn's Mill, Duns, were described and figured by Hind (1894-96) as paratypes of Anthracomya minima; these were larger than the holotype, an Upper Carboniferous form. Dewar (1939) in his revision of certain species of Anthraconauta from the Coal Measures, examined the Cairn's Mill specimens and expressed the opinion that they belong to the Modiola transversa - Modiola lata group. The writer, while acknowledging that there is a strong similarity to the modiolids, prefers to retain the name Anthraconauta in the absence of a modern comprehensive work covering these forms.

The writer has found impressions of small lamellibranchs at numerous localities in rocks of the lower part of the Cementstone Group but in most cases the state of preservation

was such that description was impossible. At three localities however (5, 7 and 8) in the parish of Foulden, lamellibranchs were found in large numbers in sandy shales associated with Spirorbis, entomostraca, and fish remains; two of these localities lie at the same horizon.

An examination of these poorly preserved lamellibranchs showed that there was considerable variation in form, size, and ornament. A study of this variation has shown that the community consists of at least four distinct form-groups (Plate XXI, fig.iii). The same forms occur at each horizon, but at the upper horizon there is variation in their relative abundance at each locality.

Variant B: L.11, H.64, T.?, $\alpha = 33^\circ$ $\beta^* = 128^\circ$
(Plate XX, fig.i)

This form is clearly distinguished by its great depth and oblong shape; the angle between the carina and the hinge-line (α) is greater and that between the extension of the ventral margin and the hinge-line, less than in the other variants: the valve is higher in relation to its length.

Variant C: L.7, H.54, T.? $\alpha = 26^\circ$ $\beta = 150^\circ$
(Plate XX, fig.iii)

The characteristic features of this group are:- small size, length less than 12 mm., large angle between ventral margin and line of hinge; irregular often wrinkled line of growth.

* β :- angle between hinge-line and postero-dorsal margin.

The anterior part of the valve is shallow and may be more or less developed showing variation within the group.

Variant D: L.17, H.59, T.?, $\alpha = 28^\circ$ $\beta = 149^\circ$
(Plate XXI, fig.1)

Some of the lamellibranchs are characterised by a fine regular ornament of lines of growth, distinct from the irregular type seen in Variants B and C. The majority of these form a distinct morphological group midway in shape between those groups, and are generally larger in size. A few, however, which show this ornamentation fall well outside this group. This form is the most abundant at locality 8.

Variant E: L.15, H.40, T.?, $\alpha = 20^\circ$ $\beta = 147^\circ$
(Plate XXI, fig.ii)

One specimen has been obtained from each horizon of an elongate form in which the ventral margin is almost parallel to the line of the hinge, and in which the height is small in relation to the length. The ornament is similar to that of the B and C Variants.

The Cairn's Mill specimens show little variation and are similar to variant C in form, although the largest specimens have a greater length and in no case is development seen in the anterior part of the valve. Variant C shows no features which are diagnostic of either Modiola or Anthraconauta in the opinion of the writer. Variant B closely resembles the

Anthracomya subparallela (Portlock), figured by Hind (Plate XXI 1-2). Variant D resembles Modiola lata Portlock, in form but not in ornament which more resembles Lithodomus carbonarius Hind. Variant E is similar to L. carbonarius in shape but differs in its ornamentation.

E. Naiadites has been recorded by several authors (e.g. Carruthers, 1921) but in no case was the locality mentioned; it is probably the same form as that described here as ?Anthraconauta minima (Hind).

Modiola sp. occurs with "Orthoceras" near Coldstream (loc. 17) and probably in the "shelly limestone" at Burnmouth, but in neither case is specific identification possible.

F. Most of the Arthropoda, Fish and Flora listed here were collected by Macconochie and Tait of the Scottish Geological Survey and were identified by Peach, Etheridge, Traquair, Kidston and others. The Foulden Fish Fauna (see page 8) was described by White (1927) and Moy-Thomas (1938).

4) Fauna of the Scremerston Coal Group.

Fossils have been obtained by the writer only from the highest parts of the group. Doubtful records list a marine fauna at the Cooper Eye horizon including Schizodus

pentlandicus Rhind; Lingula sp., and crinoid debris have been recorded (see page 61). A new gastropod genus, Bernicia praecursor, occurs in the freshwater limestone above the Blackhill (Main) coal (Cox, 1927). Lepidodiscus fistulosus sp. nov. has been described from this group at Hetton House, south of Lowick, but the horizon was not recorded (Anderson, 1939).

The Lamberton Marine Band.

The Lamberton Marine Band is exposed at three points to the north of Berwick; Hilton Bay, Lamberton cliff and Marshall Meadows Bay, but at only the latter locality are identifiable fossils obtainable. The fauna is characterised by the presence of small productids, pectinids and orthocerates; no rugose corals have been obtained.

- * +Alveolites sp.
- * Lingula squamiformis Phillips
- * +Lingula cf. mytiloides Sowerby
- * +Orbiculoidea nitida (Phillips)
- * +Pustula punctata (Martin)
- * +Buxtonia cf. scabricula (Martin)
- * +Productus redesdalensis Muir-Wood
- * Orthotetes sp.
- * +Punctospirifer scabricosta North
- * +Edmondia sulcata Phillips
- * +Sanguinolites plicatus Portlock
- * +Sanguinolites tricostatus Portlock
- * Sanguinolites striato-granulatus Hind
- * +Pinna mutica M'Coy
- * Nucula undulata Phillips
- * +Nuculana attenuata Flemming
- * +Schizodus axiniformis Phillips
- * Pterinopecten (Limiopecten) meleagrinooides
(M'Coy)
- * Aviculopecten plicatus Sowerby
- * Euchondria cf. levicula Newell

Streblochondria sp.
 Zygopleura (Loxonema) cf. robroystonensis
 Longstaff
 ? Naticopsis sp.
 Foordella cf. tereticincta Longstaff
 ? Girtispira sp.
 +Euphemites urei (Flemming)
 *+"Orthoceras" sp.
 A goniatite
 Bairdiids
 Ammodiscus sp.
 *+Fenestrellina sp.
 Crinoid ossicles
 Teeth and scales of fish

+ Forms which have been recorded from the Lower Cove Marine Band (Wilson, 1952 i).

* Forms which have been recorded from the Redesdale Ironstone Shale (Smith, 1910).

The Duddo Limestone.

Fossils have been obtained from shales associated with the Duddo Limestone at two localities, Mattilees Quarry and Duddo Mill Burn.

*+Alveolites sp.....	1B, 2A.
*+Lingula sp.....	1B.
*+Pustula punctata (Martin).....	1AB.
*+Productus cf. redesdalensis Muir-Wood.....	1B, 2A.
Gigantoproductus sp.....	2.
*+Productus undatus de France.....	1B, 2A.
+Composita sp.....	1A.
* "Orthotetes" sp.....	1A, 2A.
*+Punctospirifer scabricosta North....	1AB, 2A.
* Edmondia arcuata Phillips.....	1B.
*+Pinna mutica M'Coy.....	1B.
*+Nuculana attenuata Phillips.....	1A.
* Pterinopecten cf. granosus (Sowerby).....	1B, 2A.

*+Aviculopecten cf. semicostatus		
Portlock.....		2A.
? Girtispira sp.....	1B.	
Aclisina cf. faber Donald.....		2A.
*+"Orthoceras" sp.....	1B, 2A.	
Lithostrotion sp.....	1A, 2B.	
*+Fenestrellina sp.....	1AB, 2A.	
Other Bryozoa.....	1AB, 2A.	
Crinoid ossicles.....	1, 2.	
Bairdiids.....	1, 2.	
Ammodiscids.....	1.	

The numbers 1 and 2 refer to Mattlees Quarry and Duddo Mill Burn respectively;

The letter A or B after a locality number indicates that the fossil was obtained from the shale above or below the main limestone respectively.

+ Forms which have been recorded from the Lower Cove Marine Band (Wilson, 1952).

* Forms which have been recorded from the Redesdale Ironstone Shale (Smith, 1910).

5) Notes on the Fauna of the Scremerston Coal Group.

A. Pustula punctata (Martin) (Plate XXII, fig.11)

Several incomplete specimens of the genus Pustula Thomas, have been obtained from both the Lamberton Marine Band and the Duddo Limestone (locality 1). In general they conform closely to the description (Thomas, 1914) of Pustula punctata (Martin). The cardinal process in one specimen is well preserved and differs sufficiently from that figured by

Davidson (1858-63, pl. XLIV fig. 16) to merit description.

The cardinal process is bifid anteriorly; from the two processes lobes diverge postero-dorsally at an angle of 30° making an angle of 30° with the plane of the valve. The hollow between the ventral processes deepens posteriorly forming a deep sulcus between the lobes; the deepest part of the sulcus is 0.5 mm. posterior of the two processes, only one-fifth of the total length of the cardinal process. The depth of the sulcus then decreases posteriorly and forms a slight groove in the centre of a thin tongue-shaped lobe at the end of the process. On each side of the central process are lobes which are direct extensions of the ventral processes and which extend onto the dorsal surface.

B. Buxtonia cf. scabricula (Martin) (Plate XXII, fig.i).

This form found in the Lamberton Marine Band shows close similarity to that obtained by Wilson (1952) from the Lower Cove Marine Band. It resembles Buxtonia sp. (Muir-Wood, 1928) in its ornamentation, but has a shorter and shallower groove in the median septum and a longer hinge-line in relation to the width of the brachial valve.

	A	B
Length of hinge.....	34	37
Width of brachial valve.....	?37	45
Width of pedicle valve.....	--	50
Length (approximate) of brachial valve...	?26	40
Length of median septum.....	15	--
Length of groove in median septum..	3.5	--
Length of adductor impression.....	6.5	--
Width of adductor impression.....	3	--

C. Productus redesdalensis Muir-Wood

Wilson (1952 i) noted great diversity in the morphology of the specimens of Productus redesdalensis, which were obtained from the Lower Cove Marine Band at Thornton Mill. This brachiopod is the predominant species at Lamberton, as at Thornton Mill, and is also common at the horizon of the Duddo Limestone (locs. 1 and 2). The variation exhibited by this species makes it impossible to give a precise diagnosis.

Externally, the specimens obtained by the writer closely resemble those figures by Muir-Wood (1928). The venter is generally flat, as in the holotype, but there is a slight sinus on the trail of some examples. Ribs are well-developed laterally but are seldom discernible across the trail.

Internally, the variation is more marked. The cardinal process is bifid ventrally and can be seen to be trifid dorsally in a few specimens, as described by Wilson (loc. cit.). In the majority of cases the marginal ridges are well-developed and there is considerable variation in the angle at which these converge on the median line of the valve (65° - 90°).

The median septum is generally strong and convex at the base of the cardinal process, although a distinct median sulcus is sometimes seen at this point. It is thin and elevated between the muscle scars and becomes slightly inflated towards the anterior of the valve. The median septum extends almost to the diaphragm a feature which is also noted in a

specimen figured by Wilson (1952 i; fig.2d); in the holotype the septum is stated to be about half the length of the visceral disc.

The adductor muscle-scars are never sufficiently well preserved to enable the finer pattern to be observed, but the major features are constant and differ from those described by Wilson. The two main anterior processes are situated adjacent to the median septum but separated from it by a deep sulcus; the sulci are bordered laterally by ridges which extend posteriorly for 2mm. to fuse into the root of the cardinal process. Posteriorly, two low ridges diverge from each side of the root of the cardinal process and unite to form an elongate process which lies postero-laterally to the main anterior processes. The main processes and ridges lie upon a platform which extends back to meet the marginal ridge. The brachial ridges have not been seen.

D. Lithostrotion sp. (Plate XXIII, fig.1)

Rugose corals have not been obtained from either the Lower Cove Marine Band or the Lamberton Marine Band and only one specimen had been obtained from the Redesdale Ironstone Shale when its fauna was described by Smith (1910); this was identified as *Dibunophyllum* near θ , showing variation towards ϕ .

A fasciculate rugose coral occurs in profusion in

association with forms typical of the Lamberton fauna in the shales adjacent to the Duddo Limestone. At Duddo Mill Burn it is the only fossil which has been obtained from the calcareous black shale beneath the limestone. At Mattilees it is found only in the shale above the main limestone.

Diagnosis.

Small, fasciculate, tubular, Rugose coral; maximum diameter 6mm. - 9mm.; 27 major septa, 27 short minor septa, both extending to the epitheca; cardinal septum short; dissepimentarium narrow, with dissepiments inclined downwards centrally; tabulae conical, sloping steeply from central flattened columella; counter, and one cardinal-lateral septum reach columella in nepionic stage; at later stage counter-laterals and alar septa reach columella.

This species probably belongs to the species-group of the Lithostrotiontidae which includes such forms as L. irregulare, L. martini and L. scotica, which are representative of beds of S₂D₁ and D₁ age in marine Avonian to the south.

6) Flora of the Scremerston Coal Group.

Despite the abundance of plant remains which occur in the rocks of this group and which must have been available as a result of boring and mining activity, the only recorded forms were obtained from the shales associated with the

Lamberton Marine Band at Marshall Meadows. Tate (1856) noted the occurrence of Sphenopteris affine, "which he first saw at Lammerton" (i.e. Marshall Meadows), at the south side of Cove harbour; although Tate was unaware of it, the beds are of the same age. Plants collected by Macconochie and identified by Kidston (1900-01) from this locality include:-

- Sphenopteris (Diplochmema) schutzei Stur.
- *Cardiopteris polymorpha var. rotundifolia Göpp sp.
- *Astero calamites scrobiculatus Schl. sp.
- Pinnularia sp.
- *Lepidostrobus
- Lepidodendron veltheimianum Sternb.
- Stigmaria ficoides Sternb. sp.

* Also obtained at Cove Harbour from uppermost Scremerston Group.

7) Significance of the Fauna of the Scremerston Coal Group.

The faunal association at Duddo closely resembles that of the Lamberton Marine Band, and contains many of the typical D₁ species which characterise the horizon of the Lower Cove Marine Band and the Redesdale Ironstone Shale. The occurrence of Lithostrotion sp. at this point in the succession is of particular interest; Lithostrotion irregulare has been recorded from the Stocking Burn Limestone at Alnwick (Carruthers 1930), from which the writer has also obtained Productus cf. redesdalensis. From the faunal evidence, therefore, it seems probable that the Lower Cove Marine Band, the Lamberton Marine Band, the Duddo Limestone,

the Stocking Burn Limestone and the Redesdale Ironstone Shale represent a single marine horizon. The ironstone shale facies prevails in the extreme north and south, while at Duddo and in the Alnwick district it is replaced by a calcareous facies which excluded many of the fossils found in the ironstone shale, but which supported the growth of corals.

8) The Fauna of the Lower Limestone Group.

a) The Dun Limestone and Shale.

+Lithostrotion junceum (Flemming)
 Lithostrotion cf. clavatum Thomson
 *Lithostrotion irregulare (Phillips)
 *Lithostrotion m'coyanum Edwards and Haime
 A zaphrentid
 +Gigantoproductus sp.
 Productus (Thomasia) margaritaceus Phillips
 Chonetes hardrensis Phillips
 Productus (Linoproductus) corrugatus M'Coy
 Euphemites cf. urei (Flemming)
 Aviculopecten sp.
 Girvanella
 Fenestrellina sp.
 Entomostraca
 Ammodiscids

* Forms mentioned by Stanley Smith (1910).

+ Forms which are known to occur in the Upper Cove Marine Band (Wilson, 1952 i).

Lithostrotion junceum and Gigantoproductus are the

most distinctive fossils found at this horizon. These two forms are also found in the Upper Cove Marine Band, thus supporting its proposed correlation with the Dun Limestone.

The occurrence of Girvanella at this horizon is believed to be confined to the Berwick district.

Gigantoproductus sp.

Height.....	? 60 mm.
Thickness.....	40 mm.
Width of pedicle valve.....	116 mm.
Length of hinge-line.....	116 mm.
Number of costae in breadth of 10 mm. at distances vertically below umbo.....	at 10 mm....13 at 25 mm....11 at 45 mm....13

A latissimoid form. Slight sulcus on median line of pedicle valve; postero-lateral slopes slightly concave. Indistinct ribs on ears and flanks of pedicle valve; costae fine, flexuous; a few scattered spine-bases on trail. Brachial valve and internal features unknown.

Productus (Linoproductus) corrugatus M'Coy

Height.....	35 mm.
Thickness.....	24 mm.
Width of pedicle valve.....	39 mm.
Length of hinge-line.....	32 mm.
Number of costae in breadth of 10 mm. at distances vertically below the umbo...at	15 mm....19 at 25 mm....17
Umbonal angle.....	105°

Quadrate shell. Pedical valve geniculated, with slightly convex trail; Slight sinus on visceral disc and venter; flanks steep; ears small; ribs developed on ears and flanks, discernable on visceral disc; fine costae, increasing by intercalations; broad folds on flanks and venter below visceral disc, each surmounted by a large spine-base. Brachial valve and internal features unknown.

Lithostrotion cf. clavatum Thomson

Massive, with 22 to 26 major septa; flattened columella sometimes present, supported by a variable number of septa; diameter of corallite 4 mm. to 5 mm.; closely packed convex tabulae; tabularium 3 mm. in diameter; two to three rows of dissepiments steeply inclined inwards.

It is probable that this form is the L. m'coyanum recorded by Smith. This form is a member of the group of massive Lithostrotiontidae, (including such forms as L. portlocki ss. and L. minus), which are characteristic of D₁ marine limestones.

b) The Woodend Limestone and Shale.

Dibunophyllum sp.
 Lithostrotion junceum (Flemming)
 Lithostrotion cf. martini Edwards and Haime
 Lithostrotion cf. portlocki (Bronn.)
 Zaphrentis sp.
 Syringopora sp.
 Favosites sp.

Gigantoproductus sp.
 Productus (Eomarginifera) cf. longispinus (J. Sow.)
 A semireticulate productid.
 Pustula cf. plicatilis (J. de C. Sow.)
 Seminula ambigua (J. Sowerby)
 Composita sp.
 Spirifer sp.
 Punctospirifer sp.
 Streptorhynchus radialis Phillips
 Orbiculoidea nitida (Phillips)
 Actinopteria persulcata M'Coy
 Streblochondria sp.
 Lithodomus lingualis (Phillips)
 Edmondia sp.
 "Orthoceras" sp.
 Bellerophon sp.
 Dentalium sp.
 Euomphalus pentangulatus Sow.
 Loxonematids
 Ammodiscids
 Entomostraca
 Archaeocidaris urei (Flemming)
 Griffithides sp.

The Sandybeds Limestone.

Lithostrotion junceum (Flemming)
 Lithostrotion cf. martini Edwards and Haime
 Syringopora sp.
 ?Chaetetes sp.
 Gigantoproductus sp.
 "Spiriferina" sp.

Three species of Lithostrotion occur in the Woodend Limestone at Hud's Head, and two of these are also found in the Sandybeds Limestone. L. junceum and the massive L. portlocki are similar to the species of Lithostrotion found in the Dun Limestone. A large diameter fasciculate form L. martini is first seen at the Woodend horizon in the

Berwick area. Gigantoproductus is common in the limestone, and P. longispinus and a finely costate semireticulate productid are abundant in the overlying shale.

Lithostrotion cf. martini Edwards and Haime

Large diameter fasciculate Lithostrotion; 6 mm - 8 mm. diameter; flattened plate-like columella supported by cardinal and counter-cardinal septa and a greater or lesser number of the 26 major septa; tabulae slightly convex and flattened centrally; 1 to 3 rows of dissepiments inclined downwards centrally.

Productus (Eomarginifera) cf. longispinus (J. Sowerby)

Height.....	+8 mm.
Width.....	14 mm.
Thickness.....	9 mm.
Length of hinge.....	14 mm.

Number of costae in breadth of
10 mm. at distances
vertically below the umbo.... at 5 mm....24
at 10 mm....23

Umbonal angle..... 105°

Sub-quadrate shell; maximum width along hinge; pedicle valve geniculated, with convex visceral disc; flanks steep, venter slightly convex, prominent ears; six major spines, no minor spines; costae fine inconspicuous, faint ribs on

visceral disc.

This form shows close similarity to P. longispinus, but has a rounder outline, similar to that of P. praecursor, and coarser costation. P. longispinus is recorded from the Yoredalian (Muir-Wood, 1928).

CONCLUSIONS

A geological survey has been made of the Upper Palaeozoic rocks of the Berwick district, and the stratigraphy, tectonics and palaeontology of the area are described. The following significant points have been noted.

1. A series of andesitic lavas and agglomerates occurs on the southern flank of Lamberton Moor; they closely resemble the volcanic rocks of the Eyemouth and Ayton district and they are therefore believed to be of Lower Old Red Sandstone age.
2. The lowest sandstones on the downthrown side of the Burnmouth Fault are of Upper Old Red Sandstone facies and of probable Upper Old Red Sandstone age. The thickness of the Cementstone Group at Burnmouth is therefore 1600 feet, compared with over 3500 feet in the Tweed Valley.
3. The rocks of the Cementstone Group were deposited in a rapidly subsiding basin between the Southern Uplands and Cheviot axes; the marine conditions which prevailed in the Cumberland area in Z₂ to C₂ times do not appear to have extended to the north of the Cheviot axis.

4. The Fell Sandstone overlies the Cementstone Group with marked disconformity at Burnmouth, but to the south of the Tweed the lower members of the sandstone group are intercalated with sediments of Cementstone facies.

5. A marine band at Lamberton in the upper part of the Scremerston Coal Group is correlated with the Lower Cove Marine Band and the Redesdale Ironstone Shale; the Duddo Limestone and the Stocking Burn Limestone at Alwick may also represent the same horizon.

6. In the Lower Limestone Group, the Dun Limestone is correlated with the Upper Cove Marine Band and the Redesdale Limestone. The Woodend Limestone is not represented at Cove or Hilton Bay and it is probable that it was not deposited across the Southern Uplands axis; in south Northumberland it is represented by the Fournalaws Limestone. The significance of the unconformity beneath the Red Shin Sandstone has been overestimated. The Watchlaw Limestone of the Ford district is represented by the Red Shin Marine Band. Another marine horizon, a discontinuous limestone, has been found above the Red Shin Sandstone.

7. The significance of rhythmic sedimentation in the Middle

Limestone Group for purposes of short-distance correlation is emphasised; e.g. the Budle Limestone is correlated with the 2nd. Limestone at Berwick (fig. 9).

8. The structure of the Berwick district is influenced by the presence of the stable block formed by the Lower Palaeozoic rocks of Lamberton Moor. Reversed faults at Burnmouth and Lamberton were initiated by approximately east-west compressive forces which had already given rise to the Scremerston Anticline; stress was relieved by north-east to south-west dextral tear-faults, and east-west normal faults downthrowing to the south.

9. The principal features of the geology of the Berwick district are related to the position of the area between the Southern Uplands and Cheviot axes.

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Figure 11.

A diagram showing the relationship of the Burnmouth-Lamberton fault-system to the normal and transcurrent faults in the Berwick district. It is clear that the compressional forces which initiated the Burnmouth-Lamberton Faults and the Scremerston Anticline acted in an approximately east-west ($082^{\circ} - 262^{\circ}$) direction; the north-east to south-west dextral transcurrent faults of the Foulden area resulted from the relief of stress on the southern flank of the rigid Lower Palaeozoic outlier of Lamberton Moor.

A :- faults to the south-west of the Scremerston Anticline, with the exception of,

B :- the Ancroft-Berrington Faults.

Fig. 11.

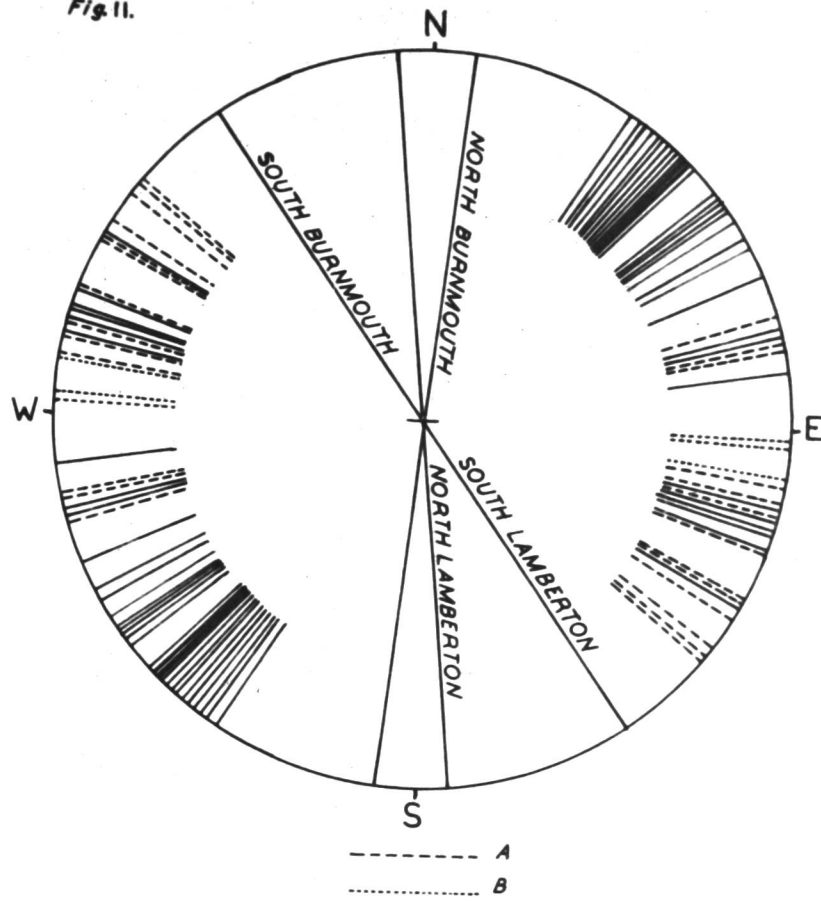


Figure 12.

Depositional areas in Fell Sandstone times, showing the spread of the Fell Sandstone delta across the north-eastern extension of the Southern Uplands axis and into the Tweed Basin. Variable rates of subsidence persisted throughout the area until D₂ times. (See also fig. 4A).

Fig. 12.

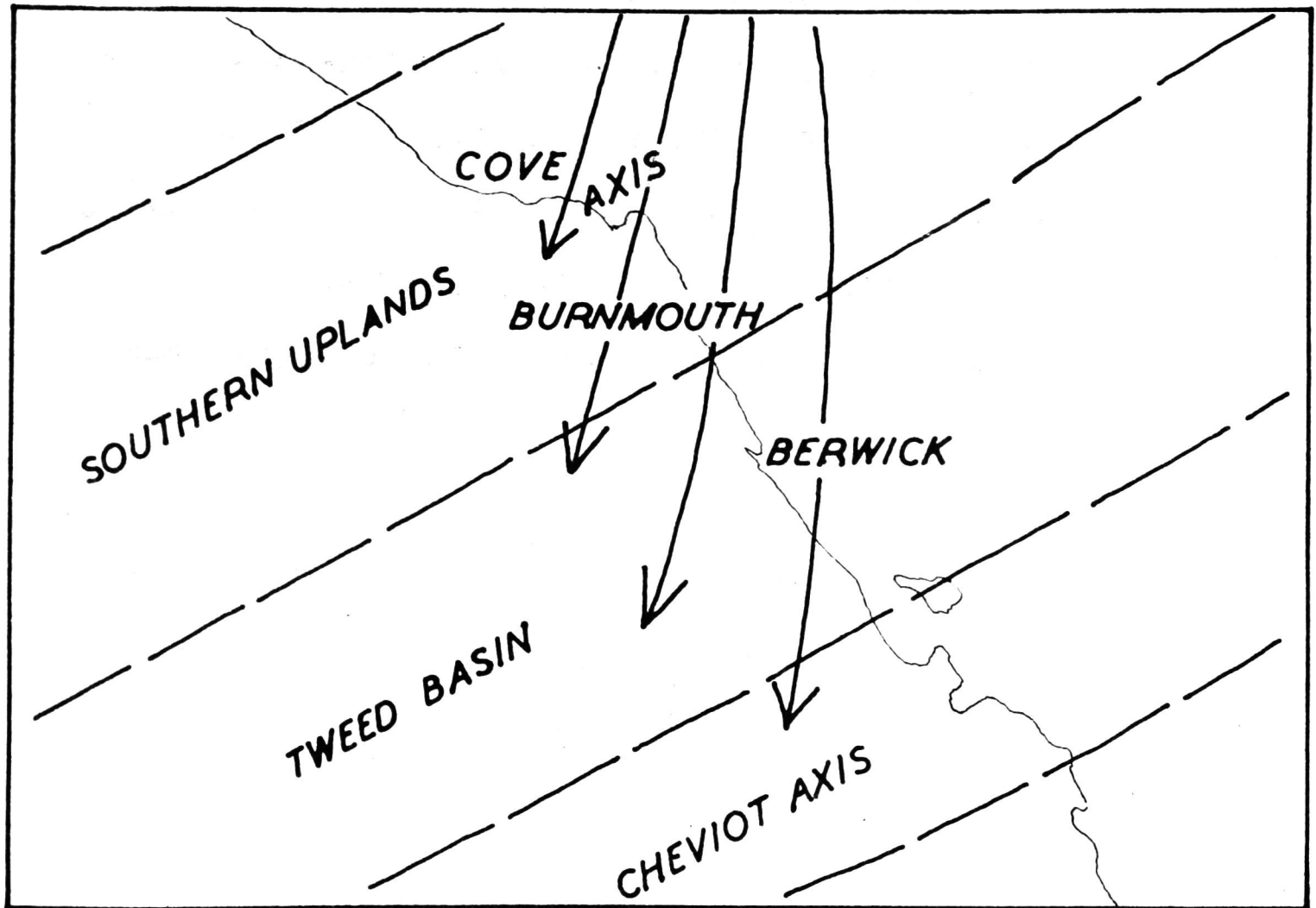


PLATE I.

Fig. i. The Merse of Berwickshire; a view from Foulden over the flat drift-covered area of the outcrop of the Cementstone Group which extends as far as the Cheviot Hills, 15 miles to the south.

Fig. ii. The Coast of Berwickshire; seen from Burnmouth. Silurian greywacke lies to the west of the Burnmouth Fault, against which the Fell Sandstone (first headland) and the sandstones of the Lower Limestone Group (second headland) are inverted; the cliffs in the background are formed of horizontal rocks of the Lower Limestone and Scremerston Coal Group.



PLATE II.

Upper Old Red Sandstone.

Fig. i. Chester Hill. An outlier of marginal breccia-conglomerate of Upper Old Red Sandstone age, lying upon Silurian rocks at a height of 400-560 ft. O.D.

Fig. ii. Bedded, but unsorted, marginal breccia-conglomerate dipping to the west at Hilton Bay, adjacent to the Burnmouth Fault.



PLATE III.

Burnmouth.

Fig. i. The position of the north Burnmouth Fault at Partanhall; the basal sandstones (Upper Old Red) are succeeded by argillaceous beds of Cementstone facies. A quartz-dolerite dyke cuts the fault to the north.

Fig. ii. A lens of cementstone-conglomerate containing locally derived angular fragments of mudstone, cementstone and sandstone, in vertical strata.

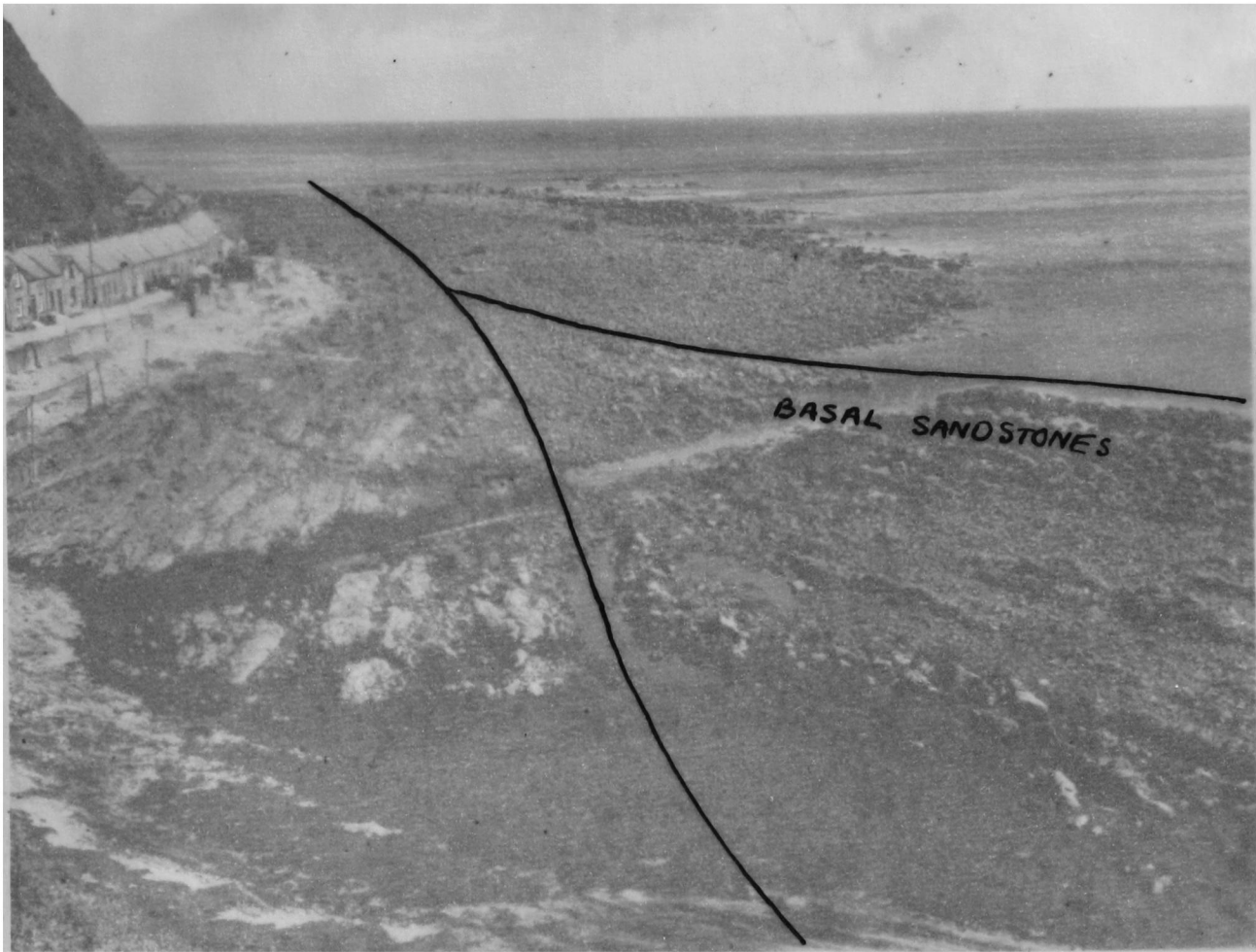


PLATE IV.

Fig. i. Part of the platform of marine erosion at Burnmouth, upon which the rocks of the Cementstone Group are exposed, showing wedge-bedding of the non-marine sediments.

Fig. ii. A diagrammatic representation of the section exposed at Horncliffe Mill, which shows evidence of pene-contemporaneous erosion of fully consolidated cementstones, before the deposition of the overlying sandstone; there is no basal conglomerate, or angular unconformity.

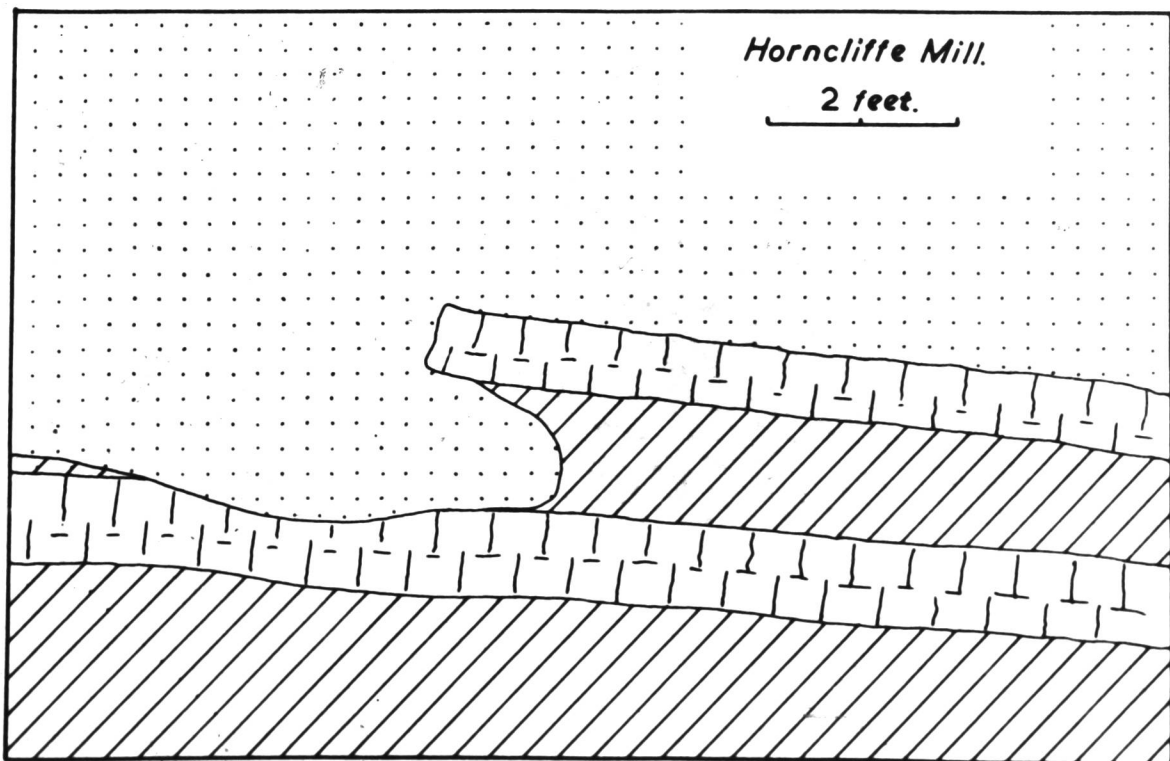


PLATE V.

The Fell Sandstone.

- Fig. i. Ross Point, near Burnmouth. The current-bedded Fell Sandstone (right) lying with slight unconformity upon the shales and marls of the uppermost beds of the Cementstone Group.
- Fig. ii. Heathery Carrs (foreground) and Ross Point. The sandstones of the Fell Sandstone Group, the base of which lies at the foot of the Maiden's Stone stack at Ross Point, thicken northwards.



PLATE VI.

Scremerston Coal Group.

Fig. i. Large scale false-bedding in sandstones of the upper part of the Scremerston Coal Group. These are close to the horizon of the Lamberton Marine Band, which has not been found at this locality. The Dun Limestone is visible in the cliff at Hud's Head.

Fig. ii. Lamberton cliffs from the north, showing the inversion of the strata adjacent to the fault, and part of the Scremerston Coal Group below the Dun Limestone.

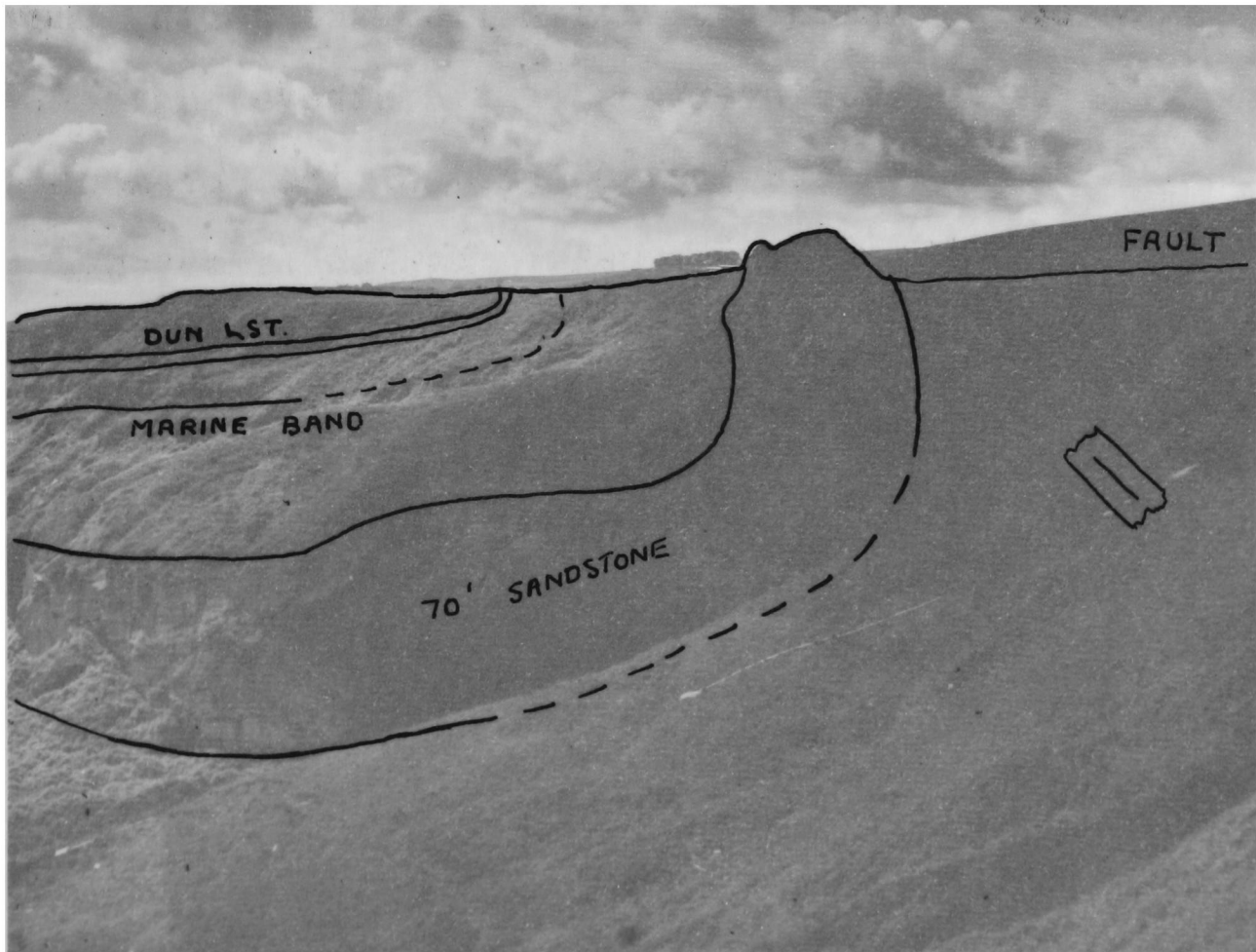


PLATE VII.

The north Lamberton Fault, Hilton Bay.

Fig. i. The sheared lower surface of the lowest sandstone adjacent to the fault on south side of the Bay.

Fig. ii. The same sandstone, viewed from the north, showing the probable hade of the fault in the south headland. The Dun Limestone outcrops midway between the fault and the first inverted sandstone; close to the fault there are large blocks of another marine limestone whose origin is obscure.



PLATE VIII.

Hilton Bay.

Fig. i. A general view of Hilton Bay from the south, on the line of the north Lamberton Fault, showing inverted Fell Sandstone in the north headland, apparently succeeded by the upper beds of the Scremerston Coal Group.

Fig. ii. Shattered, lensing, massive sandstones of the lower part of the Fell Sandstone, on which vertically slickensided surfaces hade steeply to the east; sandstones and shales of cementstone facies are faulted against marginal conglomerates of the Upper Old Red Sandstone.

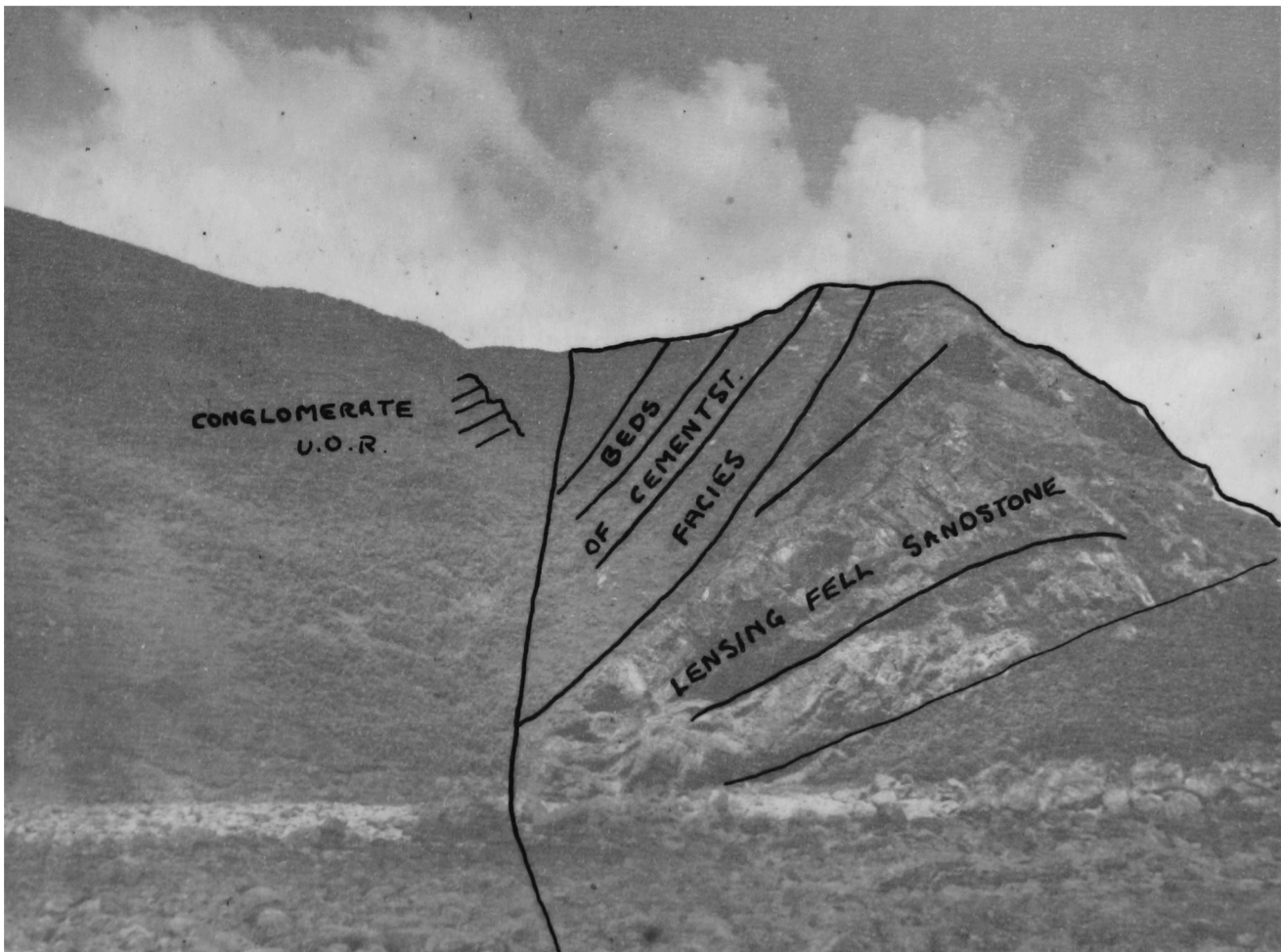
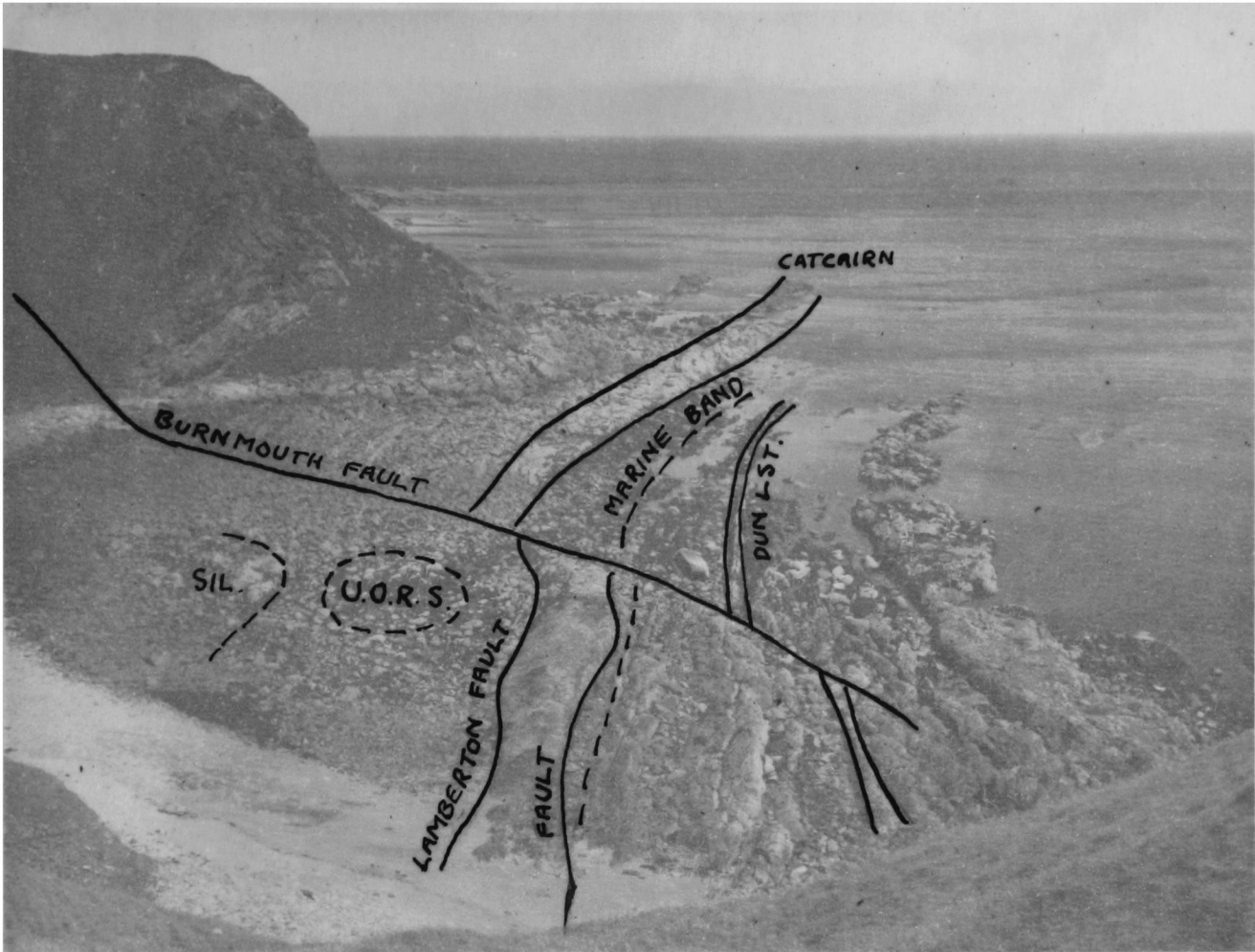


PLATE IX.

The Lower Limestone Group.

Fig. i. The succession between Hud's Head (left) and Red Shin Cove; the Red Shin Marine Band (? Watchlaw Limestone) lies above the local unconformity and is succeeded by shales which are followed in turn by the Red Shin Sandstone. The previously unrecorded Red Shin Limestone can be seen above the sandstone (extreme right).

Fig. ii. The succession between Maidenkirk Brae and Seahouse; The Red Shin Sandstone and Limestone can be seen beyond Red Shin Point and are exposed again to the south of the sinistral tear-fault. Slickensides can be seen on the truncated Maidenkirk Sandstone.

The Lower Limestone Group is exposed at Calot Shad, Berwick, which is visible in the background.

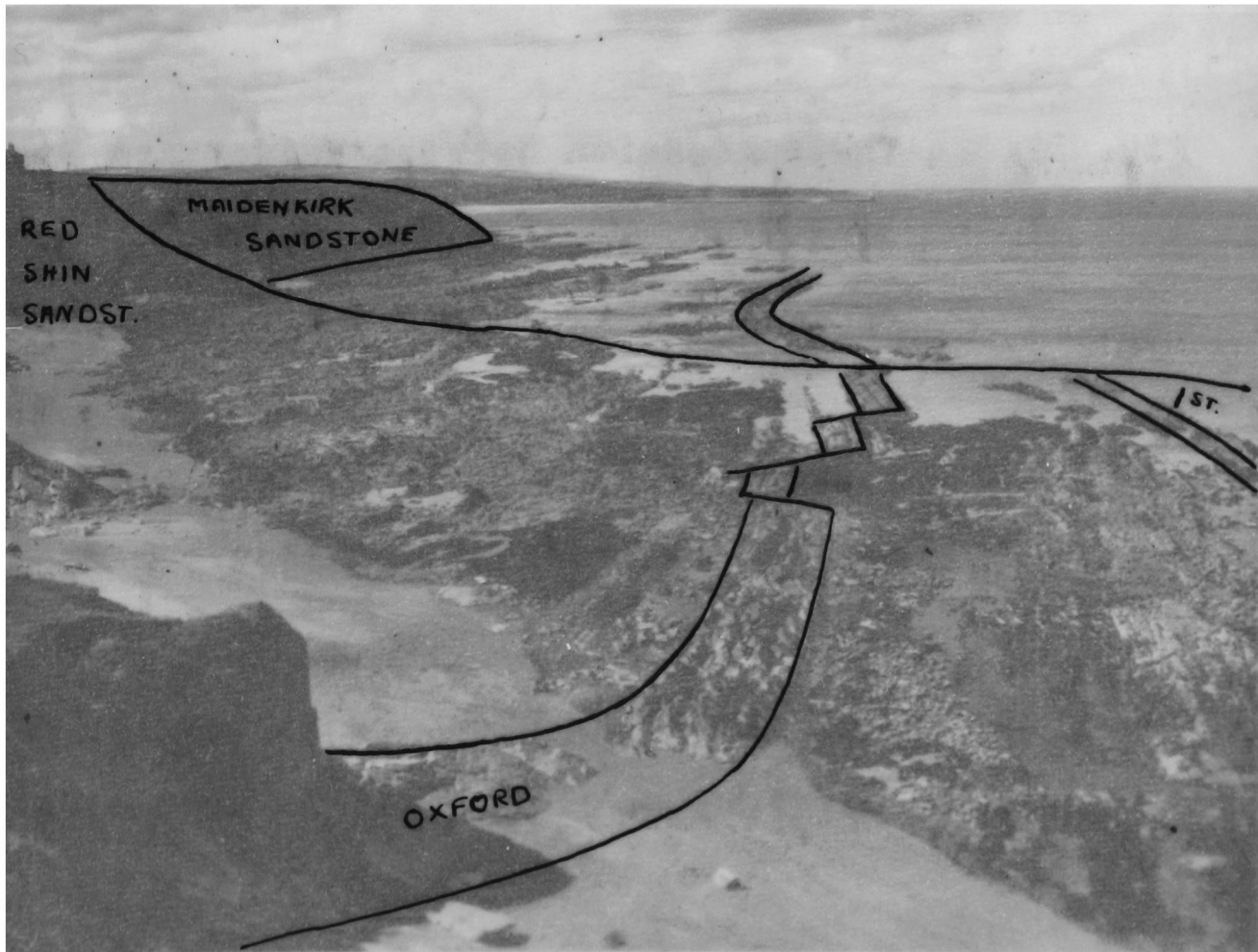
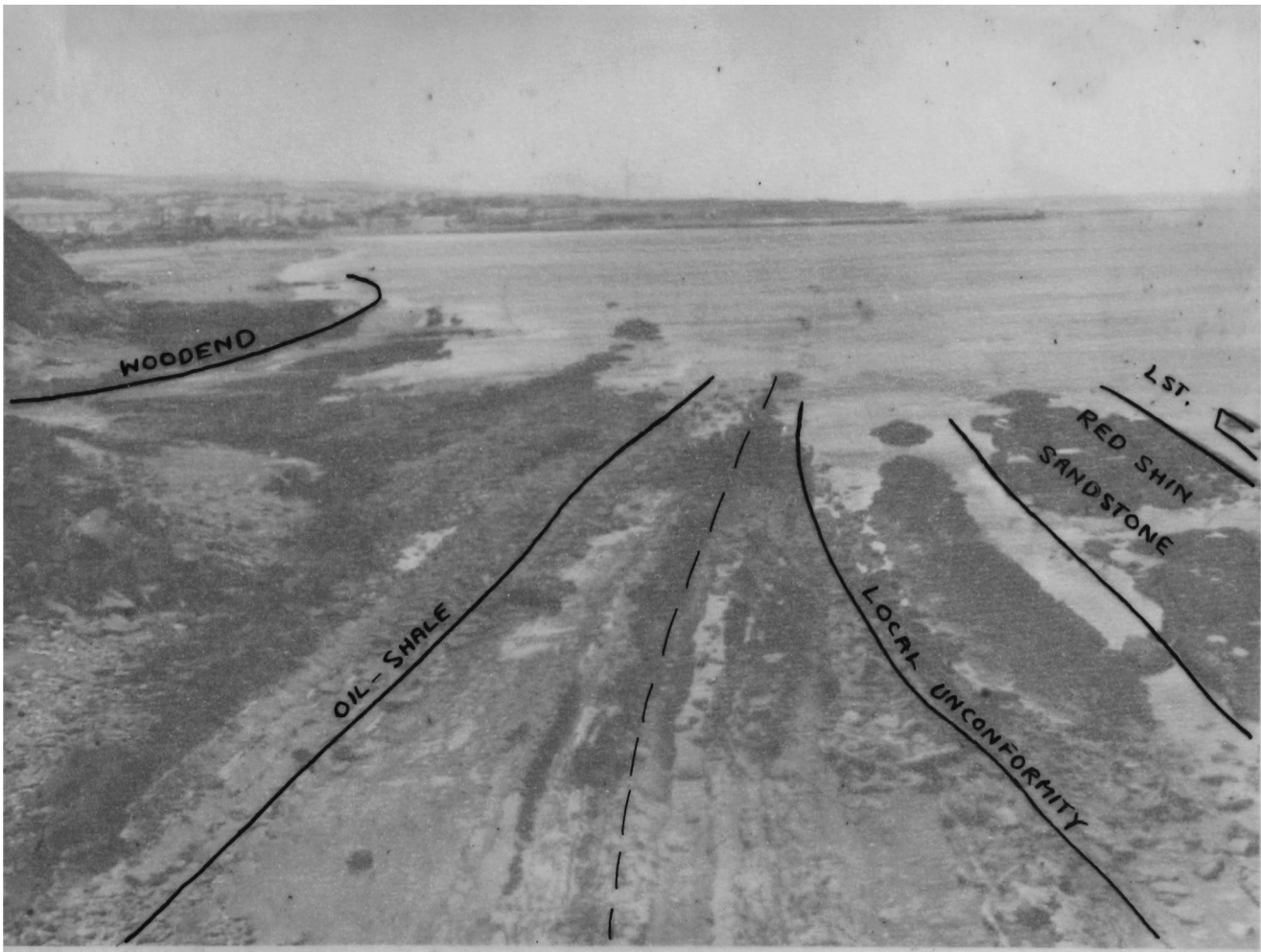


PLATE X.

Fig. i. The upper surface of the "Somphospongia" algal band which lies 3 ft. below the Doupster Oil-Shale at Red Shin Cove (Lower Limestone Group).

Fig. ii. The southern limit of the northern outcrop of the Red Shin Limestone, where it is surrounded by red and purple sandy marls; the dolomitized limestone thickens rapidly to the north.



PLATE XI.

Fig. i. A corallum of Syringopora sp. on the upper surface of the 8th. Limestone, Middle Limestone Group.

Fig. ii. One of a number of concretionary mounds which are seen on the upper surface of the 8th. limestone at Seahouse.



PLATE XII.

Folding in the Middle Limestone
Group at Berwick.

Fig. i. The Eelwell and 8th. limestones in a syncline at Green's Haven, faulted against horizontal sandstones of the upper part of the Lower Limestone Group.

Fig. ii. The Sandbanks Limestone lying in a shallow synclinal basin, faulted against the 5th. Limestone at Meadow Haven.

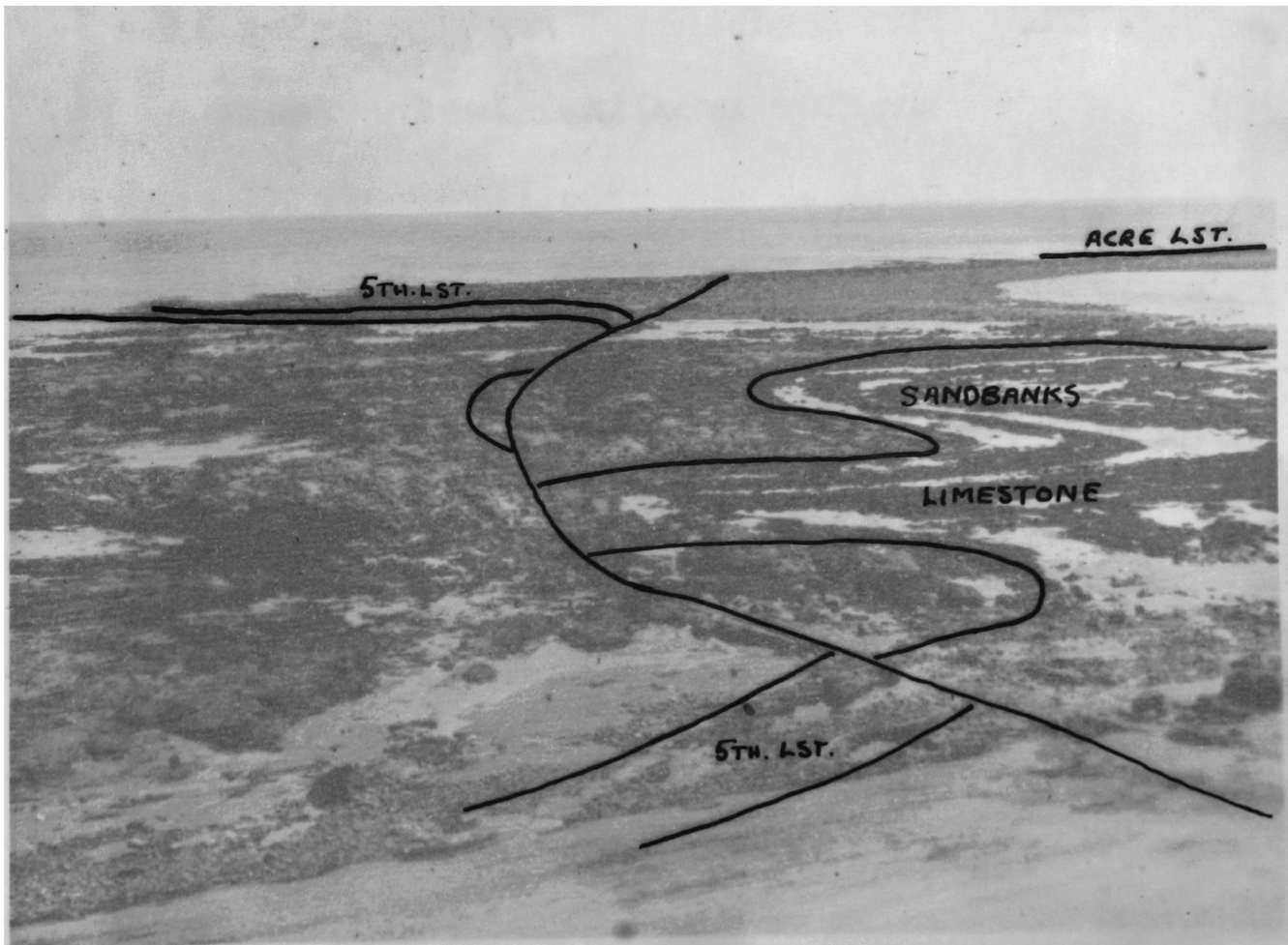
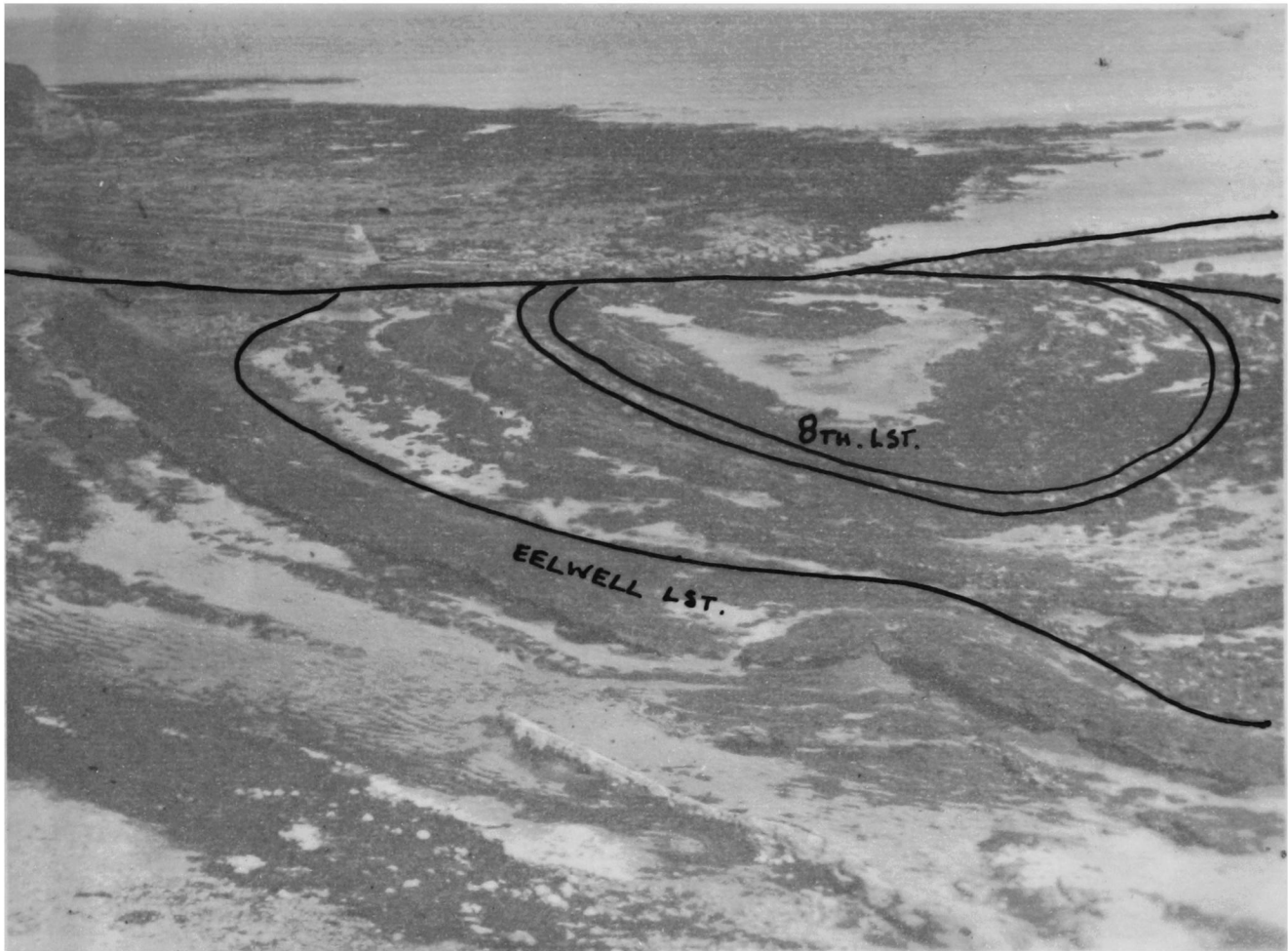


PLATE XIII.

Drag-folds in the Eelwell Limestone,
at Seahouse on the north-east flank
of the Scremerston Anticline.

Fig. i. An over-fold, viewed from the north, resulting from dextral movement of the overlying strata; the normal dip at this point is 20° - 25° to the east.

Fig. ii. The same fold, viewed from the south showing the decollement which characterises the folded limestones at Seahouse.



PLATE XIV.

Seahouse

- Fig. i. Drag-folding of the Eelwell Limestone and the shales which over-lie it; the 8th. Limestone is scarcely affected. The plunge of the folds is to the north. The outermost reef is formed by the Acre Limestone.
- Fig. ii. A small thrust cutting a one-foot coal, seen from the north; the dextral movement here is another form of expression of the differential movements initiated by the formation of the Scremerston Anticline.



PLATE XV.

- Fig. i. Photomicrograph of banded cementstone from Burnmouth x 15, ordinary light. In the upper part, the texture is that of a normal cementstone with scattered quartz grains in a fine-grained argillaceous lime/magnesium carbonate matrix. An ostracodal band can be seen in the middle of the figure, and in the lower part there is evidence of contemporaneous disturbance, possibly due to rising gases.
- Fig. ii. Photomicrograph of agglomerate, Mordington Bridge, x 15 ordinary light; showing a portion of a large fragment, and a number of smaller angular fragments of andesitic material in a fine ground-mass of red-iron oxide containing rare quartz grains.

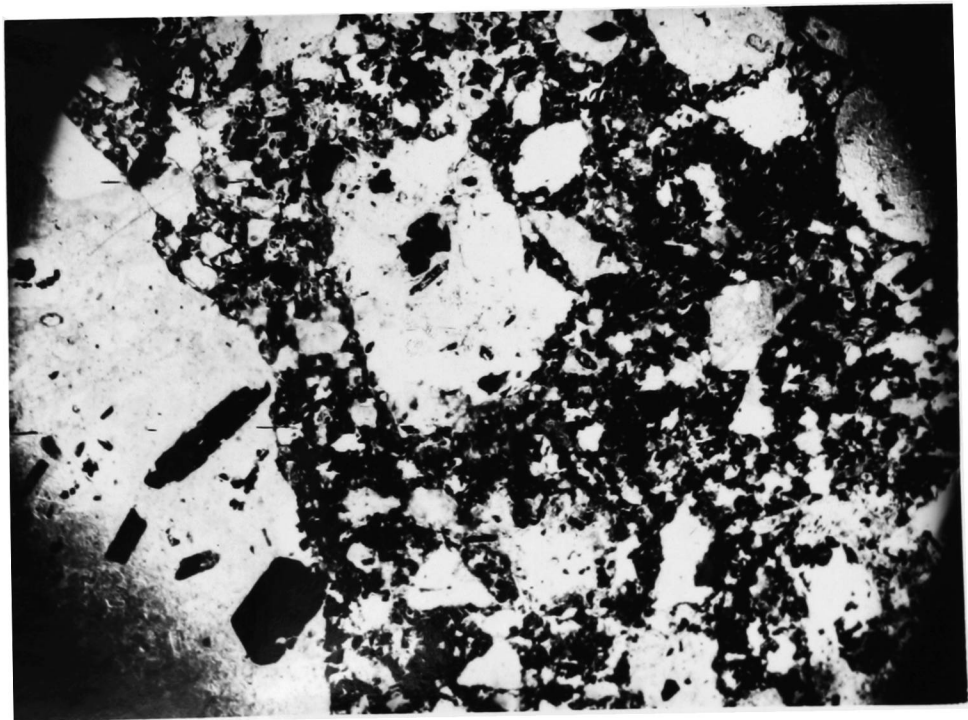
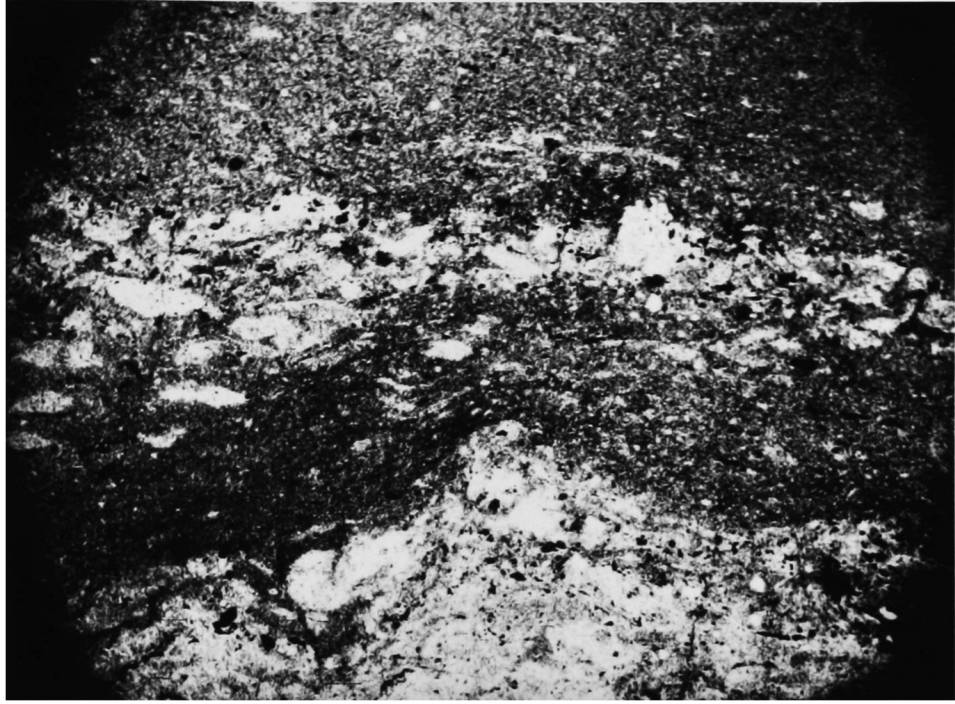


PLATE XVI.

- Fig. i. A size-weight percentage frequency histogram of a fine-grained red sandstone of presumed Upper Old Red Sandstone age, from Catch-a-Penny Burn, Ross. The presence of two maxima clearly demonstrates that both aeolian and fluviatile sedimentation took place concurrently.
- Fig. ii. A calcareous siltstone from the same locality containing a higher percentage of wind-blown millet-seed sand grains, probably as a result of slower fluviatile sedimentation. The size-range of the millet-seed grains is similar to that of the sandstone (fig. i.) 45 per cent passed through the 200-mesh sieve after 9 per cent of carbonate had been removed by acid.

FIG. i

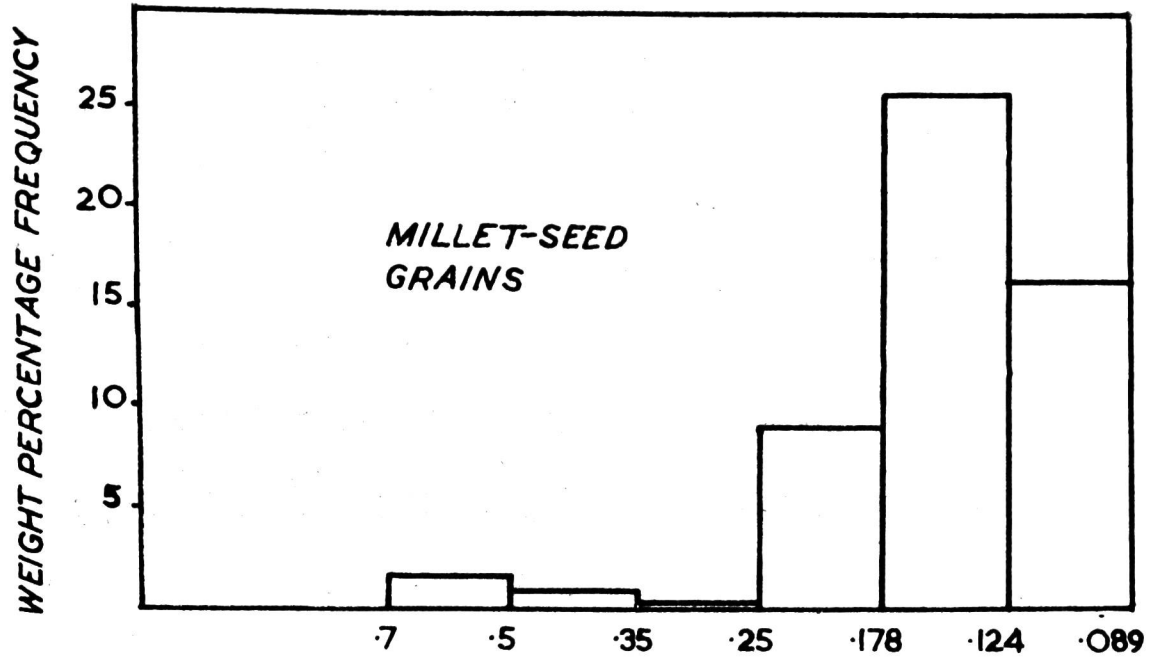


FIG. ii

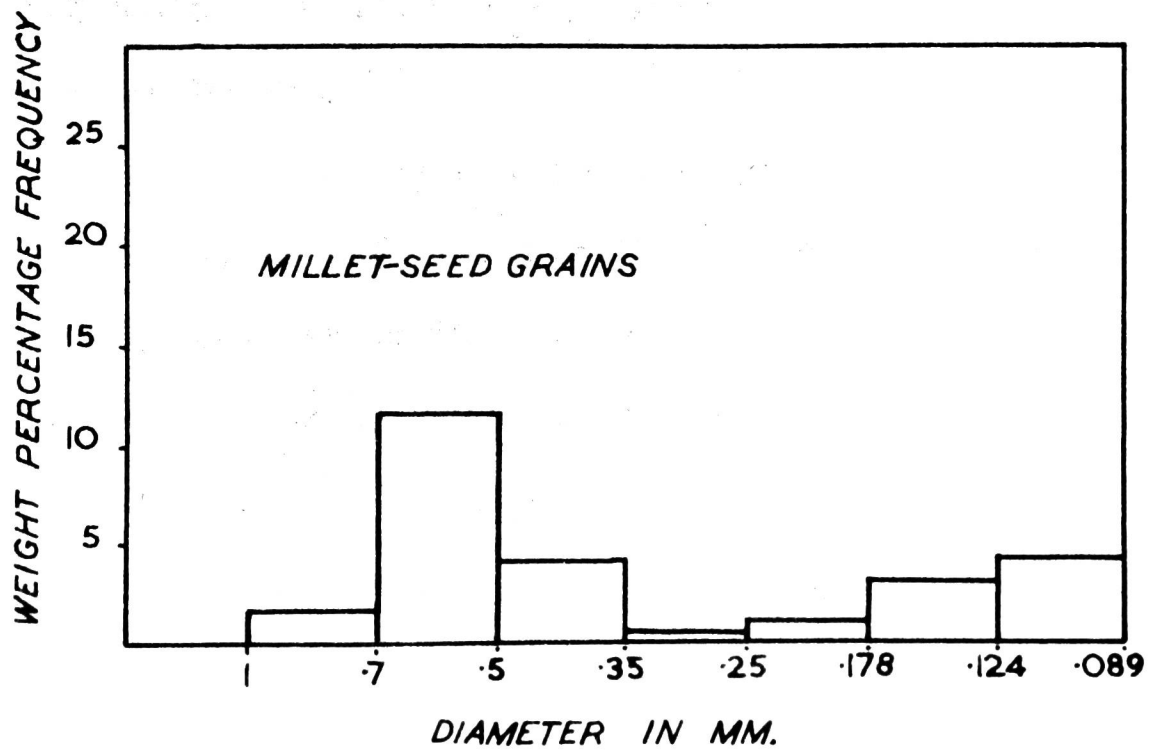


PLATE XVII.

Fig. i. A size/weight percentage frequency histogram of a sample of Fell Sandstone, from Thornton (Map Ref. 36/961493). This is a well-sorted fine-medium grained yellow sandstone.

Fig. ii. The Kip Carle Sandstone at Cove, Berwickshire, which is believed to represent the Fell Sandstone of Northumberland. This sandstone is similar to the Fell in mineral composition and colour, and closely resembles the Thornton sample in degree of sorting and grain-size.

FIG. i

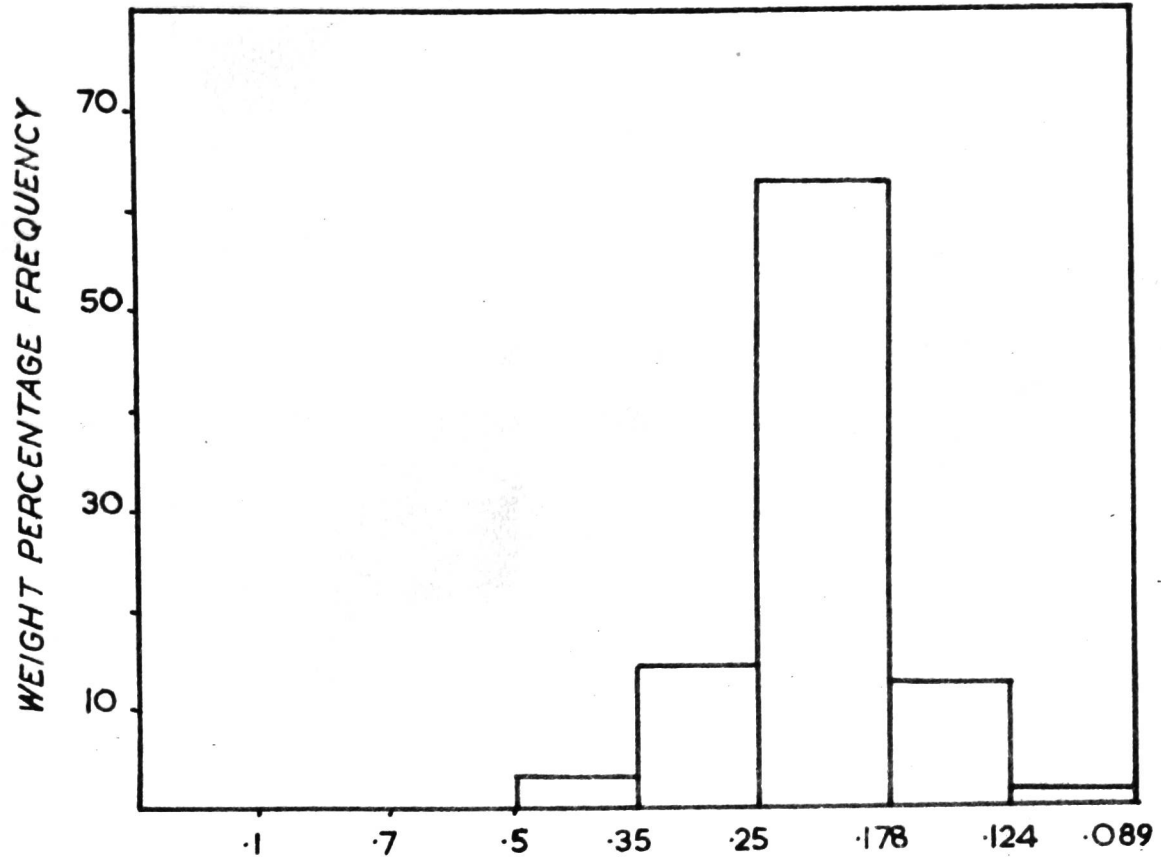


FIG. ii

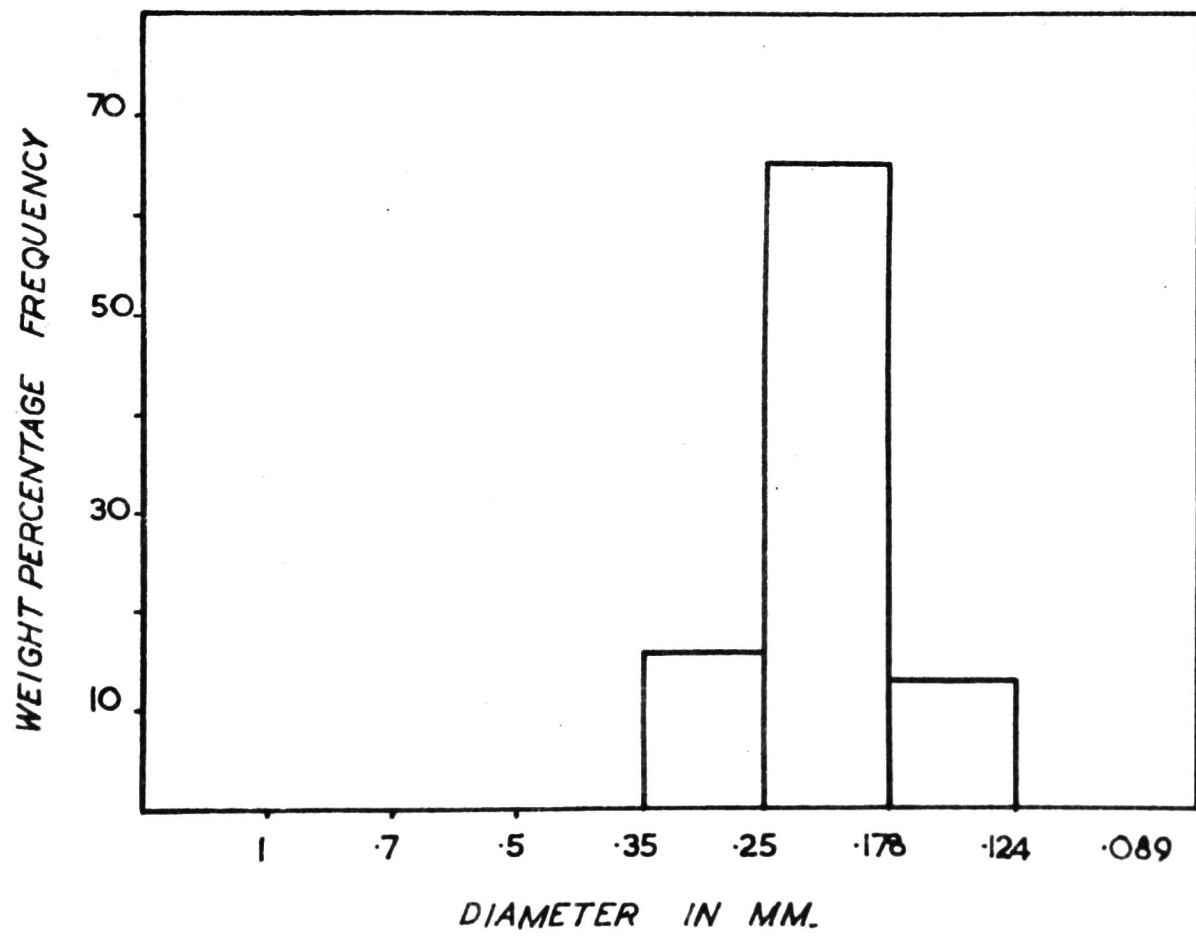


PLATE XVIII.

- Fig. i. Serpulid sp.. Transverse section, x 12.
Burnmouth, (CM. 356); lower Cementstone
Group. With smaller associated tubes.
- Fig. ii. The same, longitudinal section showing
concave partitions.
- Fig.iii. Serpulid sp., x 1. Lowest Serpulid Bed
(CM. 340) Burnmouth. In this form
partitions are rare.
- Fig. iv. Serpulid sp., x 1. Castle Heaton
(locality 20), upper Cementstone Group.
Showing zone of reproduction.
- Fig. v. Serpulid sp., x 12. Heaton Mill (locality
19), upper Cementstone Group. Showing
partitions, with prominent central
indentation.
- Fig. vi. Serpulid sp., x 12. Castle Heaton. Showing
central indentation and ostracodal fragments.

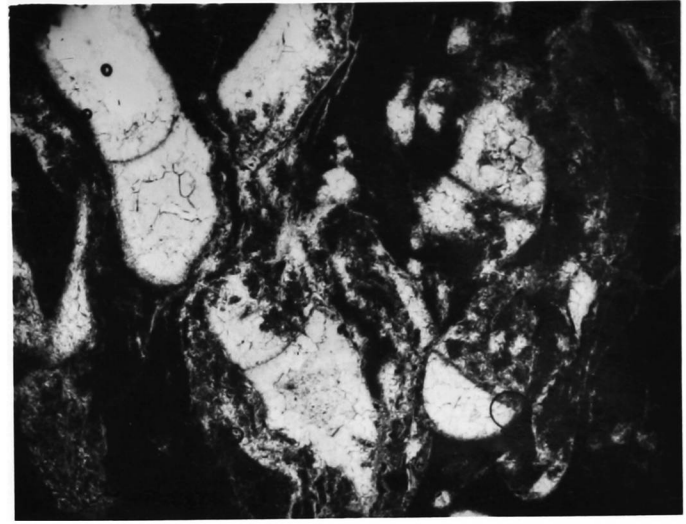
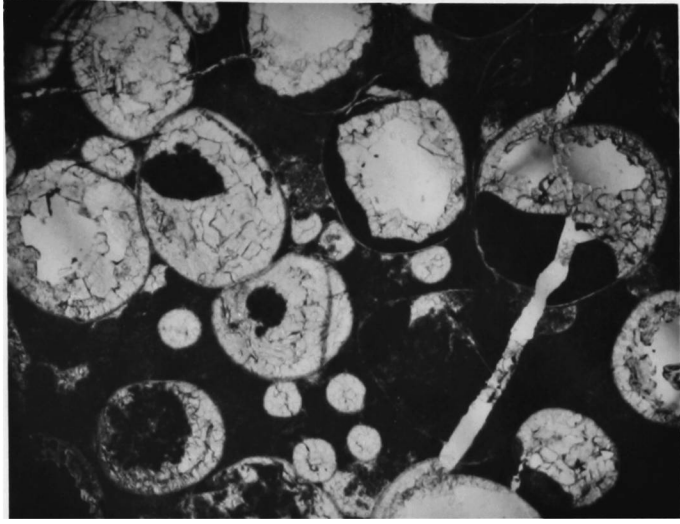


PLATE XIX.

- Fig. i. Serpulid sp.. Longitudinal section.
Norham Serpula Bed, locality 15.
Cerioid form, showing corresponding concave
partitions in adjacent tubes.
- Fig. ii. The same, distal transverse section.
Locality 14.
- Fig. iii. The same, proximal transverse section.
Locality 14.
- Fig. iv. Serpulid sp.. Dumfriesshire, Cementstone
Group.
- Fig. v. Serpulid sp., Castle Heaton, locality 20.
Portion of tube showing mode of reproduction
and concave partition with central indentation.
- Fig. vi. Serpulid sp.. The same locality. Showing
parts of three young individuals, and trans-
verse growth-wrinkles.

All specimens occur in the upper Cementstone Group.
Magnification x 12.

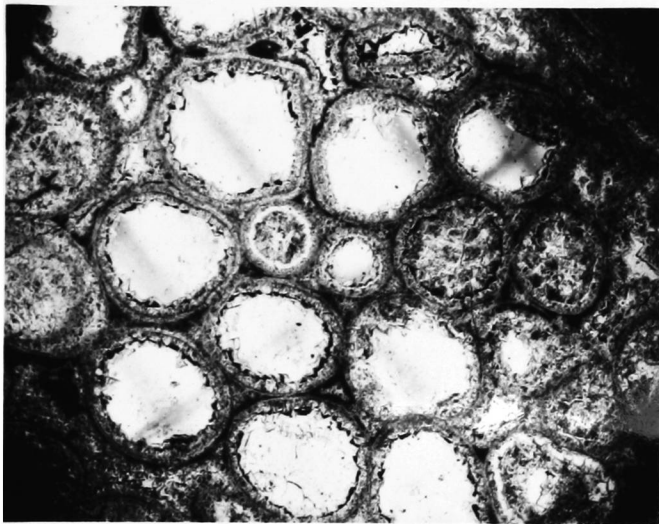
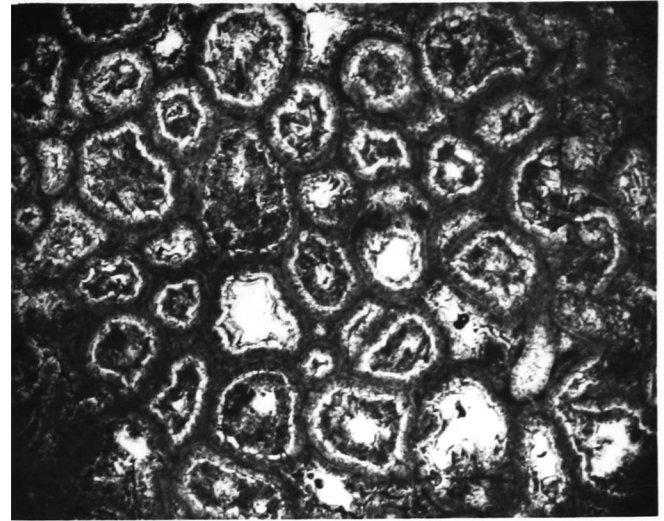
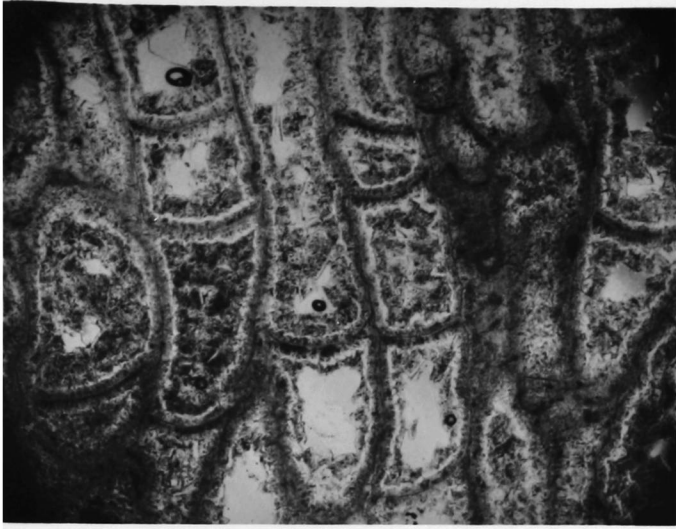


PLATE XX.

Variants of ?Anthraconauta minima s.l. (Hind).

Fig. i. Variant B, 'holotype' x 2; locality 7.

Fig. ii. Variant B, 'paratype' x 2; locality 7;
with Spirorbis sp..

Fig. iii. Variant C, 'holotype' x 2; locality 7.

Fig. iv. Variant C, 'paratype' x 2; locality 7.

Fig. v. Variant C, 'paratype' x 2; locality 7;
form showing anterior development.

Locality 7. The north bank of the Whiteadder Water,
300 yards west-north-west of Clarabad Mill.

Horizon. Lower Cementstone Group.

See pages 133 - 136.

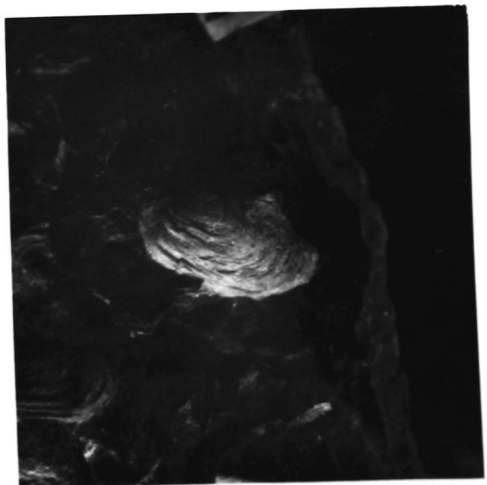
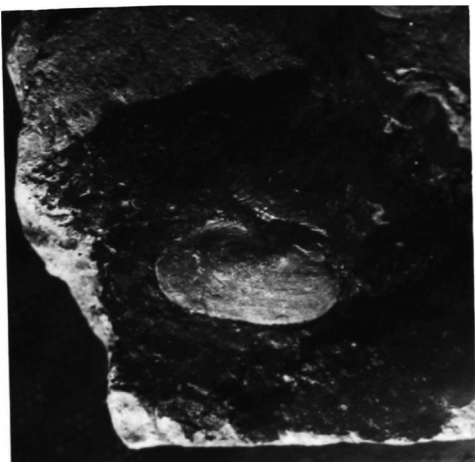
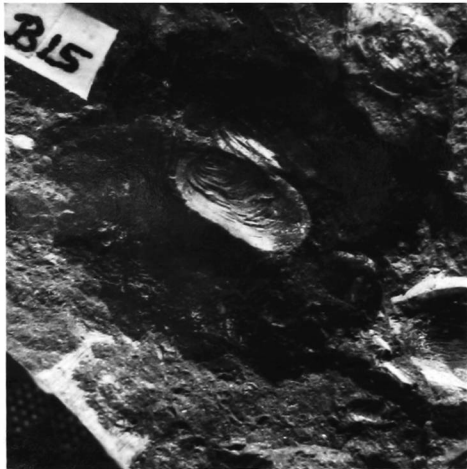
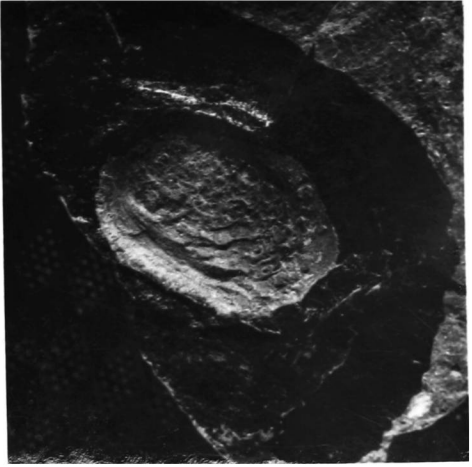
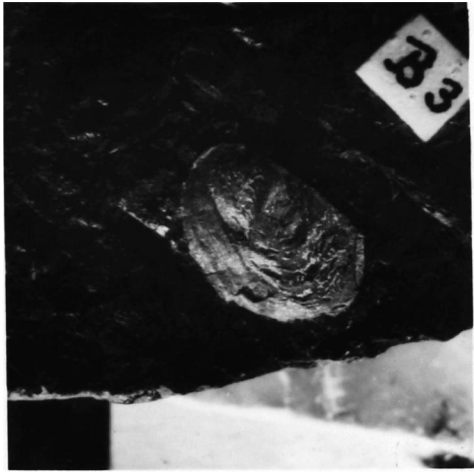


PLATE XXI.

Variants of ?Anthraconauta minima s.l. (Hind).

Fig. i. Variant D, 'holotype' x 2; locality 8; showing fine regular ornament.

Fig. ii. Variant E, 'holotype' x 2; locality 8.

Fig. iii. Scatter-diagram composed of the most complete specimens from localities 5, 7 and 8. The height at the umbo is taken perpendicular to the line of the hinge. Specimens showing D-type ornament are indicated by the letter O. Figured specimens are enclosed by a circle. Crosses indicate the position of the Cairn's Mill specimens.

Locality 5. Foul Dean Quarry, Foulden.

Locality 8. North bank of Whiteadder, 300 yards east-north-east of Hutton Bridge.

Horizon. Lower Cementstone Group.

See pages 133 - 136.



Fig.iii Variants of ?*Anthraconauta minima* (Hind)

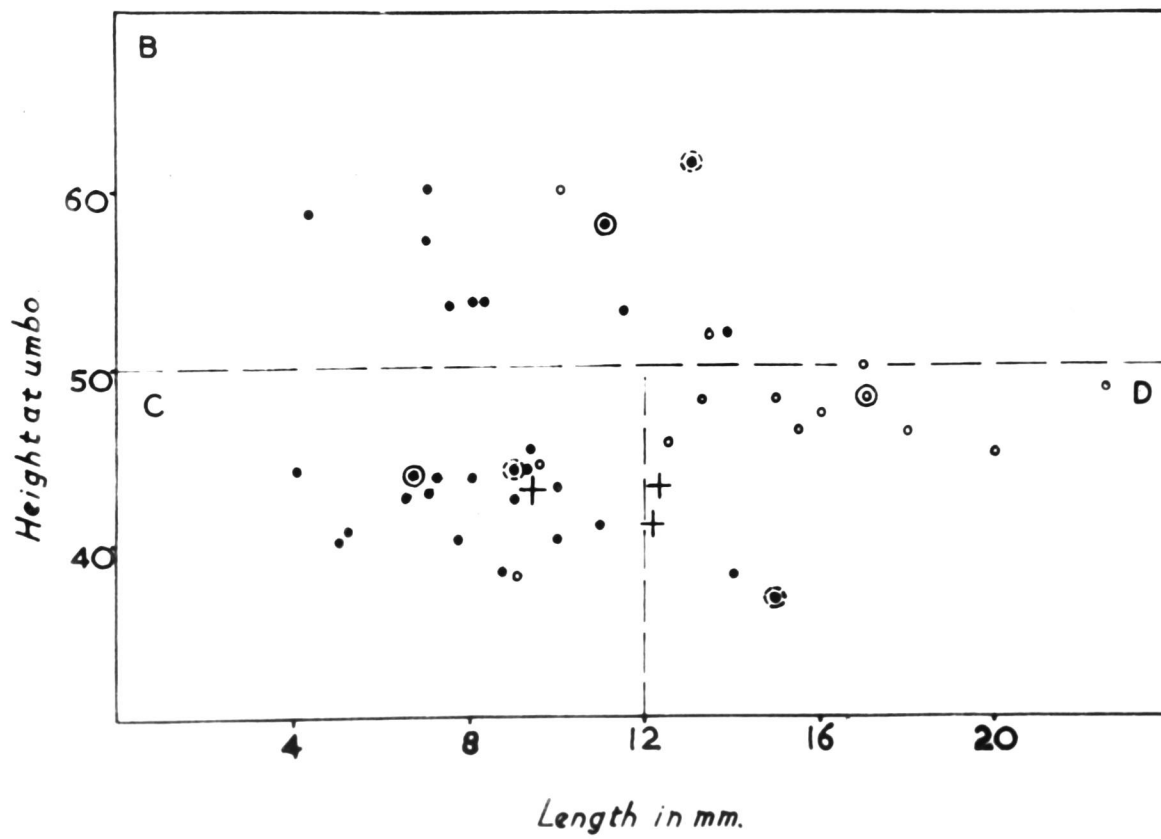


PLATE XXII.

Fig. i. Buxtonia cf scabricula (Martin).
Specimen A. x 1. Brachial valve
showing the median septum (with groove),
adductor muscle-scars and cardinal
process. Lamberton Marine Band,
(Upper Scremerston Group), Marshall
Meadows Bay, Berwick.

Fig. ii. Pustula punctata (Martin). x 1.
Brachial valve, showing median ridge
and prominent bifid cardinal process.
Same horizon and locality.

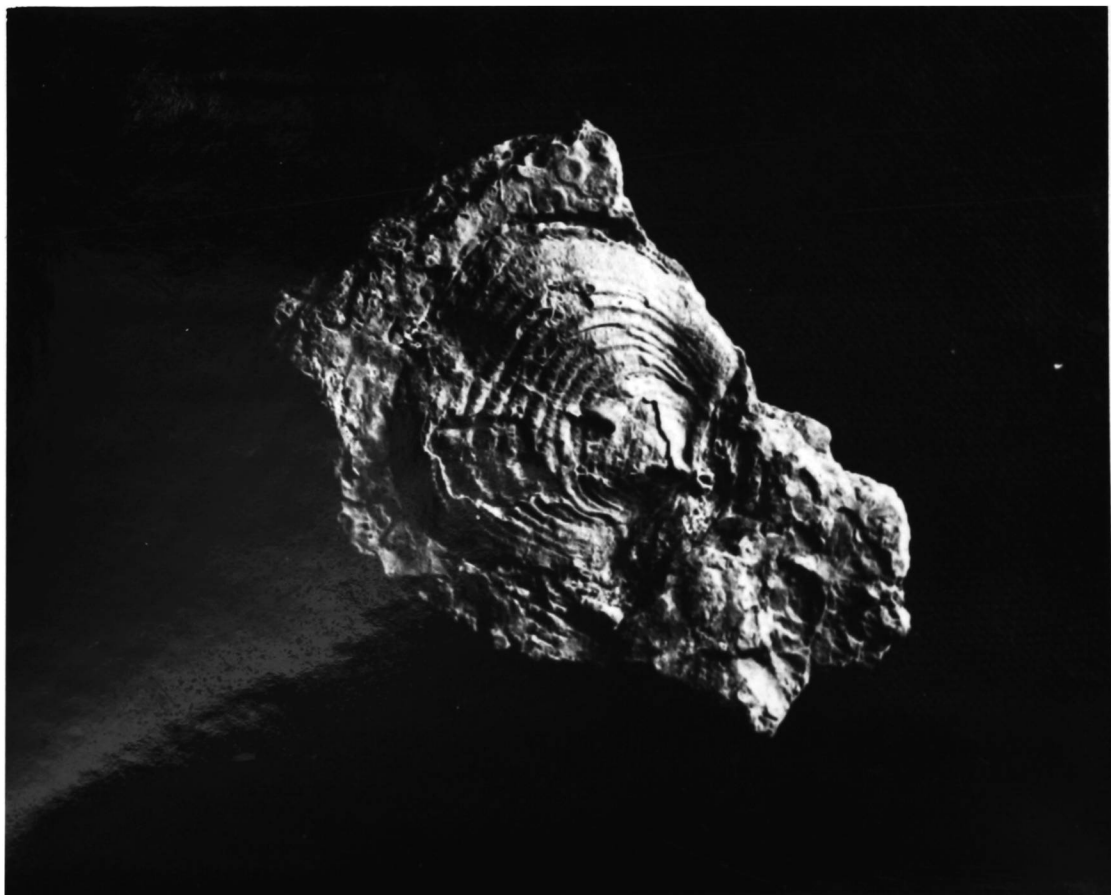
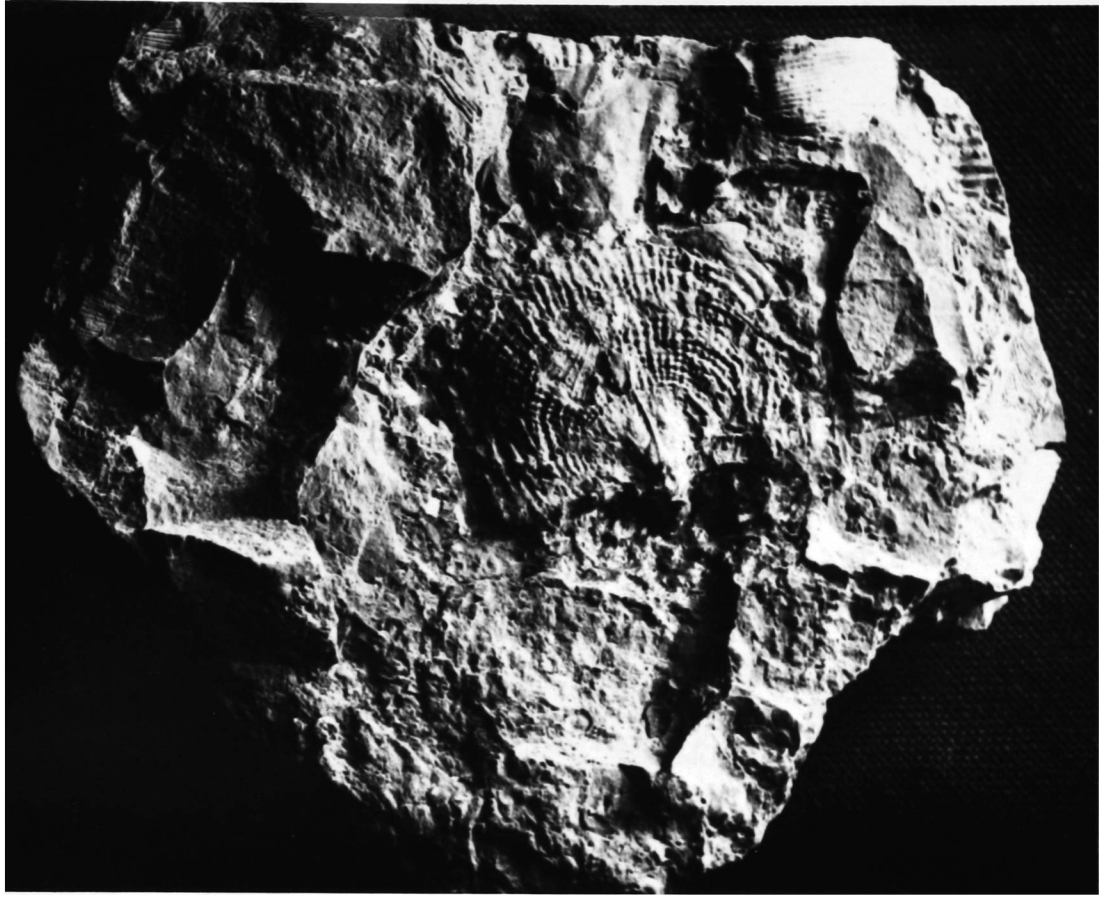
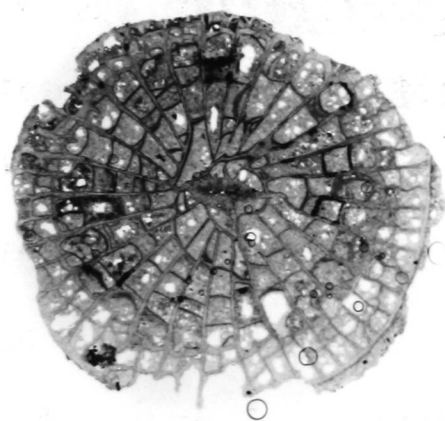
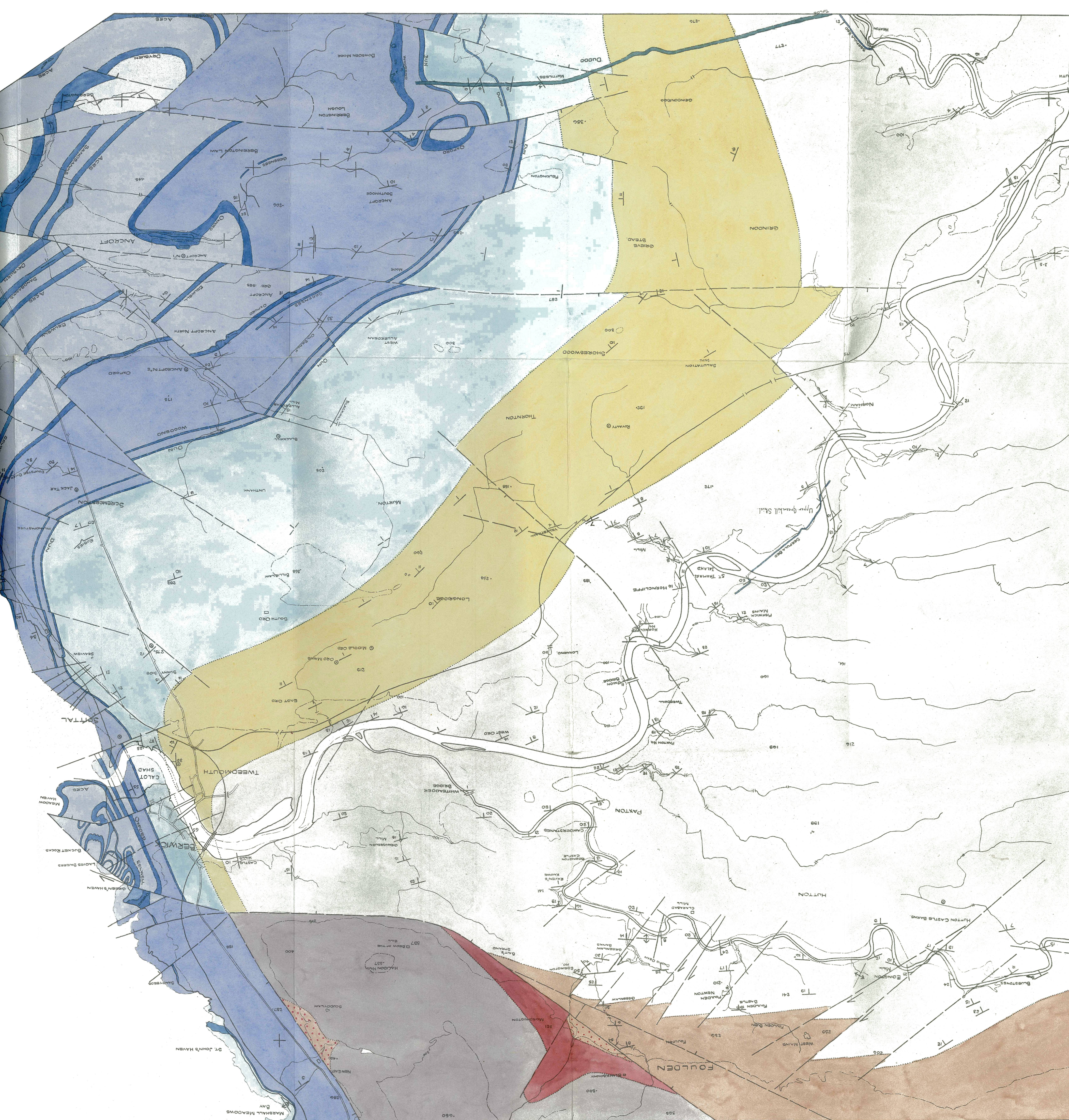


PLATE XXIII.

Fig. i. Lithostrotion sp. x 5. Transverse section of adult corallite showing columella and distinctive septal arrangement. Shale below Duddo Limestone, (Upper Scremerston Group) Duddo Mill Burn, Northumberland. See page 142.

Fig. ii. Posidonia becheri (Bronn), and Goniatites crenistria (Phillips) x 1. Shale above 2nd. marine limestone (Middle Limestone Group), Seahouse, near Scremerston. See page 96.





A
 GEOLOGICAL MAP OF
 THE BERWICK DISTRICT
 BY
 J.M. BOWEN BA., F.G.S.
 1954

LEGEND

+ HORIZONTAL STRATA.
 / STRIKE CERTAIN, DIP UNCERTAIN.
 \ DIP AND STRIKE CERTAIN.
 / STRIKE CERTAIN, DIP UNCERTAIN.
 \ DIP AND STRIKE UNCERTAIN.

Agglomerate of Lower
 Old Red Sandstone Age
 Greywacke and Shale
 of Silurian Age
 Quartz Dolerite of Carbo-
 Permian Age
 Porphyritic Micro-diorite
 of Lower Old Red Age

Upper Limestone Group
 Middle Limestone Group
 Lower Limestone Group
 Scremerston Coal Group
 Fell Sandstone Group
 Cementstone Group
 Upper Old Red Sandstone

FAULTS (CERTAIN)
 FAULTS (UNCERTAIN)

Scale: 1:25,000
 1 MILE