GEOLOGY OF THE CODROY VALLEY, SOUTHWESTERN NEWFOUNDLAND, INCLUDING RESULTS OF A PRELIMINARY PALYNOLOGICAL INVESTIGATION

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Geology of the Codroy Valley, Southwestern Newfoundland, Including Results of a Preliminary Palynological Investigation

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Abstract

A detailed field mapping programme and palaeontological study of Codroy Valley area, southwestern Newfoundland, has yielded evidence that the boundary between the Codroy Group (Mississippian) and the Searston beds-Barachois Group (Upper Mississippian and Pennsylvanian), as mapped by earlier workers, required emendation.

A general lack of diagnostic macrofossils in critical areas has been commented on by previous workers, and microfossils have been listed only in a few cases, but little work appears to have been done in this field. Rock samples were collected from the map area and later investigated in the laboratory for microfossils. Eighty eight rock samples were macerated for spores and good diagnostic assemblages were found in six of these. Productive samples were found in the Codroy Group, Searston beds and the Barachois Group, comprising a total spore florule of fifteen genera. These included *Convolutispora*, *Lophotriletes*, *Lycospora*, *Reticulatisporites* and *Verrucosisporites* from the Codroy Group; *Convolutispora*, *Lycospora*, *Perotrilites* and *Raistrickia* from the Searston Beds; and *Calamospora*, *Cirratriradites*, *Densosporites*, *Florinites*, *Granulatisporites*, *Knoxisporites*, *Leiotriletes*, *Lophotriletes*, *Savitrisporites nux* and *Schopfipollenites* from the Barachois Group.

Five previously unrecorded localities containing ostracods were found and specimens of *Glyptopleura sagae*? and *Paraparchites sp*. were identified.

A number of new macrofossil localities were also discovered comprising a total assemblage of 15 genera and 17 species. Vertebrate skeletal remains and fossil trackways of tetrapods were found in rocks of the Codroy Group.

Structural studies revealed four general fault trends in the Codroy Valley area. A detailed sedimentary investigation was made of a coastal portion of the Searston bed sequence. Here, more than 70 diastems were counted separating cyclothems made up of conglomerate-sandstone units and lutite units. The depositional environment in which they were laid down appears to have been one of fluviatile sedimentation under warm humid climatic conditions.

Five lithostratigraphic types - coal, limestone, arkosic sediments, a boulder (conglomerate) bed, bedded chert - were investigated with a view to establishing marker or key beds in the Searston beds-Barachois Group. The first four types proved inadequate for the role of marker beds. Evidence is given for the continuity of a chert bed permitting it to be used for a key bed. The boundary between the Searston beds and the underlying Codroy Group is arbitrarily chosen at the base of this chert bed.

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MAP 1

MAP 2

Chapter 1

Introduction

Introductory Statement:

During the summer of 1964, the writer conducted a field investigation to determine the presence of guide micro-fossils in rocks of the Codroy Group and the Searston-Barachois strata. This information, in conjunction with evidence from guide macro-fossils, was used to attempt a more precise location of the Mississippian-Pennsylvanian boundary in this region. The age of the Codroy Group has been considered by previous workers to be Upper Mississippian, and the Searston-Barachois Group to include younger Upper Mississippian and Pennsylvanian strata.

Stratigraphic, sedimentary and structural studies were also carried out in conjunction with the main palaeontological work.

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Location and Area

The area studied occupies a wedge-shaped unit (See Map. 1) between the Long Range Mountains and the Anguille Mountains. It is approximately 20 miles in length, 8 miles at the greatest width along the coastline of the Gulf of St. Lawrence, and tapers inland to 2 miles at Coal Brook.

The Trans-Canada Highway and the Canadian National Railway traverse the length of the area giving good access both by road and rail.

Regional Relations

The region is within the Appalachian system, which extends northeastward from the Maritime Provinces into Newfoundland. Both of these areas were within the Carboniferous basin of deposition, an area which is now bisected by the Gulf of St. Lawrence.

Previous Work

Rocks of the Codroy Valley were first described by J. B. Jukes (1843, pp. 51-53)[1]. He divided the Carboniferous rocks of southwestern Newfoundland into Upper portion and Lower or red portion. A. Murray (1881, p. 87 and p. 182) described and measured the coastal section between the Grand Codroy and Little Codroy Rivers, and also gave an account (p. 88) of the Carboniferous fault contact with the Pre-Carboniferous rocks of the Long Range. A. Murray (posthumous) and J. P. Howley (1918, pp. 360-384) published a report on coal beds of the Codroy Valley. Coal outcrops were listed, measured, and described stratigraphically. C. S. Schuchert and C. O. Dunbar (1934, p. 110) described the probable environment of deposition for rocks considered to be Carboniferous near Trainvain Brook at the contact with the crystalline rocks. A general description of the geology of the Bay St. George Carboniferous Area was given by A. O. Hayes and H. Johnson (1938, pp. 5-22) who proposed a three-fold division of the Carboniferous strata (Anguille Series, Codroy Series and Barachois Series), and listed fossils.

W. A. Bell (1948, pp. 1-2 and pp. 36-38) examined in detail early Carboniferous strata in the Codroy area and on the southeast shore of St. Georges Bay in the region between Ship Cove and Fishels. In the Codroy area he also measured the section from Cape Anguille to Stormy Point, and proposed acceptance of the term "Searston beds" for descriptive purposes.

[1] Names and/or dates in parentheses are those of referances cited at the end of this Thesis.

In 1949, (pp. 72-91) G. Phair investigated the contact of the Carboniferous rocks with the crystalline rocks of the Long Range Mountains. D. M. Baird's report (1951) lists information concerning gypsum deposits of southwestern Newfoundland. On the basis of spore analysis, P. A. Hacquebard, M. S. Barss and J. R. Donaldson (1960, pp. 237-245) suggested that the term "Howley Beds" should provisionally be adopted as a reference term (not a stratigraphic unit) to beds considered to be of Westphalian A age, which lie above the Searston beds but stratigraphically below the Riversdale coals of the St. George's area. Separation of the Codroy Group into Lower and Upper Divisions was made by D. M. Baird and P. R. Coté (1964, pp. 509-520), who also pointed out the relationship of the Lower Carboniferous rocks of southwestern Newfoundland with similar strata in western Cape Breton Island.

Chapter II

Local Topography and Structure

The local topography of the area is to a very large extent controlled by the structure and it would appear appropriate to discuss both topics under the same chapter heading.

Local Topography

The area studied lies between the Anguille and Long Range Mountains and is locally known as the Codroy Valley.

The Anguille Mountains, which form the western border of the area, have a flat topped summit ridge, ranging from 1,500 to 1,800 feet above sea level, and are composed of early Mississippian strata. The eastern border is formed by the Long Range Mountains, which rise from the lowland region in a steep fault line escarpment. They comprise crystalline and metamorphosed rocks of Pre-Carboniferous age and are from 1,800 to 2,000 feet in altitude. The Codroy Valley is composed of Mississippian strata (younger than that of the Anguille Mountains), and early Pennsylvanian strata. The valley is occupied by the Grand Codroy and Little Codroy Rivers. The former drains the larger part of the valley and at a distance of about 12 miles from its mouth, near the settlement of South Branch, it divides into two main tributaries, North and South Branch. The latter is smaller and occupies a channel at the foot of the escarpment of the Long Range Mountains. Both rivers enter the Gulf of St. Lawrence by broad estuaries, which are partially blocked by sand dunes and sand spits. At the mouth of the Grand Codroy River a sand spit is attached to the northern bank, in contrast to the Little Codroy River where a spit is tied to the southern bank.

The elevation of the base of the valley is generally 50 to 100 feet, but a distinct area of upland with a maximum relief of 425 feet occurs at the mouth of the valley between the two river estuaries, and extends inland for about 6 miles. The coastal section between the estuaries consists of conglomerate-sandstone units alternating with lutite units. The strike is normal to the general coastline, and consequently erosion removes the less resistant lutite more rapidly than the conglomerate-sandstone lithologies and results in an alternation of bays and headlands along the coast.

STRUCTURE

In general, the Carboniferous rocks in the map area strike northeasterly and dip towards the escarpment of the Long Range Mountains (See Map 1). There are however, three significant exceptions to this general system. Firstly, in proximity to the Long Range escarpment within a relatively narrow belt of approximately 500 yards, the dip and frequently the strike show a variation from the aforementioned regional trend (See sections $A-A^1$, $B-B^1$ and $C-C^1$). Secondly, in the Loch Lomond area, north of St. Andrews, the strike of the rocks have a more northerly trend and the dips show considerable variation both in their direction and amount. Thirdly in the channel of the Little Codroy Rover, at locality F_7 on Map 1, a ten foot thick limestone bed resting on grey lutite exhibits an anomalous dip direction. This outcrop is geographically isolated and the general structural relationships of this anomaly were not resolved.

Faults are common throughout the map area, but to trace these for any distance is made difficult by lack of exposure. Most of the faults found were steeply dipping normal faults, although bedding plane slickensides were common in the coastal section of the Searston beds (Faults noted in this section are shown on Map 2). Observations made in the field were used in conjunction with information from aerial photographs, to determine general fault patterns, which are plotted on Map 1 (The speculative nature of these should be appreciated). For descriptive purposes the faults are categorised into four generalised trends, which are described below:

1. Northeasterly Trend:

This direction is followed largely by the fault contact of the Carboniferous strata with the crystalline rocks of the Long Range. This contact was investigated in considerable detail by G. Phair (1949, pp. 72-88), in the few localities where it is exposed, it is found to be essentially vertical, or steeply dipping to the northwest. Movement along this fault affected the rocks in the map area in the following manner:

The arkosic nature of the alluvial fan (?) sediments in the Overfalls Brook region is a probable indicator of movement along the fault zone in the late Mississippian and/or early Pennsylvanian, depending on the age of these sediments (yet to be definitely established). If, as is tentatively proposed by the present writer, outcrops of bedded chert located at Ct_1 and Ct_2 are of the same bed, and represent the top of the Codroy Group, then an age equivalent to the Searston beds would be favoured for the arkosic sediments. This would suggest movement along the fault zone in Canso times. Considerable vertical movement along the fault after deposition of the Barachois Group is strongly suggested by the abovementioned change of dip in the proximity of the Long Range.

The deformation of rocks in the area close to the Long Range suggests considerable movement with a vertical component in post-Barachois times, leading to large scale drag-folding of the down-thrown Carboniferous strata. At the same time, the abovementioned bedding plane faults in the Searston beds were probably formed. Movement with a horizontal component is indicated also however, and is evidenced by horizontal slickensiding found where the fault contact is exposed on Stevenson's Brook. It seems possible that this movement also produced lateral drag-folding of contiguous Carboniferous strata, and may explain the marked variations in strike noted close to the contact, but the direction of this lateral movement was not established.

2. West-northwesterly Trend:

This trend is found frequently in the cliff section at Capelan Cove and in the area to the north. Faults with this trend have led to fragmentation of the section into a number of isolated blocks. For example in Capelan Cove, a block of the Lower Codroy gypsiferous zone is thrust up into Upper Codroy Woody Head beds. Also, in this same cove Searston beds are downfaulted against rocks of the Upper Codroy Group, which are considered by the present writer to be equivalent in age to Windsor subzone E.

3. Westerly Trend Progressively Changing to Northwesterly.

This trend is followed by large scale faults which appear to displace both the Carboniferous strata and rocks of the Long Range. The faults show a westerly trend in their eastern portion but towards the west this changes to a more northwesterly direction.

4. Northerly Trend Progressively Changing to Northeast.

Only one example of this trend was found in the Loch Lomond area. At this locality, approximately 1½ miles west of Tompkins, a fault has produced a relatively distinct escarpment. As in the case of the fault trend discussed in the previous section, a change of direction takes place progressively along its length. The southern extremity has largely a northerly trend whereas towards the north it swings northeasterly.

Chapter III

Sedimentary Geology

Introduction:

The wedge-shaped map area described in Chapter I comprises rocks of the Codroy Group, the Searston transition beds and the Barachois Group. Rocks of the Anguille Group form the northwestern limit of the wedge and the crystalline rocks of the Long Range form the southeastern margin.

Anguille Group:

The portion of the Carboniferous basin which occupied southwestern Newfoundland in early Mississippian times is considered to have had a predominantly non-marine environment previous to the deposition of the Codroy Group. W. A. Bell (1948, p. 6) suggested that the Anguille Group was laid down in an alluvial flood plain type environment. The group is described by D. M. Baird and P. R. Coté (1963, p. 510) as consisting of immature greywacke, arkose and feldspathic sandstone, dark grey, thinly laminated, brittle siltstone and minor dense, argillaceous limestone. Bell suggested (1948, p. 36) that the regional palaeogeography during this time may be envisioned as: "... an intermontane subsiding basin that extended southwest into St. George's Bay area from the central interior of Newfoundland during the time that similar valley deposits were laid down as the upper part of the Horton Group in Nova Scotia." The climatic environment suggested was pluvial.

Rocks of the Anguille Group are not exposed within the wedge shaped area investigated, although they form the Anguille Mountains to the northwest.

Codroy Group:

The environment at the beginning of deposition of the Codroy Group contrasts with that of the Anguille Group. Bell (1948, p. 6) first proposed the Ship Cove limestone as the basal member of the Codroy Group, and Baird and Coté (1964, p. 514) presented evidence suggesting that this limestone was formed during unstable depositional conditions caused by the advance of the "Codroy Sea" over the area. The reason for this conclusion was, they stated, the presence of coarse clastic interbeds in the Ship Cove limestone where it crops out on the south of Codroy Island. Folding, considered to have resulted from flow movement previous to consolidation, was observed by the present writer at the same locality. This evidence would appear to favour an unstable depositional environment. (See fig. 1)

Deposition of the gypsum beds in the Lower Codroy suggest that climatic changes, ranging from pluvial to semi-arid, accompanied the marine invasion. Towards the northeast, in the St. George's area, depositional conditions remained moderately stable. Deltaic deposits, which rarely contain evidence of marine encroachment, are found, suggesting generally a more continental aspect.

In the Codroy area however, intercalated alternations of marine and non-marine beds occur throughout the group.

The type section of the Codroy Group, which is disturbed considerably by faulting, extends along the coast from a point south of the settlement of Codroy to a point in Capelan Cove, a distance of approximately 2½ miles. The group was divided into Lower and Upper Codroy by Baird and Coté (1964, p. 510), however, the former will not be described in this report.

Upper Codroy:

This sub-group is shown in Figure 2 to be generally equivalent to Bell's Woody Cove and Woody Head beds which, in turn, are generally equivalent with the Woody Cove shale and Woody Point sandstone of Hayes and Johnson.

The Woody Cove beds are in fault contact with the Lower Codroy sub-group north of Woody Cape, the fault being manifested as a sheared zone of brecciated siltstone. The general lithological description originally given by Hayes and Johnson (1938, p. 14) for Woody Cove Beds in the type section is: "... fine-grained siltstones of a gray color, thinly laminated dark gray shales, thick-bedded, black, hackly shale, black limey shale and two members of black bituminous limestone."

In the same report a shallow marine type environment has been suggested for these beds on the basis of the contained brachiopod, gastropod and lamellibranch faunule, which is used to correlate the beds with equivalent Windsor Group subzones of the Windsor area in Nova Scotia. Bell stated (1948, p. 37) that subzones C, D and E of the Windsor Group are represented in the Woody Cove beds. He also listed (p.19) the presence of intercalated beds and subzones containing non-marine conchostracans (Leaia and Pseudestheria) indicating that oscillations from marine to non-marine took place.

The fauna reported by Hayes and Johnson (1938, p. 14) in the Woody Cove beds is given below:

Brachiopoda:

Chonetes sp. nov. (large form).

Productus avonensis Bell.

Bustonia sp. cf. B. comagunensis Bell.

Martinia galataea Bell.

Spirifer sp. cf. S. nox Bell.

Spirifer bisulcatiformis Bell.

Pelecypoda:

Sanguinolites sp. nov., 2 new species.

Schizodus fundiensis Bell.

Modiola hartii Bell.

Gastropoda:

Straparollus sp. nov.

Flemingia sp. cf. F. minuta Bell.

Bellerophon 2 new species.

Euphemus cf. E. urei Fleming.

Murchisonia (Stegocoelia) sp. nov. (very small form)

Naticopsis sp. nov.

Zygopleura sp. indet., cf. sp. nov.

Cephalopoda:

Orthoceras sp. indet.

Poterioceras sp. Bell.

One curved form gen. et. sp. indet.

Arthropoda:

Ostracoda, not determined.

Phillipsia eichwaldi Fischer.

Towards the top of the formation Bell also listed *Sphenopteridium pachyrrachis* and *Adiantites* sp.

(The fauna and flora found by the present writer is listed in Chapter IX.)

The Woody Head beds are a stratigraphic unit proposed by Bell (1948, p. 20) who pointed out that, at the time of writing, there were no satisfactory criteria for the separation of this formation from that of the Woody Cove beds, and that the base of the Woody Point sandstone formation of Hayes and Johnson, which they considered to be non-marine, occurs 410 feet below a horizon containing a marine fauna. The environment of deposition for these beds was evidently shallow water. Cross-bedding, mud cracks, and salt pseudomorphs are common. Fossil footprints occur in at least three localities at Woody Cape, and were first discovered and recognised by Dr. E. S. Belt during a traverse along the shore line with the present writer.

Correlation with the rocks of Nova Scotia suggests that because the Woody Cove beds contain fossils of Late Windsor age, then the Woody Head beds are probably equivalent to basal Canso beds.

Searston beds and Barachois Group[1]

A. O. Hayes and H. Johnson (1938, pp. 21-22) gave the first published description of the Barachois 'series', which they considered to extend from Stormy Point southwards along the coast for nine miles, to a point near the mouth of Trainvain Brook, where crystalline rocks of the Long Range crop out. They described the basal rocks of the Barachois 'series' as consisting of coarse-grained, reddish-coloured, feldspathic sandstone and suggested the following three fold division:

Upper: Mainly grey, fine-to coarse-grained, well-sorted sandstones and intercalated grey-green shales.

Middle: Conglomerates, grits, sandstones, and shales, green, red or grey in colour.

Lower: Mainly gritty, feldspathic, ripple-marked and much cross-bedded sandstones, with intercalations of mottled, red and green micaceous shale.

The badly faulted nature of the sections was mentioned and a thickness estimate of more than 5,000 feet of continuous deposition was made by the authors.

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[1] The Barachois stratigraphic unit would ordinarily, by present usage of the Geological Survey, Canada be designated 'group' and not 'series'.

The stratigraphic unit, Barachois 'series', was defined as consisting of rocks from both the Upper Mississippian and Lower Pennsylvanian until W.A. Bell (1948, pp. 20-21) first differentiated the Searston beds. He suggested that they represent a transitional facies from the Mississippian Codroy Group to the Pennsylvanian Barachois Group. He emphasised however, (p. 4) that the 'beds' were not intended to be a mappable lithologic unit. Bell qualified his proposed differentiation when he stated: " ... all these terms are used here solely for the purpose of description and correlation, and are not proposed as standard mappable units. One important group of beds thus differentiated is the 'Searston beds'."

In the type section Bell included rocks from Capelan Cove to Larkin Point in the Searston beds. In Capelan Cove the Searston beds are down-faulted against rocks of the Upper Codroy Group. The present writer found in the latter unit a fauna suggesting an equivalent age to Windsor subzone E. This Upper Codroy fauna comprised specimens of Phillipsia eichwaldi, Bucanopsis beedei and Spirifer nox.

Bell measured the section of Searston beds from the above-mentioned fault to Stormy Point and listed specimens of Diplotmema adiantoides. South of Stormy Point exposures generally were found to be lacking for a distance of about $1\frac{1}{2}$ miles, this area being occupied by the estuary of the Grand Codroy River. Near Searston, Bell recorded Diplotmema adiantoides and near Larkin Point Lepidodendron volkmannianum. He considered that this flora indicated an early Namurian age (1948, p. 20).

The section from Cape Kennedy to Larkin Point was first measured and described by A. Murray (1881, pp. 182-183). A detailed investigation was carried out by the present writer with the object of discovering potential lithological or palaeontological marker horizons. The results of this study are listed in Chapter IV.

No exposures occur from Larkin Point to near the mouth of Trainvain Brook, a distance of approximately 2½ miles, where the area is largely occupied by the estuary of the Little Codroy River. Consequently the stratigraphic relationship of the Searston beds with the Barachois Group is not clear in the type section.

A definite age for the coal beds occurring within the Barachois Group near South Branch and St. Andrews was established by P.A. Hacquebard, M.S. Barss and J.R. Donaldson (1960, pp. 237-248) as lower Westphalian A. The spore florule suggests an age older than that found in samples from the St. George's coalfield to the north, which indicate an equivalent age to the Riversdale Group. The same authors suggested the term 'Howley Beds' as a local reference term (not a new stratigraphic unit) for beds in this area which lie below the Riversdale coals, but above the Searston beds.

Inland areas shown on the map of Hayes and Johnson (1938, map 4) as underlain by the Barachois 'series', and that of Baird and Cote (1964, fig. 1) as undifferentiated Searston beds and Barachois Group, were investigated by this writer for the possibility of potential mappable marker horizons. The results of this survey are listed in Chapter V.

Chapter IV

Searston Beds of Coastal Section

The Searston beds were studied in detail from Kennedy Point to Larkin Point, and an attempt made to determine the depositional environment and to recognise mappable lithological units and/or palaeontological horizons which could be traced inland.

General Stratigraphy:

Regular alternations of conglomerate sandstone units with predominantly lutite units occur along the section line, and the original description given by A. Murray (1881, p. 87), who measured this section is as follows:

> "On the coast between the Grand Codroy and Little Codroy River, a section of the measure was obtained in a pretty regular sequence consisting of green and red conglomerates, sandstones, red and green marls, and red, green and black shales, the whole accumulation of which amounted to a thickness of 2,306 feet. All this mass of strata is very micaceous, and most of the beds are more or less characterised by the presence of carbonised plants - in some parts the carbonaceous material derived from an accumulation of them being found packed in irregular beds and nests, but in no case did there appear to exist anything like a workable seam of coal."

The present writer counted a total number of 140[1] conglomerate-sandstone units and lutite units representing at least 70 diastems. Hayes and Johnson (1938, p. 21) stated that "at least 42 such repeated diastems may be seen between Searston and Larkin Point."

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[1]The individual units mentioned in the text by reference numbers are shown on Map 2.

General Sedimentary Characteristics of the Conglomerate-Sandstone Units and Lutite Units.

General sedimentary characteristics are shown in figure 3 which is a composite section of a complete cyclothem including features described below. Figure 4 shows the typical alternation from sandstone to lutite to sandstone.

An intraformational conglomerate frequently forms the base of the cyclothems. It rests on a generally flat surface of lutite, although detailed observation reveals channelling and local unconformities are common. Frequently the conglomerate layers wedge out laterally. Upward gradation into a coarse sandstone is usually rapid, although in some cases a hiatus was observed between these two clastic types. The well-sorted coarse sandstone grades upwards through medium grade to fine at the top of the unit. The coarse-and medium-grained sandstones are strongly cross-bedded, and as the sandstone becomes finer, the cross-bedding becomes smaller. Occasionally the fine sandstone grades upwards into a lutite, although in other cases the junction is a sharp break. In contrast to the cross-bedded sandstone, the lutite is well bedded, and may contain flat-bedded ripple-marked sandstone intercalations.

Sedimentary Features Observed in the Conglomerate-Sandstone Units and Lutite Units

Cross-Bedding in the Conglomerate-Sandstone Units:

The coarse-grained sandstone frequently contains trough cross-bedding, good examples of which can be seen at Z 141 and Z 33 (See Map 2).

Tabular cross-bedding also occurs, and on some bedding planes a type intermediate between the two was observed. This is in agreement with observations by P. E. Potter and F. J. Pettijohn (1963, pp. 71-74), who pointed out that the trough-shaped type and tabular type should be thought of as "end members" and gradation between the two may occur. Potter and Pettijohn (p. 71) wrote: "both can occur in the same outcrop and even in the same sedimentation unit."

Thirty measurements, each from different lithological units, were made of cross-bedding features of the trough type, and these gave general directions coincident with the regional dips. This suggests that the current which deposited the sands was flowing from north to south.

Micro-cross Lamination in the Sandstone Units:

Small scale cross-bedding of the type called "Schrägschichtungsbogen" by Gürich and micro-cross lamination by Hamblin (Potter and Pettijohn (1963, p. 74)) occurred most frequently towards the top of the units in the fine grained sandstone. J.R.L. Allen (1963, p. 326) considered that small scale cross-stratification forms were generated by the migration of small-scale asymmetrical ripples. He called attention to work by Simmons et al., which has shown that: "small scale ripples are formed at relatively low flow intensities in the lower flow regime."

Bedding Features of the Lutite Units:

The general features observed have been described already in the section on general stratigraphy. Thin sections showed further details which are described on page 30.

Quicksand Deformation in the Conglomerate-Sandstone Units.

This type of disturbance was observed infrequently along the section, but a good exposure occurs in unit Z 125 (See fig. 5). This fine - to medium - grained, micaceous, slightly calcareous, yellowish-brown sandstone, is strongly contorted. The contorted shapes have been outlined by fracturing. R. C. Selley (1963, pp. 364-366) has described structures of a similar nature in the Precambrian Torridonian Sandstone of northwestern Scotland. He gave an account of a laboratory experiment which produced comparable forms when grains of water saturated sand were vibrated. Selley pointed out that when:

> "Vessels of loosely packed water saturated sand were vibrated. This resulted in a tightening of the packing of the sediment. As excess pore water escaped vertically it dragged up the sand laminae into shapes analogous to those seen in the Torridonian."

If such a mechanism was involved for the sandstone Z 125, the source for the vibration possibly came from adjustments of the basement in response to movement along the Long Range fault zone, located at a distance of approximately $3\frac{1}{2}$ miles to the southeast, but such an explanation is speculative and other mechanisms may well be involved.

Calcareous Concretions in the Conglomerate-Sandstone Units.

Calcareous concretions occur in several of the sandstone units and good examples are located at Z 69 and Z 71 (See Map 2 and fig. 6). The clusters in which they most frequently occur are confined to a single set of bedding planes. Individually, their shape varies from oval to approximately spherical with a maximum diameter recorded of three feet six inches. Freshly fractured concretions are darker grey than fresh matrix. Bedding features, such as cross bedding, pass undisturbed through the structures, suggesting a post-depositional time of origin for the concretions.

The mode of formation suggested by this writer for the calcareous concretions found in the sandstone units of the Searston beds, involves post-depositional solution of calcite in the slightly calcareous host rock with subsequent precipitation about a nucleus.

A thin section (Slide No. Z 141) made from a concretion in sandstone unit Z 141 revealed abundant sub-rounded to angular medium-sized quartz grains with occasional equi-dimensional angular orthoclase, microcline and plagioclase feldspar grains. The matrix comprises medium-grained recrystallised calcite, forming a mosaic of interlocking crystals. The quartz and plagioclase grains generally show strongly etched margins. The plagioclase grains are frequently penetrated by thin fissures, filled with very fine calcite, running parallel to the twinning planes.

F. J. Pettijohn (1956, p. 203) suggested that diversity in the dimensions of such concretions may in part be caused by variations in permeability of the host rock, the larger forms being more prevalent in the more permeable coarser sandstone. Insufficient supplies of calcium carbonate also may explain cases when the concretions are poorly developed.

Calcareous Concretions in the Lutite Units.

Calcareous concretions occur abundantly in the lutite units (see fig. 7) but possibly on account of the impermeable nature of the lutite, they never attain such large dimensions as those of the sandstone. The maximum diameter observed was six inches. Similar concretions termed "race" have been described by J.R.L. Allen (1964, p. 177) from the Lower Old Red Sandstone (Lower Devonian) of the Anglo-Welsh basin. He considered their presence probably to indicate fluctuating groundwater table and exposure in the depositional environment.

Thin sectioned (Slide No. Z72), the concretions were seen to consist of a nucleus surrounded by a layer of different aspect. This layer is composed of fine-grained partially recrystallised calcite. The nucleus, which occupies about one third the volume of the concretion, comprises a mosaic of medium-grained recrystallised calcite. The contact of the calcareous concretion with the surrounding lutite is generally smooth, but under medium power (X 80) was seen to be pitted and irregular.

Colour Variations and Grain Size Changes of the Conglomerate-Sandstone Units

Thin sections were made of basal conglomerate, and of coarse-, medium- and fine-grained sandstones. Details of the basal conglomerate are described on page 31.

Thin sections of the sandstones, which all showed marginal recrystallisation of the quartz grains, are described below:

Coarse Sandstone: (Slide No. Z 21)

This sample was collected towards the base of Z 21. The weathered surface was light brown in colour, and a fresh surface was light grey to light brownish-grey. It contained coalified plant stems and showed no apparent effervescence when tested with dilute HCl, but the presence of dolomite patches was indicated when tested with dye.[2]

The thin section consisted predominantly of coarse, very angular, frequently strained quartz grains, with less frequently strained muscovite grains, plagioclase and orthoclase feldspars. The matrix mainly comprises fine-grained, angular quartz, with muscovite and dolomite grains.

Medium Sandstone (Slide No. Z 63)

This sample was collected from conglomerate-sandstone unit Z 63. The weathered surface was light brown but the fresh surface pale grey. Effervescence occurred when tested with dilute HCl, and on addition of the dye calcite was shown to be present.

In thin section, it was seen that the rock consists of nearly equal proportions of sub-angular to angular quartz and calcite grains. Rare muscovite grains and small amounts of malachite bordered a coalified plant stem. A **small amount** of pyrite was associated with the coal.

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[2] Details concerning dye used are given on page A1.

Fine Grained Sandstone: (Slide No. Z 11)

This sample was collected from conglomerate-sandstone unit Z 11. The weathered surface was greenish grey in colour dotted with small black coaly specks. Fresh surfaces were a dull greenish-grey. The sample was inert to the action of dilute hydrochloric acid, and addition of dye showed no significant staining.

A thin section of the rock consisted mainly of fine-grained, angular quartz with infrequent pyrite, muscovite, chlorite, mica, plagioclase feldspar grains and specks of coal. The matrix was difficult to observe on account of greenish-grey staining, but appeared to be very fine quartz and calcite.

Colour Variations and Grain Size Changes in the Lutite Units

The colour of the lutite units is mainly reddish-brown except contiguous to the contacts with the sandstone horizons. The basal portion of the lutite units is generally medium grey, grading upward into reddish-brown tones. Towards the top of the units, the colour shows a gradual change to grey or, in cases where the proportion of organic matter is quite high, to dark grey. Colour changes from grey to reddish-brown, and that from brown to grey are generally gradual, but occasionally occur within a distance of less than one inch. In certain cases, several such alternations occur within a single lutite unit, for example Z 52.

In many of the reddish-brown lutite sections, local reduction of the iron oxide has led to mottling with greenish-grey specks and streaks, typically exemplified in unit Z 4. A.O. Hayes and H. Johnson (1938, p. 22) recorded similar phenomena from their Barachois 'series', which they termed "bull's eyes". In Z 4, the small greenish-grey spheres were observed to be hollow in the centre, and they did not appear to show any relationship with the calcareous concretions. The petrographic characters of the two types of lutite are as follows:

Reddish-brown Lutite: (Slide No. Z 72)

This specimen of reddish-brown lutite from unit Z 72 exhibits well-developed fissility, and effervesces slightly on addition of dilute HCl. It is fairly micaceous, the maximum grain diameter measured was ½ mm.

In thin section the rock was seen to consist predominantly of angular fine-grained quartz, with etched margins, and more rarely muscovite and chlorite grains set in a groundmass of richly stained clay minerals and very fine-grained calcite.

Grey Lutite (Slide Nos. Z 12 and Z 63):

Two samples of the grey lutite were thin-sectioned, one sample from unit Z 12 and the other from Z 63.

Sample No Z 12:

The hand specimen is medium-grey, finely laminated, very fine-grained lutite. It is extremely fragile, breaking with sub-conchoidal fractures across the laminae. Slight effervescence occurs on the addition of HCl.

The thin section, which had been cut normal to the lamination plane, showed that the rock is made up of a fine alternation of predominantly brownish calcite layers, alternating with layers containing predominantly clay minerals. The section also showed microscopic truncated cross-bedding which probably resulted in the sub-conchoidal fracturing patterns. Previous work by this writer had shown that the specimen contained abundant spores, and these could be seen under medium power (X 80) as very small dark-brown spots occurring in clusters generally confined to distinct laminae. There appeared to be no correlation with their presence and the composition of the laminae, spore clusters being observed in both calcite-rich and clay mineral-rich laminae.

Sample No. Z 63:

A hand specimen from unit Z 63 is slightly darker grey than from unit Z 12, and contains poorly preserved unidentified plant fragments. The specimen is poorly laminated and tends to fracture sub-conchoidally.

In thin section the texture was observed to be very fine-grained and a faint bedding could be seen. The rock consists predominantly of clay minerals with coaly specks, and infrequent very fine recrystallised quartz grains.

Sedimentary Features at the Contact of the Conglomerate-Sandstone Units with the Lutite Units

Channel Scour and Fill Structures:

Channel scour and fill structures frequently occur at the base of the conglomerate-sandstone units, with characteristic examples found at Z 121 and Z 97. (see fig. 8). The channels cut into the lutite are frequently filled by an intraformational conglomerate.

Petrography of Intraformational Conglomerate:

Samples of conglomerate were collected from the base of units Z 89, Z 105 and Z 125, and show the following characteristics:

The conglomerate contains dark grey pebbles, with a maximum diameter of 2 cm. coalified plant material, infrequent quartz pebbles and fairly abundant muscovite grains, with a maximum diameter of 3 mm. set in a light brownish-grey matrix. On addition of HCl, both the dark grey pebbles and the matrix effervesced, but the former more vigorously than the latter.

In thin section, the dark grey calcareous pebbles were observed to consist of a coarse-grained crystalline calcite nucleus surrounded by a layer of finer texture and different composition. (see fig. 9). This layer consists of fine-grained calcite which contains occasional small grains of coal restricted to distinct bands, and more rarely fine angular quartz grains with hazy recrystallised margins. In many cases this layer was seen to be incomplete as if flat limestone fragments had been folded over during transportation. This suggests that erosion and transportation occurred while the limestone was only partially consolidated, resulting in the formation of an intraformational conglomerate.

The matrix in which the pebbles are set consists of medium-grained quartz and microcline angular to sub-angular (etched at the margins), set in fine grained calcite. Strained quartz, muscovite, orthoclase and plagioclase feldspar grains occur rarely.

In some cases, for example Z 97 (see fig. 10), the intraformational conglomerate is entirely lacking, the channel fill comprises a coarse sandstone, commonly showing load casting along the contact with the channel edge.

Bedding of the Channel Fill Material:

Channel fill consisting of conglomerate and/or coarse sandstone generally showed bedding of the type considered by E. D. McKee (1957, pp.129-13 to indicate channel filling by means of a sub-fluvial moving current. (see fig.11 and 12) Channel filling by settling in quiet water results in bedding of the type shown in figure 13.

In a few localities only, such as Z 125, lutite fill occupies a channel cut into sandstone. The original bedding appears to be of a type similar to that shown in fig. 14 , but much of the original bedding has been destroyed by deformation, possibly the result of desiccation during the process of induration of the lutite.

Load Casting and Intrusion of Lutite:

At the basal contact of the conglomerate-sandstone units with lutite, load casting was frequently observed. In cases where channelling into the lutite had already occurred deformation in the inter-channel areas was frequent, often culminating in intrusion of the lutite into the unit above. Examples are illustrated in figures 15 and 16 .

Depositional Environment

Probable sedimentary and climatic environments prevalent during the deposition of rocks in the type section from Kennedy Point to Larkin Point are discussed below.

Sedimentary Environment:

Certain of the sedimentary features seen in the type section, suggest a fluviatile origin for the sediments. Cross-bedding, observed in all of the sandstone units, occurs abundantly in fluvial deposits, although P. E. Potter and F. J. Pettijohn (1963, p. 63) pointed out that it is found also in other major sedimentary environments i.e. littoral, marine and aeolian. Large coalified branches of trees, were observed deposited in the sandstone parallel to the general bedding plane, but cutting through cross-bedded structures. Such forms are indicators of fluviatile deposition, but are not inclusive to such an environment.

The frequent channel fill features, with their characteristic bedding are considered by the present writer to provide strong evidence in favour of a fluvial environment. Lower Devonian rocks with a similar lithological aspect have been described by J.R.L. Allen (1963, p. 194) from the Anglo-Welsh basin. He stated that:

> "each of the cyclothems is underlain by a scoured surface probably swept out through erosion at the floor of a wandering river channel. Erosion forms from these surfaces agree with those in the beds of modern rivers."

For similar cyclothems in the Anglo-Welsh basin Allen suggested (1963, p. 194) that the lutite units were the result of deposition by vertical accretion in floodplains from 'overbank' deposits carrying suspended 'fines'. Where rapid alternation of lutite and sandstone occurs deposition probably took place on levées and crevasse-splays.

Sedimentary features observed in the lutite units suggest periods of exposure. Desiccation cracks were frequently present and are considered to indicate exposure and probably non-marine deposition. C. O. Dunbar and J. Rodgers (1957, p. 200) stated: "In general, mud-cracks may be considered one of the best evidences of non-marine deposition."

The presence of calcareous concretions in the lutite is considered to indicate periods of exposure and fluctuation of the ground water table Allen (1963, p. 181).

The thin regular bedding suggests deposition under quiet conditions, though very fine truncated microscopic cross-bedding indicates the presence of weak currents. Thin beds, generally less than 6 inches thick, of flat-bedded ripple-marked sandstone commonly occur in the lutite horizons indicating an interruption of such conditions.

The bulk of the lutite units are reddish brown in colour, indicating the presence of ferric iron. Distinct grey beds are intercalated with the reddish brown lutite in many of the units, suggesting either the ferric iron has been reduced or removed by solution, or was lacking at the time of deposition. F. B. Van Houten (1961, p. 221) suggested that in some cases reduction of ferric iron was a factor of poor drainage, which in turn was partially controlled by the level of the water table, the probable fluctuation of which has already been mentioned in connection with the formation of calcareous concretions.

Occasionally the grey lutite beds are relatively dark on account of contained organic matter, the presence of which was confirmed when the samples were macerated for spores, although the actual proportion of such material was often quite low. This may be explained by the fact that decaying organic material results in the production of dark colloidal humus, which with its subsequent adsorption on clay mineral platelets leads to dark grey colouration.

Following Allen, three explanations may be suggested for the cyclic nature of the conglomerate-sandstone and lutite units:

1. Wandering of one or more rivers carrying a steady sediment supply over a large floodplain, which was gradually subsiding.

2. Changes in sea level, accompanied by steady subsidence and sediment supply, may have resulted in an alternation of periods of erosion and periods of aggradation of the floodplain. Channel wandering still occurred, but was not the fundamental cause of the cyclothems.

3. Cyclicity was controlled by bursts of tectonic activity in the source area, which led to alternating periods of erosion and deposition.

The first of these explanations seems, to the present writer, to be the most applicable here, but only a single section was available for detailed study, and the three dimensional relationships of the sediments needs to be determined before any definite conclusion can be made.

Climatic Environment

Red Beds were considered by early workers to be indicators of arid climate, but according to Pettijohn (1957, p. 629), Krynine has suggested that they indicate a climate with high precipitation (say 50 inches per annum) and high temperature (say 70-80°F annual mean). Desiccation cracks in the lutite units of the map area suggest the possibility of dry periods and/or seasons.

Coalified tree stems and small coal 'nests' in the sandstone units indicate a climate suitable for coal formation. Details of such climatic environments are, however, still speculative. Van Houten (1961, p. 122) stated: "estimates of the climate of Pennsylvanian coal measures in the northern hemisphere range from temperate to tropical, with the consensus favouring a rather warm climate."

From palaeomagnetic evidence A.E.M. Nairn and N. Thorley (1961, p. 179) considered the Carboniferous equator to pass through the southeastern part of Labrador, running from northeast to southwest.

Conclusions

The depositional environment of rocks of the Searston beds proposed from evidence in the type section from Kennedy Point to Larkin Point is fluvial deposition under a warm humid climate.

Chapter V

Searston Beds and Barachois Group of Inland Region

Introduction:

The regular alternations of conglomerate-sandstone units and lutite units found in the section from Kennedy Point to Larkin Point, persist to a considerable extent inland in the areas which have previously been mapped as the Barachois 'series' by Hayes and Johnson (1938, Map 4), and the combined Searston beds and Barachois Group of Baird and Coté (1964, fig. 1).

Limestone, arkose and chert beds, in addition to coal seams make an appearance in the inland region and their potential as marker horizons for field mapping was investigated. Recognition of such horizons is hindered by the lack of exposure along the coast south of Larkin Point, the general paucity of outcrop inland, and the frequent faults throughout the area.

In the process of this investigation, evidence was found indicating that the definition of the boundary of the Codroy Group and Searston beds as mapped by previous workers required modification. The proposed boundary is shown on Map 1 and discrepancies with previous maps are discussed in Chapter IX.

Potential Marker Horizons in the Searston-Barachois Strata

Five types of lithology are described below and details given of their location and stratigraphical relationships; and an assessment made of their potential as marker horizons.

Coal Seams:

These generally occupy thin lenses, and are difficult to use with any confidence as marker beds on account of their lack of persistence. Further statistical spore analyses need to be carried out before any detailed correlation of the seams in the area can be made. The early Pennsylvanian age for coal from Coal Brook and St. Andrews established by Hacquebard, Barss and Donaldson (1960, p. 238), suggests that in the map area, coal seams are definite indicators of the Barachois Group. Details of coal seams found are listed in the following section, from northeast to southwest, and the brooks listed are shown on Map 1.

Coal Brook:

Coal occurs within approximately 140 yards of the Long Range Mountains occupying two or three lens-like bodies showing no apparent lateral extension. The seam was described by Hayes and Johnson (1938, p. 28), who called attention to the shearing, fracturing and slickensiding in the area. The coal strata which strike 53° east of north and dip 70° to the southeast, are associated with light grey coarse-grained sandstones and grey shales and were found to contain an abundant spore florule (See F 13, Map 1).

John's Brook:

No coal seam was observed, although coal particles are abundant at locality (c) on Map 1.

Stevenson's Brook:

Three exposures of coal were found on this brook and the possible repetition of one of these seams by drag folding appears likely (See section A-A1.) The first seam crops out approximately 180 yards upstream from the Trans-Canada Highway bridge, and occurs in the following upright section:

30' 0" Reddish brown sandstone and lutite

0' 6" Coal seam.

12' 0" Grey to dark grey lutite and sandstone bands.

5' 0" Coarse grey sandstone

25' 0" Reddish-brown lutite, alternating with sandstone.

Approximate strike N 73°E, dip 25° to the south.

The second outcrop occurs approximately 725 yards upstream from the Trans-Canada Highway bridge (see F 14, Map 1) in the following upright section.

3' 0" Sandstone with intercalated lutite wedge.

15' 0" Lutite containing numerous thin (less than one inch) coal seams.

5' 0" Grey-brown silty sandstone with rusty specks.

Within approximately 25 yards of the Long Range fault contact a 6 inch coal seam occurs in the following upright section:

4' 0" Grey and reddish-brown sandstone and lutite.

0' 6" Coal seam.

17' 0" Coarse grey sandstone.

Bed strikes N 33°E and dips 70° to the northwest.

Mollychignic Brook:

No coal observed.

Overfall's Brook:

No coal observed.

Un-named Brook (Labelled L.C.$_1$ on Map 1):

No coal observed.

Big John's Gulch:

Approximately 280 yards downstream from the exposure of the crystalline rocks of the Long Range, a thin seam about one inch thick crops out in a medium grained calcareous sandstone. Exposure in the area is poor, but a considerable amount of faulting is evident. The seam strikes N 43° E and dips 45° to the southeast.

Campbell's Brook:

Little trace of the working on Campbell's Brook described by Hayes and Johnson (1938, p. 28) was found by the present writer. At the time of their investigation, the 30 foot shaft which had been sunk to mine the coal had largely collapsed. The coal apparently occurred in a coarse grey sandstone, but faulting in the area has made the prospect of little value.

Limestone Beds:

Thin beds of limestone were found infrequently throughout the area, and these are listed below from northeast to southwest.

Coal Brook:

Limestone beds crop out at two places on Coal Brook, the first a distance of approximately 450 yards upstream from the Trans-Canada Highway, and the second just prior to where the brook is joined by its tributary. (See Map 1). The first outcrop contains two separate beds of limestone associated with grey and reddish-brown sandy lutite. The lower impure limestone bed is 18 inches thick and 30 feet above its upper contact occurs the upper bed which is 40 inches thick. The latter is a light brownish grey colour, with dark grey streaks. Approximate strike is S 8° W, with a dip of 10° to the west. The second outcrop contains two limestone wedges associated with a reddish-brown lutite. Approximate strike is N 78° E, with a dip 25° to the south.

John's Brook:

The first outcrop of limestone noted in a traverse upstream, occurs approximately 730 yeards from the Trans-Canada Highway bridge. The limestone, which is arenaceous and associated with reddish-brown lutite, is 28 inches thick and occurs in a small localised outcrop in the following upright section.

3' 0"+ Reddish-brown lutite.

2' 4" Arenaceous limestone.

5' 0" Reddish-brown lutite.

6' 0"+ Reddish-brown and grey medium to coarse sandstone.

Approximate strike N 83° E, dip 35° S.

The second outcrop occurs 140 yards further upstream in the following upright stratigraphic sequence.

12' 0"	Dark grey and reddish-brown medium to fine silty sandstone.
2' 6"	Dark grey shaley siltstone.
2' 1"	Limestone with distinctive nodular nature.
12' 0"	Reddish-brown sandstone.
2' 6"	Limestone.

Approximate strike N 73° E, dip 35° S.

Stevenson's Brook:

No limestone was observed.

Mollychignic Brook (or Limestone Brook):

From the Trans-Canada Highway bridge, upstream for a distance of approximately 770 yards, thin limestone beds in the order of 4 to 6 inches are fairly frequent. They are intercalated with reddish-brown and grey lutite and sandstone alternations.

In thin section (Slide No. M_3), the limestone was observed to consist largely of cryptocrystalline calcite containing infrequent very angular strongly etched medium grained quartz grains. The limestone is cut by numerous fissures filled with limonite, and also contains infrequent concentrations of reddish-brown chert.

Un-named Brook ($L.C._1$ on Map 1)

Approximately 330 yards upstream from the Little Codroy River occurs a bioclastic limestone 42 inches thick, striking N 3° E and dipping 50° to the southeast. In thin section (Slide No. 1, $L.C._1$) it is seen that a large proportion of the rock comprises shell fragments and crinoid fragments (See F 8 on Map 1 and figs. 17 and 18).

Measurements of the upright section are as follows:

3' 0" Shaley Limestone
----Fault Contact-----

1' 0"+ Greyish shale and crumpled reddish brown lutite.

3' 6" Bioclastic limestone
-------Unconformity--------

4' 0"+ Reddish-brown mottled grey lutite.

A further 50 yards upstream a bed of limestone one foot thick occurs intercalated with reddish-brown and grey lutite.

Approximately 60 yards further upstream, a brecciated limestone occurs in the following upright succession.

3' 0"+ Brownish grey calcareous lutite.

1' 0" Brecciated limestone.

15' 0" Dark grey lutite.

A thin section (Slide No. 2, $L.C._1$) of the brecciated limestone showed a considerable variability in texture. The general aspect of the thin section suggests that the brecciated limestone consists of fragments of bioclastic limestone of the type found downstream.

Big John's Gulch:

Several beds of limestone, approximately four to six inches thick, occur about 550 yards downstream from the exposure of the Long Range crystalline rocks (See Map 1). One of these beds contains small unidentified shell fragments.

Little Codroy River:

Close to the point where Big John's Gulch enters the Little Codroy River, but on the opposite bank, a limestone bed at least 10 feet thick crops out. This bed contains abundant reddish-brown chert nodules, which are mainly confined to a distinct band approximately three inches thick. The limestone rests on reddish-brown lutite and the upper contact is not exposed.

Bedded Chert:

The presence of nodular chert in many of the limestone beds was noted in the previous section, but bedded chert was recorded from only two localities, separated by a distance of two miles.

In the channel of the Grand Codroy River, bedded chert crops out close to the west bank at a point approximately $2\frac{1}{4}$ miles downstream from the mouth of Mollychignic Brook, (See reference number Ct_1 on Map 1). The other outcrop occurs in a cliff exposure on Mollychignic Brook (See Ct_2 on Map 1).

The potential use of this lithology as a marker horizon or possibly as an arbitrary boundary for the Codroy Group and Searston beds is discussed on page 51.

A detailed description of the two exposures follows:

Grand Codroy River Exposure: (Ct. 1)

A small isolated local outcrop only was found in the channel of the Grand Codroy River. The bed of chert is approximately one foot thick and strikes N 36° E and dips 45° to the southeast. Contacts with contiguous beds are not exposed, but a small amount of digging disclosed that the chert is in contact with sandy lutite both above and below.

The bed is made conspicuous by its distinctive jointing and weathering. Two sets of joints, intersecting at an angle of 60°, are developed normal to the bedding plan (See fig.19). The weaker set is approximately parallel to the strike, and the stronger set thus makes an angle of 30° with the true dip direction. Spacing of the joints in the latter set is at about $\frac{1}{2}$ inch intervals.

During the process of weathering, the chert tends to break up into small rhomb-shaped blocks, whose dimensions are controlled by the joint pattern. The weathered surface of the chert has a distinctive vitreous lustre and is brownish black in colour, in contrast to the dull dark grey of a fresh surface. The top $\frac{1}{4}$ to $\frac{1}{2}$ inch of the bed is composed of a micro-breccia which contains angular fragments of chert (maximum diameter 1/10 inch), imbedded in a fine grained recrystallised quartz matrix, which is of a lighter grey colour than the chert. The matrix is less resistant to weathering than the chert, with the result that differential erosion has given the top surface of the bed an irregular knobbly appearance.

A thin section of the chert (Slide No. Ct_1.) indicated textural dissimilarities within the bed, in the form of fine grained globular concentrations of partially recrystallised quartz set in a cryptocrystalline matrix, possibly suggesting that irregular lithification of the original silica gel occurred. Silicified plant tissue with good preservation of the internal cellular structure was seen, but examples also were noted where this detail had been destroyed by recrystallisation, although the material was still recognisable as a gross plant pseudomorph. Spherulites and small amounts of very fine interstitial calcite are rare. Limonite staining peripheral to the globular masses occurs frequently (See fig. 20).

Mollychignic Brook Exposure (Ct. 2):

At the point of outcrop marked as Ct_2 on Map 1, a steep river cliff has been cut in the northeast bank of the brook by the recession of a small waterfall. The chert bed, which is exposed towards the top of this cliff, is approximately one foot thick, with a strike identical to that of Ct_1 (N 36° E) and a dip 55° to the southeast. The vitreous lustre of Ct_1, possibly acquired from frequent submergence by the waters of the Grand Codroy River, is lacking on the dark grey weathered surface of Ct_2. A fresh surface of Ct_2 is medium to dark grey in colour.

Contiguous beds consist of poorly consolidated deeply weathered micaceous medium-grey lutite, with patchy brown iron staining. They contain unidentified fragmentary plant debris. The basal contact of the chert bed is sharp, but the upper contact shows a gradual rhythmic introduction of argillaceous material in the top $\frac{1}{4}$ to $\frac{1}{2}$ inch, which would appear to take the place of the breccia described for the upper surface of Ct_1.

In thin section (Slide No. Ct_2), a considerable amount of silicified plant debris is evident, and as in Ct_1 recrystallisation has occurred in some cases. The texture is generally cryptocrystalline with infrequent angular quartz grains and spherulites, although towards the top of the bed and within the layer which shows the gradational introduction of argillaceous material, fine grained calcite fills cavities and cracks. Irregular fissures containing limonite occur throughout the section (See fig.

<u>Proposed origin for the Chert Beds Ct1 and Ct2:</u>

Six lines of evidence suggesting a possible mode of origin are described in the following section:

1. Organic matter preserved in the chert appears to be confined to fragments of plant tissue, and precipitation of the chert as an organic accumulation from siliceous shells and skeletons appears unlikely.

2. Contained plant tissue frequently shows preservation of the cellular structure, indicating that silica replacement occurred relatively quickly previous to any significant decay.

3. The thickness of the limited outcrops found is constant. No stringers, discordant structures or lateral decline of the beds into nodular formation was seen.

4. Bedding of the chert was observed in both cases, but is generally faint.

5. In both chert beds recrystallisation, indicated by plant pseudomorphs and spherulites, has taken place. In the past, the latter have been attributed to late recrystallisation features of a colloidal gel, but F. J. Pettijohn (1957, p. 202) pointed out that experiments show that no such gel stage is necessarily implied.

6. Sedimentary evidence exists in both examples favouring a contemporaneous formation of the chert. Firstly the micro-breccia found at the top of Ct_1 indicates that the silica was indurated and subject to erosion previous to deposition of the overlying lutite, strongly suggesting primary origin of the chert.

In Ct_2, the intercalations of argillaceous material with the chert indicates a possible transition from conditions suitable for chert formation, to those favouring the deposition of lutite.

Conclusions concerning the Chert Beds:

The evidence outlined above is considered by this writer to indicate a probable primary origin for the chert beds, and their presence serves as an indicator of geographical conditions at that time. W. H. Twenhofel (1950, p. 409) stated that silica can be chemically precipitated where fresh and salt waters mingle, and suggested that Mid-Continental Pennsylvanian cherts were formed in this manner. Pettijohn (1957, p. 463) challenged this statement and claimed that in many cases no such correlations can be proved. He also mentioned work by Correns, which has shown that concentrations of silica considerably greater than those in present day streams, cannot be flocculated by any known inorganic agent, strongly suggesting that precipitation was by biochemical agents. H. J. Bissel (1959, p. 177) however, gave definite evidence of silica deposition in modern sediments and stated:-

> "Today jell-like masses of pure to impure silica are forming in recent miogeosynclinal sediments of the Gulf Coast, in the Mississippi River delta. The writer observed numerous of these "gobs", blebs, and irregular masses forming in shallow depressions in brackish and marine waters on the delta."

He also called attention to the fact that Russell et al. considered these siliceous masses to have resulted from flocculation.

Thus it would appear that the evidence favours a deltaic environment subject to flooding by the sea and consequent chemical precipitation of the silica where mingling of fresh and salt water took place. Such a mode of formation would lead to only local significance of the bed as a marker horizon, because the site of deposition would be constantly changing with migration of the delta front.

On the other hand, chert beds were found exposed only in two localities. The strike and thickness of both chert outcrops are identical, and the dip showed a discrepancy of only ten degrees. It therefore seems probable that both these exposures are outcrops of the same chert bed (See Map 1). The age of the chert beds was not determined with any certainty, no spore florule being found in the chert or immediate contiguous beds, but general stratigraphic relationships are shown on section B-B^1.

Nevertheless on Map 1, for lack of any other evidence, the chert bed is used arbitrarily as marking the top of the boundary of the Codroy Group and Searston beds, but this is essentially speculative.

Arkosic Sediments:

Reddish arkosic type sediments, alternating with reddish-brown and/or sandy lutite units occur abundantly especially in the region of Overfalls Brook, and its tributary. Individually, the units show marked lateral wedging and thus their use as a marker horizon must be their gross stratigraphic relationship with contiguous strata. Their arkosic nature appears to be the direct result of the proximity of granitic bodies within the Long Range.

Boulder Bed:

A detailed description of a boulder bed considered by previous workers to be Carboniferous in age is given by G. Phair (1949, p. 87-88). It occurs in contact with crystalline rocks at the mouth of Trainvain Brook, and is exposed for about ½ mile along the coast to the southwest, where the outcrop is terminated by fault contact with the crystalline rocks.

The unit appears to be of local significance, and its relationship with other Carboniferous strata obscure. This writer could find little evidence either to substantiate or contradict a Carboniferous age.

General Conclusions

The faulted nature of the inland section and lack of coastal exposure makes the recognition of marker horizons difficult. The beds described above are generally unsuitable in that they are either too thin and/or laterally lacking in persistence.

Chapter VI

Palynological Techniques

Introduction:

In the following chapter, techniques used for the separation of spores, their concentration and making of permanent mounts are described.

Technical Procedure for Separation of Spores:

1. The sample was washed in tap[1] water and cleaned thoroughly.

2. It was then broken up in a pestle by a mortar or, if poorly consolidated, with a hammer on a flat clean surface, until the fragments were approximately pea-sized. Finer grinding appeared to damage contained spores.

3. The material next was tested with a drop of dilute HCl to determine if it was calcareous. If effervescense occurred, approximately 5g of the sample was placed in a beaker and covered with dilute HCl. Highly calcareous samples required more than one acid treatment. Where calcareous material was not completely leached, it later caused a violent reaction on addition of Schulze's solution (See Stage 8).

When action with the dilute HCl ceased, the contents of the beaker were poured into 50 ml test-tubes and centrifuged[2] for 5 minutes. The supernatant liquid was then poured off. The residue was washed with water

[1]The reservoir of the water supply is located in Precambrian rocks.

[2]Apparatus used listed in Appendix A.

three times using the same method, and then transferred to a Teflon beaker placed in a chemical hood.

4. HF (approximately 52% Technical Grade) was added and the beaker placed on the hot plate which could also be mechanically agitated. A temperature of 45°F was maintained and the hot plate agitated periodically to mix thoroughly the contents of the beaker. The length of time required for the acid to dissolve constituent silicates varied with the rock composition, ranging approximately from one to six hours. In the case of highly silicified rocks, more than one acid treatment was necessary.

5. The contents of the beaker were diluted with tap water, which prevented excessive test-tube corrosion, and assisted in the segregation of spores when the liquid was centrifuged.

6. The diluted sample was centrifuged and clear supernatant liquid decanted. The residue was then washed three times.

7. At this stage the sample was tested in the following manner to determine the necessity for oxidation. A drop of 5% KOH was added to a drop of residue on a glass slide. If constituent organic matter dissolved and gave the liquid on the slide a brownish cast, treatment with an oxidising agent was considered unnecessary, i.e. in the case of weathered coals already oxidised in nature. On the other hand lack of such brownish colouring indicated the need for oxidation.

8. In order to oxidise the samples, either Schulze's solution, or a solution made by saturating nitric acid with chromic anhydride was used.

The former agent most frequently was utilized, although the latter, which is more active and thus time saving, was used for several samples.

Schulze's solution, first used by Franz Schulze in 1855, is made by adding two or three parts of cold concentrated nitric acid to one part of a saturated solution of potassium chlorate. The reaction of Schulze's solution in the presence of an oxidisable substance such as coal is given by R. M. Kosanke (1950, p. 9) as:-

$$2HNO_3 + KClO_3 \longrightarrow 2NO_2 + KCl + H_2O + (4O)$$

Coal is oxidised in the following reaction:-

Coal + Oxygen i.e. (4O) from Schulze's solution yields partially oxidised coal, i.e. oxides of carbon, water, soluble muds, humic acids, etc.

9. A small quantity of the liquid was first washed free of oxidising agent with water and then the necessity for further oxidation was determined by repeating the method described for Stage 7. If, with the addition of a drop of 5% KOH to the washed residue, a brown colour was imparted, then oxidation had taken place to some extent. The presence or absence of spores could now be determined by microscopic examination, and if a sufficient number had been released, the bulk of the residue was washed three to four times.

10. At this stage a base was added (5% KOH), which dissolved the humic acids resulting from the action of the oxidising agent.

R. M. Kosanke (1950, p. 10) gives the reaction with the base as follows:-

Partially oxidised coal + H_2O + KOH ⟶ Soluble portion (salts of humic acids) / Insoluble portion (preserved botanic ingredie[nts])

During this stage of the maceration precaution was required in order to neither destroy nor significantly etch the spores, especially those possessing a thin cingulum. Basic chemical over-activity was prevented by periodic examinations of the material under the microscope. The time required for treatment with the base varied from several minutes to several hours.

11. After the treatment with a base was complete, the sample was washed repeatedly, until water added to the residue remained clear.

In most of the samples spores were not abundant and there was a necessity for further concentration. The method used is described in the next section.

Spore Concentration Procedures.

Two concentration methods were employed, one a heavy liquid separation method and the other utilising detergent. In most cases only the former procedure was necessary, but in some samples the additional use of the latter technique yielded improved concentrations. The detailed procedures follow:-

12. With completion of stage 11 described in the previous section, a

portion of the residue was transferred to a 50 ml tube, centrifuged and the water completely decanted.

13. **Onto** the water-free residue was poured a saturated solution of zinc chloride. (It was found that if the residue was not water free, the specific gravity of the heavy liquid was lowered quite considerably.) The test-tube was approximately half filled with heavy liquid and placed in the ultrasonic generator for five to ten minutes, which allowed thorough mixing, broke up coagulated particles, and separated adhering matter from the spores. No damage to the fossils appeared to result from ultrasonic treatment, although according to J. J. Funkhouser and W. R. Evitt (1959, p. 371), thin walled and brittle forms can be destroyed.

Zinc chloride was recommended for heavy liquid separation by Funkhouser and Evitt (1959, p. 371), and was used extensively by the present writer. J. B. Urban (1961, p. 191) has demonstrated however, that zinc chloride can have a corrosive effect on the fossils, unless processing is carried out quickly. He suggested, as an alternative chemical, stannic chloride, which has a maximum specific gravity of 1.97 compared with 1.96 of zinc chloride. He also recommended a specific gravity of 1.55 for the initial separation, and the present writer found this value generally gave good separations.

14. The contents of the test-tube were then poured into a flexible transparent plastic tube, $9\frac{1}{2}$ inches long and with a 3/8 inch diameter. The tubing was filled to such a level that after it was folded into a

closed U shape, the liquid came to within [illegible] inch of the two open ends. (See Fig. 22).

The tubing was then inserted into a 50 ml test-tube and centrifuged at approximately 1,500 r.p.m. for about 15 minutes. Organic matter and fossils rose to the top of the tubing, and clamping beneath this level permitted the concentrate to be poured into 15 ml pointed test-tubes.

15. A drop of dilute HCl was then added to prevent the formation of zinc hydroxide, a white precipitate, which would otherwise form when zinc chloride was diluted with water. Dilution of the heavy liquid resulted in a lowering of the specific gravity, thereby allowing the spores to sink. The liquid was then decanted and the redidue washed three to four times with water. Each wash, with the exception of the last, was accompanied by the addition of a drop of dilute HCl. In most cases the sample was then ready for permanent mounting, although stage 16 also was required on occasion.

16. In a few of the samples, some colloidal material remained in the final residue. This was removed by using a method similar to that suggested by T. A. Bond (1964, pp. 212-213) for removing microfossils from clay. A portion of the residue was transferred to a 15 ml pointed test-tube, centrifuged, and all the water decanted. The tube was then filled with a solution made up by adding 10g of Alconox to one gallon of water. It was then placed in the ultrasonic generator and agitated for

approximately five minutes and then centrifuged at 2,200 r.p.m. for two minutes. It was found that colloidal matter present stayed at the top of the tube and spores went to the bottom. The colloidal matter and solution were then decanted and the remaining residue washed twice. This sample was then ready for making permanent mounts.

Slide making technique:

1. A drop of the concentrated residue was placed on a cover glass (22 x 30 mm), smeared evenly over the surface to within approximately $\frac{1}{2}$ cm of the margin, and allowed to dry. Dust contamination was prevented by placing the cover glass in a chemical hood.

2. A portion of glycerine jelly was warmed on a watch glass until liquid, and the dry smear covered with a thin layer, which was then allowed to reset to a jelly. A thick preparation was found to be unsatisfactory because it limited the number of spores which could be observed under the higher magnification of a microscope and resulted in the objective touching the cover glass before definitive focussing could be attained. In addition, the number of spores for which the higher magnification could not be used tended to increase as migration took place within the glycerine away from the cover glass. This could only be prevented by inconvenient storage with the cover glass facing downwards. Migration also impeded relocation of individual forms, and was best prevented by keeping preparations as thin as possible.

Chapter VII

Results of Palynological Investigation

Introduction:

In the following chapter, the results of the palynological investigation are described and samples which were found to contain spores are listed. Identification of spores was at the generic level except in one case in which a species determination was possible.

Results Obtained from Macerated Rock Samples:

Rock samples for spore analyses were collected from a wide variety of lithological types in the Codroy Valley. A total number of eighty-eight samples were macerated but only nine of these were found to contain spores, although heavy liquid flotation recovery techniques were extensively used. Spore bearing lithologies were found to include: bioclastic limestone, macrofossiliferous calcareous dark grey lutite, slightly calcareous medium-grey lutite, coarse-grained sandstone (spores rare), and coal. Spores were not found in reddish-brown and greenish-grey lutite, neither in reddish-brown and greenish-grey sandstone, nor in those limestone lacking macrofossils, nor in fine-to medium-grained sandstone, and not in chert.

In three, of the nine samples described above as productive, spores occurred very rarely and these three would appear to be of little use for accurate dating as assemblage are generally required. From permanent mounts of the six remaining samples, generic identifications of contained spores were made and photomicrographs taken.

With the assistance of L.R. Wilson, Research Professor of Geology, University of Oklahoma and M.S. Barss of the Geological Survey of Canada, the following spore determinations were made.

Fossil Locality F_2 (See Map 1):

The sample is composed of calcareous, dark-grey lutite, and contains a macro-fauna with an age equivalent to Windsor B or possibly C (see page 85).

Spore genera:

*Convolutispora sp.

Lophotriletes sp.

Lycospora sp. (see Fig. 23)

Reticulatisporites sp. (see Fig. 24)

Verrucosisporites sp.

*Concerning Convolutispora sp., Barss stated that there were present " ... numerous specimens of a type common to the Windsor Group. This type is like a Convolutispora, but is yet undescribed".

Barss considered the assemblage to be equivalent to Windsor in age.

Fossil Localities F_{10} and F_{11} (see Map 1):

Both samples were of similar rock type and were collected from the Searston beds. They comprised slightly calcareous medium grey lutite.

Spore genera:

Convolutispora sp. and also Convolutispora of the undescribed type listed from F_2.

Endosporites micromanifestus (see Fig. 25)

Lycospora sp.

Perotriletes sp.

Raistrickia sp. (see Fig. 26)

Barss considered the age indicated by the spore florule was probably equivalent to the Canso Group (Namurian A).

Fossil Localities F_{13} and F_{14} (See Map 1):

Coal samples collected from Coal Brook and Stevensons Brook respectively.

Spore genera:

**Calamospora sp.* (see Fig. 27)

Cirratriradites sp.

**Densosporites sp.* (see Fig. 28)

**Knoxisporites sp.*

**Leiotriletes sp.*

**Lophotriletes sp.*

Lycospora sp.

Punctatisporites sp.

Raistrickia sp. (see Fig. 26)

**Savitrisporites nux* (see Fig. 30)

**Schopfipollenites sp.*

Waltzispora sp. (see Fig. 29)

*Forms marked by an asterisk were present on slides examined by Barss, who stated that

"In comparison with our standard assemblages, this assemblage is the same as the Coal Branch, St. Georges and Howley Coal (Westphalian A)."

General Conclusions:

Spore assemblages were found in rocks from the Codroy Group, Searston Beds and Barachois Group. As far as this writer is aware, localities F_2, F_{10}, F_{11} and F_{14} have not previously been recorded as containing spores.

Chapter VIII

Fauna Collected and Identified from Map Area

Introduction:

The fauna comprises the following:

Mollusca:

Gastropoda. 5 genera, 7 species.

Pelecypoda. 5 genera, 5 species.

Cephalopoda. 1 genus, 1 species.

Brachiopoda:

1 genus, 1 species.

Arthropoda:

Ostracoda. 2 genera, 2 species.

Trilobita. 1 genus, 1 species.

Echinodermata:

Crinoidea. Fragments only.

Vertebrata:

Bone fragments.

Trackways.

Description of Fauna:

PHYLUM MOLLUSCA

GASTROPODA

Bucanopsis beedi Bell

(See Fig. 33)

Description:

Body whorl and apertural lips expanded laterally. Maximum diameter exceeds height. Umbilicus small, junction of external and umbilical margins abrupt. Longitudinal keel 1mm wide near the aperture, raised and flattened medially. Fine thread like striae preserved rarely. Specimens are crenulated microscopically by growth lines, and crossed by broader growth lines which bend sharply away from the aperture at the keel.

Dimensions:

Height 20mm, maximum diameter 22 mm. Aperture 15 mm high.

Horizon and Locality:

Specimens found at F 6 in beds of the Codroy Group, close to the fault contact with the Searston beds in Capelan Cove.

Reported by Bell as common in Windsor subzone E of the Horton-Windsor district of Nova Scotia.

Bucanopsis sp.

Description:

This form appears to be almost identical to Bucanopsis beedi with the exception that near the apertural margin, the longitudinal keel occupies a depression, which deepens aperturally.

Horizon and Localities:

The specimen described as Bucanopsis sp. was found in association with a fauna considered by this writer to be equivalent to Windsor subzone B or C at locality F.

Bell stated, in personal communication, that he found a form similar to Bucanopsis beedi in rocks of Windsor subzone B or C of the Pugwash district of Nova Scotia.

Bulimorpha maxneri? Bell

(See Fig. 34)

Description:

Fusiform shell consisting of 5 whorls. The whorls are compressed with sutures slightly channelled. Aperture not seen. Fine convex growth lives visible only on body whorl.

Dimensions:

Shell height 13 mm (c.f. 6mm in Bell's description).

Greatest diameter, 5mm. Height of last whorl 7mm. Apical angle about 55 degrees.

Remarks:

The shell height is approximately twice that of Bell's description, but with this exception, the specimen compares well.

Horizon and Locality:

One specimen only from locality F_1.

Bell reported this species to be common in Lower Windsor subzone B of the Horton-Windsor district of Nova Scotia.

Murchisonia gypsea Dawson

Bell's emended description: (1929, p. 173)

"Shell small, conical, composed of 10 or more whorls that are convex and somewhat depressed at the sutures, contiguous or overlapping slightly, umbilicate. The surface features are indistinctly exposed on the smooth, internal moulds of the shell, but 4 revolving ribs are indicated, the 2 most prominent enclosing a median band."

Dimensions:

Length, 7.5 mm., width of body whorl, 2.6 mm., apical angle about 18 to 20 degrees.

Remarks:

The present writer's identification of this species from locality F_2 was confirmed by Bell (personal communication).

Horizon and Localities:

Specimens were found at F_1, F_2 and F_5.

Bell considered that this form indicated that a Windsor subzone B age was slightly favoured to that of subzone C.

Murchisonia (*Stegocoelia*) *compactoidea*? Bell

Description:

Conispiral shell small. Composed of six (?) whorls, separated by deep pronounced sutures. There are 4 prominent angular revolving carinae on each whorl, approximately equidistant, but the space between the first and second that lie below the suture, a little wider. The strongest of the 4 keels lies slightly above the centre line of the whorl. A fifth very small keel is barely visible below the suture line. (This was seen only on the second whorl of the specimen studied). Indistinct growth lines in the form of a narrow sinual curve are found between the main keel and the next prominent one above. The specimen studied by this writer also showed similar very indistinct growth lines between the main keel and the one below.

Dimensions:

Length, 5.5 mm? (Tip of spire broken, consequently apical angle not measured, but for this species Bell's description states approximately 30°.)

Horizon and Locality:

One specimen only was found at F_1.

This species was recorded by Bell as abundant in the Lower Windsor subzone B of the Horton-Windsor District of Nova Scotia.

<u>Naticopsis</u> <u>howi</u>? Dawson.

(See Fig. 35)

Description:

Low spired shell consists of 5 adpressed whorls. The adapical portions of the body whorl are depressed near the suture. Outer lips of aperture strongly prosocline. Fine growth lines well developed on specimen.

Dimensions:

Height 7.5 mm, maximum diameter 8 mm. Apical angle approximately 115 degrees.

Horizon and Locality:

One specimen from F_1. Recorded by Bell as abundant in Windsor subzone B of Horton-Windsor District, Nova Scotia.

Platyshisma? dubium? Dawson

(See Fig. 39)

Description:

Naticiform shell, low spired, adpressed with 5 whorls. Phaneromphalous, about one half the height of early whorls enveloped by subsequent ones. Growth lines poorly preserved on specimen studied, but gently convex.

Dimensions:

Height not measured as specimen incomplete; greatest diameter of body whorl, 9 mm; apical angle about 100 degrees.

Remarks:

Specimen lacking abapical portion of body chamber.

Horizon and Locality:

One specimen from F_1. Recorded as common by Bell in Windsor subzone B Horton-Windsor District, Nova Scotia.

PELECYPODA

Edmondia? hartti? Dawson

Edmondia hartti Dawson, Acad. Geol., 1868, p. 303, fig. 104.

Original Description:

"Transversely oblong, flattened, regularly rounded posteriorly, marked with very coarse concentric lines of growth...... Length 1 6/10 inches, breadth 8/10 inch."

Remarks:

The identification of this form is tentative as all specimens collected were fragmentary and in no instance was the hinge area preserved.

Horizon and Locality:

This form is fairly common at F_1. Bell recorded it as rare in Windsor C and D of Horton-Windsor District, Nova Scotia.

Sanguinolites striatogranulatus Hind

(See Figs. 36 & 37)

Description:

Shell transversely elongate, subrectangular; anterior end narrowly rounded; inferior margin, flatly convex, sub-parallel to dorsal margin; posterior-inferior angle approximately 90 degrees, but well preserved, in only one specimen. The posterior margin about midway in its course curves forwards to meet the hinge line in an obtuse angle of about 140 degrees. The hinge line is nearly straight towards the posterior. Umbones small, contiguous little raised above hinge line, apices directed anteriorly.

Greatest tumidity of the valve along a narrowly rounded elevation, running obliquely from the umbone to the postero-inferior border: the surface anterior to the elevation is depressed. The carinae mentioned by Bell (1929, p. 153) were not seen. The dorsal margin of the shell is bordered by a large escutcheon.

The coarse concentric ribbing noted by Bell in the internal moulds was seen in the two larger specimens, but was less well developed in the smaller.

Dimensions:

Largest specimen found was approximately 48 mm in length and with a height of 22 mm.

Remarks:

One of the specimens collected from F_2 was identified by Bell as probably Sanguinolites parvus?, but the possibility that it was a young S. striatogranulatus could not be entirely eliminated. (Personal communication from Bell).

Locality and Horizon:

Two specimens were found at locality F_{1a}, which showed similar dimensions to the large form listed by Bell (1929, p. 153). Bell recorded S. parvus as abundant and S. striatogranulatus as rare in Windsor subzone B of the Horton-Windsor District, Nova Scotia.

Schizodus fundiensis? n. sp. Bell
(See Fig. 38)

Description:

Anterior margin of shell gently convex, rounding insensibly into the superior margin but more abruptly into the inferior margin. Posterior margin fractured in all three specimens studied by the present writer. Approximately three-fourths of the shell is tumid, the greatest tumidity lying below the umbones; the remaining fourth comprising the postero-superior corner is depressed and concave. The depression takes place suddenly, but without distinct angulation. Umbonal angle about 90 degrees. Beaks acute, inclining slightly forwards, and rising slightly above hinge-line.

Dimensions:

These were taken of the most complete specimen and are: Length 15 mm.; height 11 mm.

Horizon and Locality:

Three specimens from F_1.

Bell recorded this form as rare in the Windsor subzone B of the Horton-Windsor District, Nova Scotia.

Leptodesma? sp?

Description:

Right valve only found, margin incomplete. Shape sub-rhomboidal. Hinge line straight. Anterior margin broadly rounded, posterior margin incomplete. Umbone close to anterior margin. A narrowly rounded elevation runs from the umbone to the posterior inferior margin, making an angle of approximately 45 degrees with the hinge line. Shell marked by fine concertric growth rings which are deflected sharply at the narrowly rounded elevation.

Dimensions:

Length approximately 8 mm, height approximately 7mm.

Remarks:

The incomplete nature of the specimen makes identification uncertain.

Horizon and Locality:

One specimen was found at F_1.

Bell recorded the genus Leptodesma as being restricted to the Lower Windsor in the Horton-Windsor District, Nova Scotia.

CEPHALOPODA

Orthoceras? vindobonense? Dawson

(See Fig. 40)

Description:

Fragmentary form, which has undergone compression. Form probably sub-circular previous to compression. Specimen studied was 3 cm long, with a diameter tapering from 22 mm to 10 mm. The apical portion not preserved, but apical angle calculated as 25 degrees. Septa fairly distinct and approximately 2 mm apart where the diameter is 10 mm.

Siphuncle barely visible, but sub-marginal.

Horizon and Locality:

One specimen found at F_1.

Bell recorded this form as common in Windsor subzone B of the Horton-Windsor District, Nova Scotia.

PHYLUM BRACHIOPODA

Spirifer nox? Bell

(See Fig. 41)

Spirifer nox Bell, Geol. Surv. Can. Mem. 155, p. 137, Plate XXII figs. 10, 10a, 10b. (1929).

Description:

Shell wider than long. Greatest width along the hinge line. Cardinal extremities acute. Pedicle valve only found. Valve gibbous with greatest tumidity of valve near middle in umbonal regions which is narrowly convex transversely, and extends beyond the hinge line. Antero-lateral slopes regularly convex. The convexity along the median line of the sinus increases markedly from the anterior border to the beak, which is narrowly incurved. The sinus begins near the beak and continues over the umbone as a narrow groove flattened at the bottom. The anterior portion of the grove is not well exposed and slightly fractured, but broadening and deepening is evident. In the sinus a median costa was observed in the umbonal region, but was not preserved towards the anterior. Ten costae occur on each lateral flank and no bifurcation was noted. Two faint costae were seen on the nearly smooth, postero-lateral extremities. The costae are depressed rounded. The surface is marked by fine undulating growth lines and 2 coarse concentric ribs, resulting in an imbricating ornamentation. Cardinal area not well preserved.

Locality and Horizon:

One specimen from locality F_7.

Hayes and Johnson recorded S. sp c.f. Spirifer nox from the Woody Cove Shale. Bell listed this form as common in the Windsor subzone E, of the Horton-Windsor District, Nova Scotia.

PHYLUM ARTHROPODA

OSTRACODA

Glyptopleura sagae? Cooper

Remarks:

This form was tentatively identified by the present writer as *Glyptopleura bicarinata*. H. W. Scott who compared the material with the types stated:

> "In regard to Glyptopleura: I compared your material with the types; they are very close to *G. bicarinata*, the only difference is that the dorsal costa along the dorsal margin is slightly more strongly developed in your specimens. I would consider this to be within the range of variability. In addition, your material is very close to *G. spinosa* Jones and Kirkby (see Cooper, C., Rept. Invest. 77, pl. 7, 1941) Again the dorsal costa on yours is stronger. However, the species *G. sagae* (Cooper pl. 7, fig. 38-39) is almost identical. *Sagae* is from the Clore, *spinosa* is from the Menard, *bicarinata* is from the Otter of Montana. Of these, your specimens are closest to *sagae*, however, the similarity of the three species is so great that they could be varieties of the same thing. In other words the age is certainly Chester, certainly Late Chester, and most likely Menard-Clore."

He also considered that their presence indicated marine, normal-salinity, shallow water.

Horizon and Locality:

W. A. Bell called attention to the fact (personal communication) that *Glyptopleura sp.* occurs in beds of Windsor late subzone B or early C in the Amherst area. The forms found by the present writer occur abundantly in a thin band approximately two inches thick at F_5. H. W. Scott suggested (personal communication) that a study of the instar stages might be fruitful.

Paraparchites sp.

The specimen identified by H. W. Scott belongs to the group P. kinkaidensis .... P. ovatus (Kinkaid-Clore). Specific identification was impossible on account of the single specimen which was eroded in its dorsal area. Scott stated: "...but I can say that this type of Paraparchites is limited to the Middle Mississippian to Late Mississippian. I believe this specimen to be Late Mississippian and probably Late Chester, possibly Clore-Kinkaid."

The specimen indicates a marine, normal-salinity, shallow water environment.

Horizon and Locality:

Specimens fairly common at F_1.

Hayes and Johnson (1929, p. 19) recorded Paraparchites gibbus from the Codroy Group along with a fauna considered by Bell to indicate a Windsor subzone B age.

TRILOBITA

Phillipsia eichwaldi Fischer

(See Fig. 42)

Description:

Pygidium with semi-elliptical outline, strongly convex in longitudinal and transverse plane. Width of the anterior margin 9mm, length 9mm. The axis which is depressed convex is very prominent, occupying about 1/3 of the width and with a length of 7.5 mm. It tapers gradually and uniformly towards the obtusely rounded apex. There are 16 axial rings, although segmentation is more crowded and obsolete towards the rear. Each axial ring contains 8 to 9 small tubercles irregular in size and shape, but generally confined to the posterior margin in the middle third of the ring, though their position is more difficult to establish towards the rounded apex. The pleural field contains 11 ribs, the last two indistinct. Slightly curved pleural furrows occur on the first 5 ribs in the outer third of their length. They are deeper when the ribs contact the border, and progressively weaker inwards. Very small tubercles occur on the ribs. In the inner 2/3 approximately 8 occur towards the posterior margin and then appear to bifurcate and become smaller and obscure either side of the pleural furrows. The smooth border is approximately $\frac{1}{2}$ mm wide at the anterior increasing to 1 mm at the posterior. On the posterior third of the pygidium there is an obscure shallow groove along the inner edge.

Remarks:

Of the three specimens found, two were complete pygidia, and the third comprised a badly fractured portion of a cranidium.

Horizon and Locality:

The specimens were found in the Codroy Group at locality F_6, close to the fault contact with the Searston beds (See Map 2). Hayes and Johnson (1929, p. 14) recorded P. eichwaldi from the Woody Cove shale, associated with a fauna which, they suggested, correlated with subzones D and E of the Windsor area, Nova Scotia. Bell reported the form to be common in Windsor subzone E of the Horton-Windsor District, Nova Scotia.

PHYLUM ECHINODERMATA

CRINOIDEA

Description:

The crinoid material found comprises portions of the column, fragments tentatively identified as roots, cirri and pinnules, and isolated rectangular plates considered possibly to represent portions of the calyx.

The longest portion of column was found at locality F_1.

Dimensions:

Length 25 mm, comprised of 21 columnals. The column is circular in cross section, and has a diameter which grades from 6 mm at one end to 4 mm at the other, so that the column is tapered along its length.

At locality F_8 crinoid fragments are abundant in a bioclastic limestone. When this limestone was thin sectioned (Slide No. 1, $L.C._1$), it was seen to consist largely of very small crinoid fragments and occasional shell fragments. Small rectangular shaped plates with a maximum length of about 0.5 mm also occur, and these were identified as probably portions of the calyx.

VERTEBRATA

Skeletal parts:

Two vertebrate limb bones[1] and an unidentified bone fragment were found at Locality F_5.

Trackways:

With the assistance of Dr. E. S. Belt, photographs were taken of three outcrops close to Woody Cape in the Woody Head beds of the Upper Codroy Group, which exhibited trackways (See Map 2; See Figs. 43, 44 and 45.) Latex moulds were taken also by the writer and sent Dr. Donald Baird at Princeton University. Further work is to be carried out on these trackways with a view to publishing a joint paper with Baird.

[1]Confirmed by Dr. T. W. McKenney, Department of Biology, Memorial University.

Chapter IX

In this chapter are given the fossil localities shown on Map 1. The fossils found by the present writer are listed and correlations are proposed with strata of presumably equivalent age in Nova Scotia.

Locality F_1:

Locality F_1 is approximately 250 yards west of a small un-named tributary stream which flows into the Grand Codroy River (See Map 1). The fossiliferous horizons are associated with thin limestone beds, which have a maximum thickness of six inches, and calcareous lutite beds. Attitude: Strike N 73° E and dip 55° southwards.

The fossils found are as follows:

Gastropoda:

Bucanopsis sp.

Bulimorpha maxneri?

Murchisonea (Stegocoelia) compactoidea?

Naticopsis howi?

Platyshisma? dubium?

Pelecypoda:

Edmondia? hartti?

Schizodus fundiensis?

Leptodesma? sp.

Cephalopoda:

Orthoceras? vindobonense?

Crinoidea:

Crinoid columns

Ostracoda:

<u>Paraparchites</u> <u>sp</u>.

Spores:

A spore florule, which appears to be identical to that listed for locality F_2 (See next page), was found. (Yet to be confirmed).

The abovementioned fauna compares well with that listed by Bell (1929, pp. 66-68) for the Horton-Windsor District, Nova Scotia, although according to Bell (personal communication) most of the Lower Windsor species extend upwards into subzone C of the Upper Windsor. Thus this would give a late Meramecian age or possibly early Chester for the fauna at locality F_1. The range suggested by H. W. Scott for the type of <u>Paraparchites</u> <u>sp</u>. found at F_1 was Middle Mississippian to Late Mississippian, but his tentative suggestion of a Clore-Kinkaid age would appear to be anomalous.

<u>Paraparchites</u> <u>gibbus</u> was recorded from the Codroy Group west of the Aguathuna Quarry, Port au Port Bay, by Hayes and Johnson (1938, p. 19). The species was associated with a fauna considered by Bell to indicate a typical Lower Windsor subzone B assemblage.

Locality F_1a:

This locality is on the north bank of the Grand Codroy River and is approximately 80 yards upstream from F_1. It shows the same strike direction as

F_1 but dips southward at an angle of 60°. Lithologically it is a fine grained sandstone made porous by numerous small cavities, possibly the result of solution of contained calcite.

Fossils collected comprised a left and a right valve from separate individuals of Sanguinolites striatogranulatus.

Locality F_2:

The fossiliferous beds found at locality F_2, occur in a dark grey calcareous lutite which contains thin limestone beds generally less than six inches in thickness. The fossil locality is approximately 40 yards from the Grand Codroy River, and is opposite the small island shown on Map 1.

The fauna and microflora comprises:

Murchisonia gypsea
Sanguinolites parvus?
Sanguinolites striatogranulatus

Spores:

Lycospora sp.
Reticulatisporites sp.
Lophotriletes sp.
Verrucosisporites sp.
Convolutispora sp.

Two specimens from this locality were sent to W. A. Bell for identification. He considered (personal communication) that their occurrence slightly favoured a Windsor subzone B age to that of subzone C. This locality therefore, indicates that the Codroy Group extends further to the southeast than previous workers thought. Hayes and Johnson (1938, Map 4), showed the boundary between the Codroy 'series' and Barachois 'series' passing through the position of Station F_2, and Baird and Coté (1964, Fig. 1) showed the boundary to be approximately one half mile to the northwest.

Locality F_3:

At locality F_3 on Map 1 a limestone bed approximately four inches thick was found. Contained fossils include poorly preserved gastropoda and pelecypoda. Microfossils comprising ostracods were also found and tentatively identified as Paraparchites? sp. (To be confirmed).

Locality F_4:

This locality occurs approximately 150 yards from the Grand Codroy River in the channel of a small un-named tributary (See Map 1). Fossils were found in a limestone bed approximately seven inches thick. Contiguous strata comprise grey lutites. The limestone ressembles that described for locality F_3 and contains a similar fauna, with the exception that ostracods were not found.

As proposed by Hayes and Johnson (1938, Map 4), Codroy Group age would appear to be favoured for both localities F_3 and F_4. Baird and Coté however, (1964, Fig. 1) show both to be in the Searston-Barachois strata.

Locality F_5:

This fossil locality is located on the west bank of the North Branch of the Grand Codroy River, on the slip-off slope of the meander shown on Map 1. At this place a number of thin dolomitic (?) limestone beds crop out (approximately six inches thick) in the channel of the river, but are well exposed only when the river level is low. They strike N 65° E and dip 45° southeasterly.

Macrofossils recorded from this area comprised Murchisonia? gypsea? and a common but poorly preserved form tentatively identified as Pseudamusium? sp. Microfossil collections included a number of well preserved ostracods which were identified as Glyptopleura sagae? (confirmed). Information (listed on page 77) given by H. W. Scott, suggests a somewhat later age than that indicated by M.? gypsea? and P.? sp. (Windsor subzone B or C). It would appear that an age equivalent to the Woody Head Beds is favoured, but in the coastal type section near Codroy these were considered by previous workers to be largely non-marine, whereas G. sagae is indicative of marine conditions.

Locality F_6:

This locality occurs approximately 30 yards north of the fault exposed in Capelan Cove, where the Searston beds are downfaulted against the Codroy Group.

The fauna collected comprises:

Spirifer nox.

Phillipsia eichwaldi.

Unidentified ostracods.

S. nox and *P. eichwaldi* are listed by Bell as common in the Windsor subzone E of the Horton-Windsor District, Nova Scotia. Thus it would appear that the Searston Beds are downfaulted against beds of the Codroy Group with an equivalent age to Windsor subzone E.

Locality F_7:

At this locality Hayes and Johnson (1938, p. 14) noted the presence of *Productus avonensis* and considered this to indicate an age equivalent to an upper Windsor fauna. In their report they describe the outcrop as occurring in the bottom of the Little Codroy River. When this writer visited the locality the level of the river was such that rocks on the bottom were not easily accessible, and *P. avonensis* was not found.

Locality F_8:

This locality is described on page 44 and occurs 330 yards upstream from the Little Codroy River in the channel of an un-named brook referred to as L.Cl. The large proportion of crinoidal material in the bioclastic limestone described indicates marine conditions. Traces of galena were also seen in this limestone. Hayes and Johnson (1938, Map 4) included this locality along with locality F_7 in their Codroy 'series', but Baird and Coté (1964, Fig. 1) map the area as occurring within the Searston-Barachois strata.

Locality F_9:

In the limestone horizons described on page 45 ostracods were found at one locality but the present writer's identification of Paraparchites? sp. is awaiting confirmation. In general however, it would appear that localities F_7, F_8 and F_9 indicate an age other than that shown by Baird and Coté, and the present writer is of the opinion that these should be included within the Codroy Group, as shown by Hayes and Johnson (1938, Map 4). Further upstream from locality F_9, in the channel of Big John's Gulch, the presence of a thin coal seam and the general lithological aspect suggest a Barachois age. (See Map 1).

Locality F_{10} and F_{11}:

These two localities are equivalent to the lutite units referred to as Z_6 and Z_{12} on Map 2. No macrofossils were found, but the spore assemblage listed on page 63 was discovered, which confirms a Canso age for the Searston Beds.

Locality F_{12}:

At this locality shown on Map 1 a cross-bedded greenish-grey micaceous, silty sandstone crops out and was found to contain Lepidodendron sp. Preservation of the material is not good, but is distinctive in that the areoles contain a light reddish-brown massive unidentified mineral.

Locality F_{13} and F_{14}:

No fossils other than the spore assemblages listed in Chapter VII were found at these two localities.

The material listed in this chapter is stored in the fossil collection of the Geology Department, Memorial University, Newfoundland.

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Appendix A

Dye used for Distinguishing Calcite from Dolomite by a Chemical Staining Technique:

A single solution was made from alizarin red S (0.2%), potassium ferricyanide (0.5 - 1.0%) and hydrochloric acid (0.2%).

According to B. D. Evamy[1] (1963, p. 165), this results in the following stains:

> Calcite (sensu stricto) stains red; ferroan calcite stains mauve to purple; and dolomite (sensu stricto) is not stained. Ferroan dolomite stains light blue and ankerite stains dark blue.

Apparatus Used in Palynological Work:

1. Pestle and mortar.
2. Chemical Hood.
3. International Clinical Centrifuge (Model CL).
4. Teflon beakers, 150 ml.
5. 50 ml test-tubes and 15 ml pointed test-tubes.
6. Hot plate, which could be mechanically agitated (Therm-O-Shake).
7. Olympus Trinocular Microscope (Maximum magnification, with oil immersion, x 2,000).
8. Flexible transparent tubing, 3/8 inch diameter.
9. Ultrasonic generator (Model No. T3001, Ultrasonic Industries Incorpora

[1] Evamy, B.D. (1963). The Application of a Chemical Staining Technique to a study of Dedolomitisation, Sedimentology, vol. 2, no. 2, p. 165.

Appendix B

Figures

Fig. 1. Folding as a result of flow movement in the Ship Cove Limestone. Codroy Island, looking south.

	Hayes & Johnson (1938)	Bell (1948)	Baird (1951)	Baird & Cote (1963) & This Thesis (1965)
Pennsylvanian	Barachois Series	Barachois Series	Barachois Series	Barachois Group
		Searston Beds	Searston Beds	Searston Beds
Mississippian	Codroy Series Woody Point sandstone Woody Cove shale	Codroy Series Woody Head beds Woody Cove beds	Codroy Series Woody Point beds Woody Cove beds	Codroy Group Upper Codroy
	Black Point limestone Codroy shale	Black Point limestone Gypsum beds & Codroy breccias Ship Cove limestone	Codroy beds Ship Cove limestone	Lower Codroy
	Anguille Series Snakes Bight shale Cape Anguille sandstone	Anguille Series undifferentiated	Anguille Series Seacliffs sandstone Snakes Bight shale Anguille sandstone	Anguille Group Seacliffs formation Snakes Bight formation Cape John formation

Fig. 2. Development of Carboniferous Stratigraphic Column of Southwestern Newfoundland.

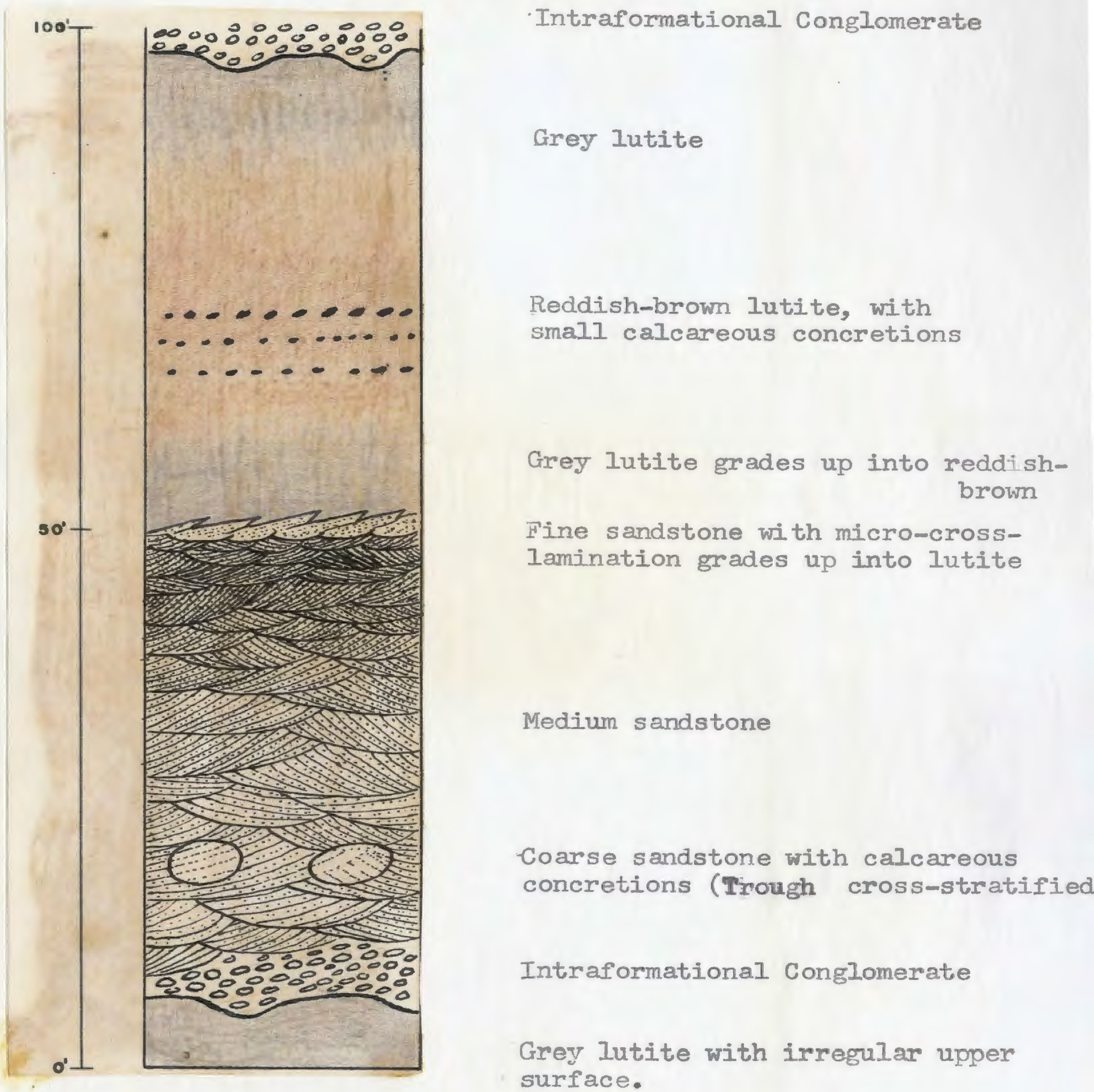

Fig. 3. Diagrammatic section of conglomerate-sandstone unit and lutite unit.

Fig. 4. Alternation from sandstone(S) to lutite(L). Searston beds.

Fig. 5. Quicksand (?) deformation in sandstone unit Z 125. Searston beds.

Fig. 6. Calcareous concretions (C) weathered out from sandstone unit Z71, at base of cliff.

Fig. 7. Calcareous concretions in lutite unit.

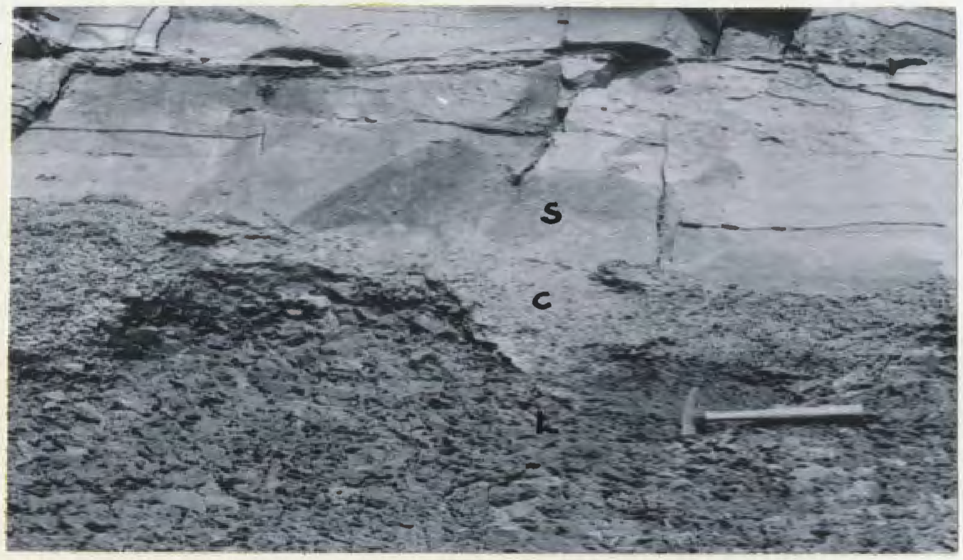

Fig. 8. Channels in lutite (L) filled with intraformational conglomerate (C) underlying a coarse sandstone (S)

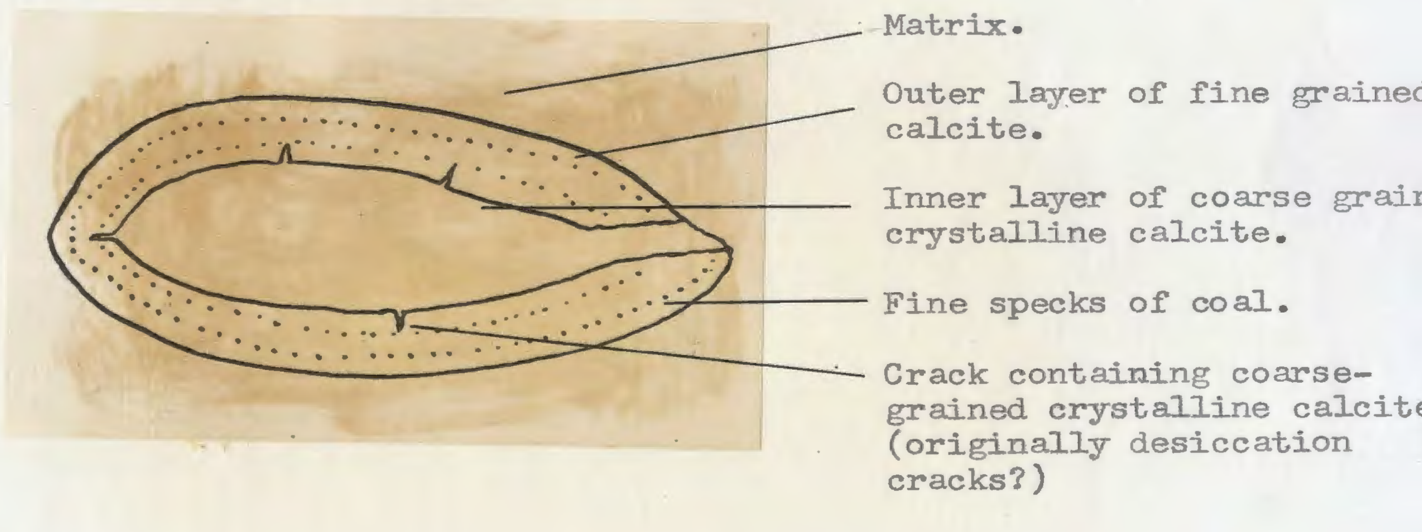

Fig. 9. Composition of typical pebble in the intraformational conglomerate.

Fig. 10. Channels filled by coarse sandstone. Unit Z97.

Fig. 11. Characteristic type of bedding resulting from channel filling by a sub-fluvial current (after E. D. McKee).

Fig. 12. Example of bedding type shown in Fig. 11.

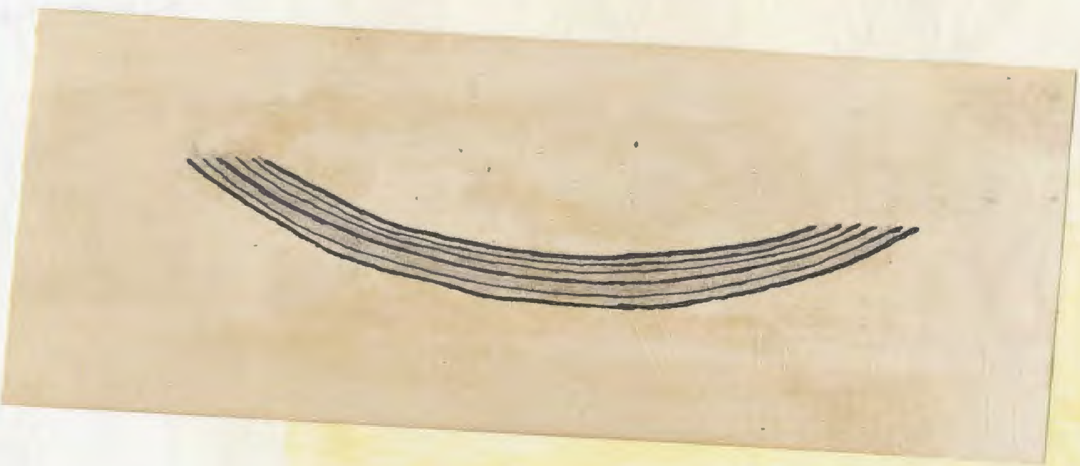

Fig. 13. Bedding produced by settling in quiet water (after E. D. McKee).

Fig. 14. Channel cut in sandstone (S) with a lutite (L) filling, exemplifying sedimentary conditions shown in Fig. 13.

Fig. 15. Large scale intrusion of lutite into overlying sandstone unit Z93.

Fig. 16. 'Fissure' type intrusion of lutite into overlying sandstone.

Fig. 17. Photograph of thin section of bioclastic limestone largely comprised of crinoidal material. (Magnification x 50 approximately)

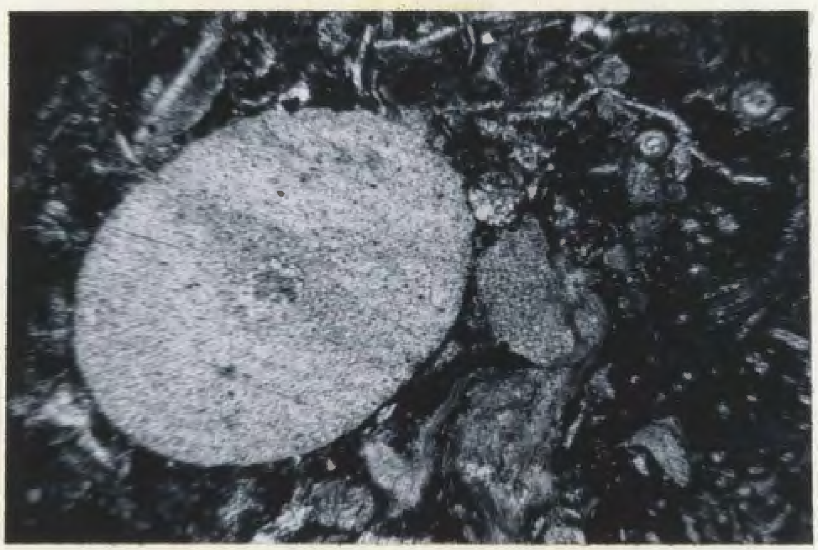

Fig. 18. Bioclastic limestone shown in Fig. 17 photographed under higher magnification (approximately X150). Shows detail of columnal section of a crinoid.

Fig. 19. Joint pattern and weathered surface of chert bed (Ct_1).

Fig. 20. Photograph of thin section of chert bed (Ct_1), showing plant pseudomorph (Magnification approximately X 50).

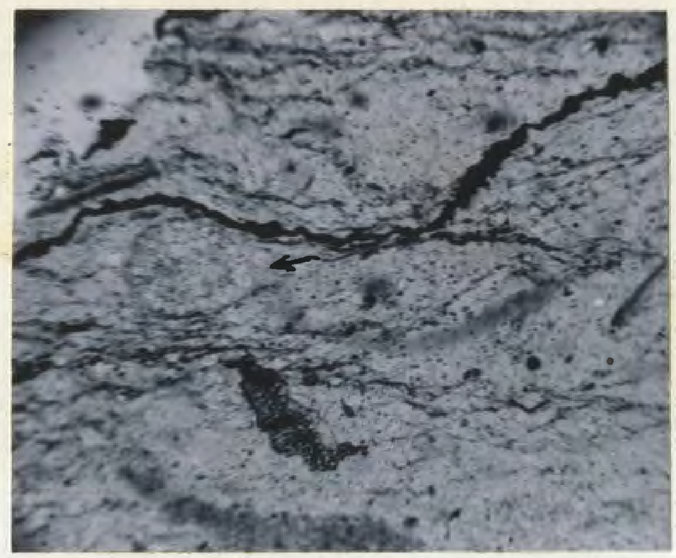

Fig. 21. Photograph of thin section of chert bed (Ct_2), showing silicified cellular plant structure (?).

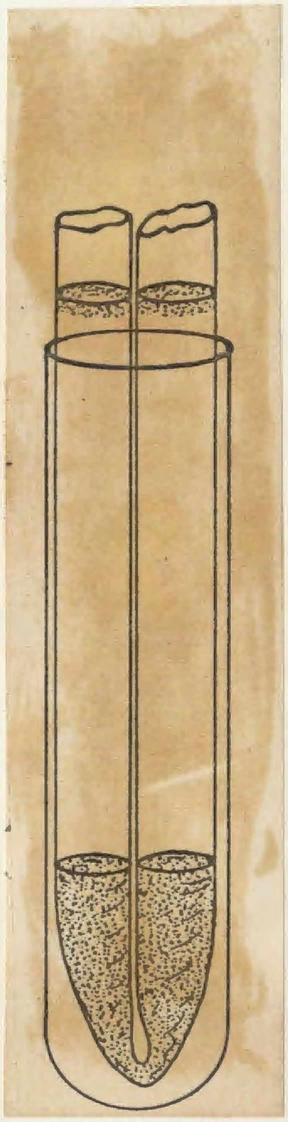

Fig. 22. Heavy-liquid separation after centrifuging. (After Funkhouser and Evitt).

(all figures of spores X 500)

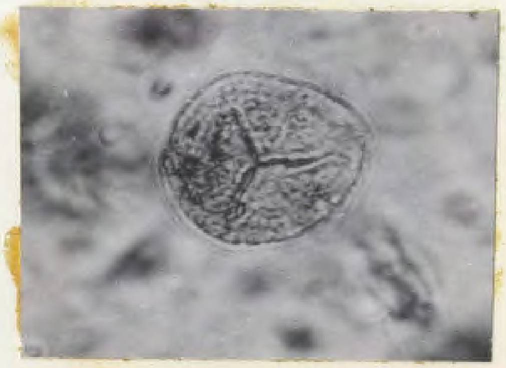

Fig. 23. Lycospora sp.

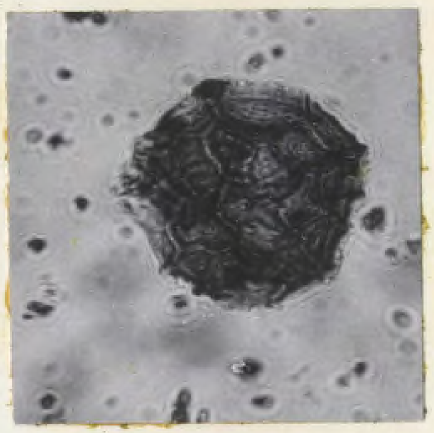

Fig. 24. Reticulatisporites sp.

Fig. 25. Endosporites micromanifestus

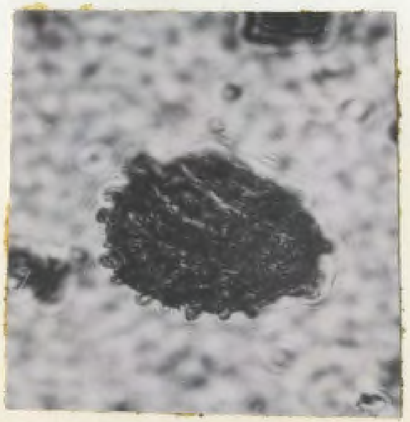

Fig. 26. Raistrickia sp.

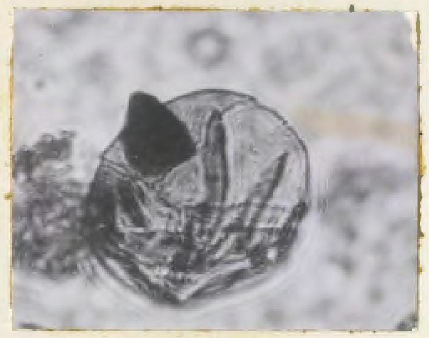

Fig. 27. Calamospora sp.

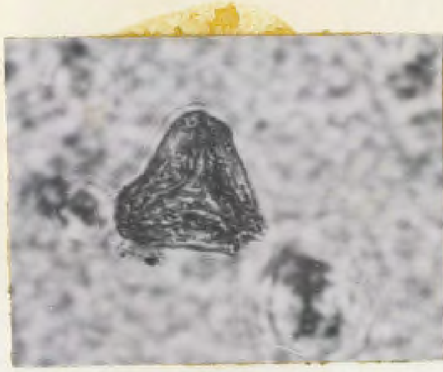

Fig. 28. Granulatisporites sp.

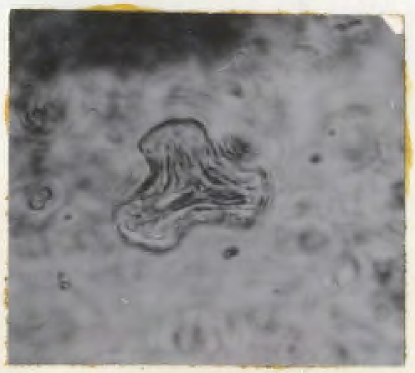

Fig. 29. Waltzispora sp.

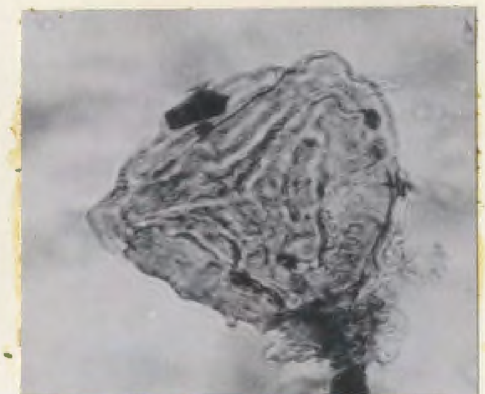

Fig. 30. Savitrisporites sp.

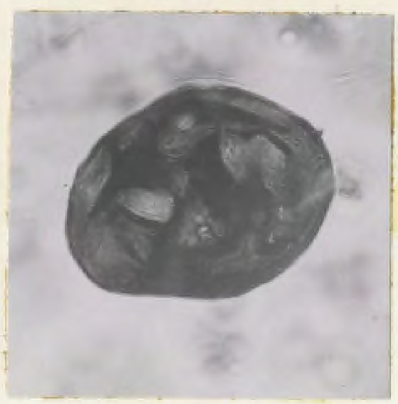

Fig. 31. Knoxisporites sp.

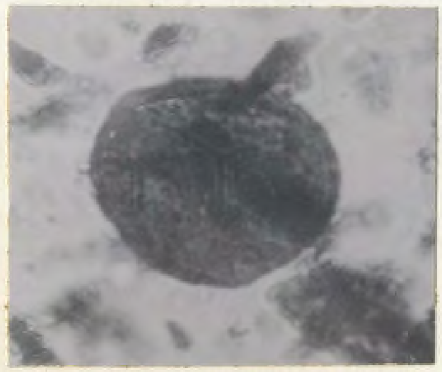

Fig. 32. Punctatisporites sp.

Fig. 33. Bucanopsis beedi X 2

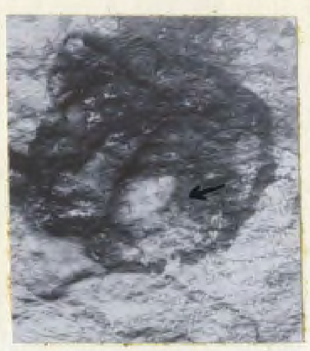

Fig. 34. Bulimorpha maxneri? Natural size.

Fig. 35. Naticopsis howi? X 2

Fig. 36. Sanguinolites striatogranulatus? Natural size (Right valve).

Fig. 37. Sanguinolites striatogranulatus? Natural size (Left valve).

Fig. 38. Schizodus fundiensis X 2

Fig. 39. Platyschisma? dubium? Natural size (approximately).

Fig. 40. Orthoceras vindobonense Natural size.

Fig. 41. Spirifer nox Natural size

Fig. 42. Phillipsia eichwaldi X $6\frac{1}{2}$

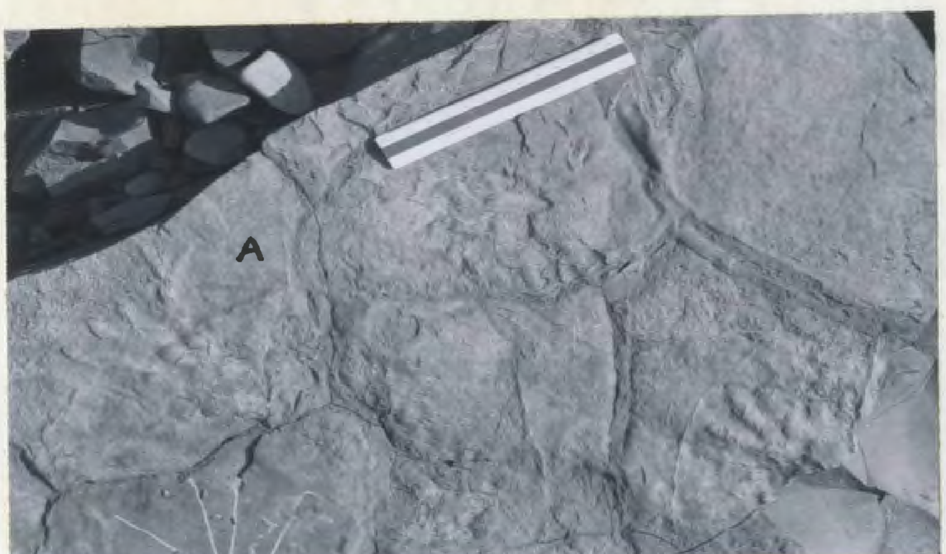

Fig. 43. Fossil trackway Tr 1.

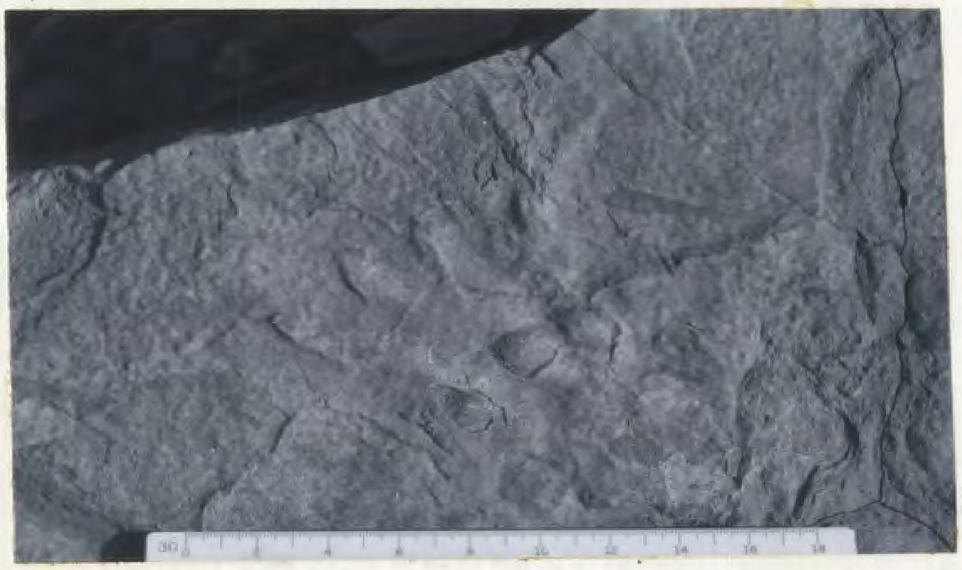

Fig. 44. Fossil trackway Tr 1.
(Close up of print A shown in Fig. 43)

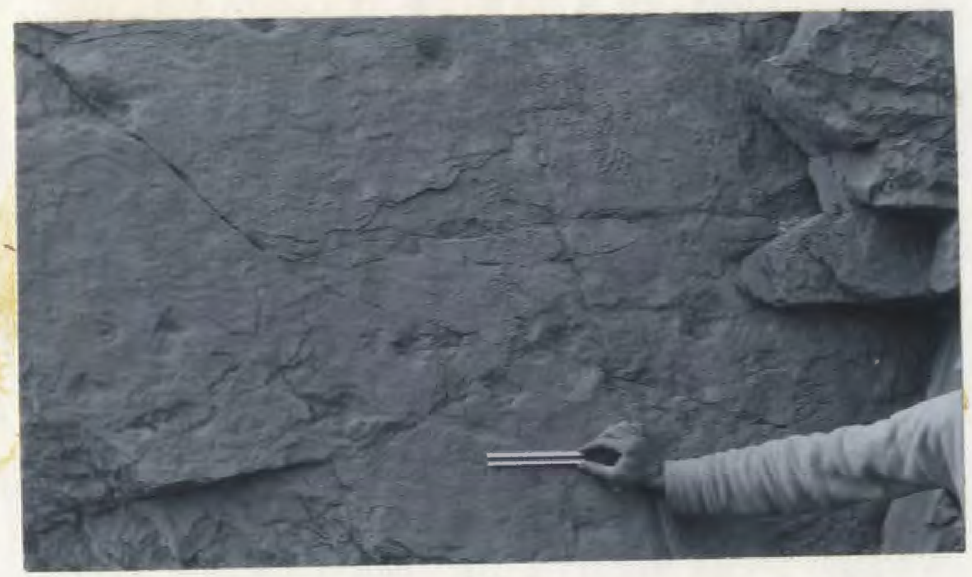

Fig. 45. Fossil trackway Tr 2.