"CONODONTS FROM THE COW HEAD GROUP, WESTERN NEWFOUNDLAND"

GODFREY S. NOWLAN

"CONODONTS FROM THE COW HEAD GROUP,
WESTERN NEWFOUNDLAND."

by

Godfrey S. Nowlan B.A. ©

A thesis
submitted in partial fulfillment
of the requirements for the degree of
Master of Science
Memorial University of Newfoundland

August 1973

ABSTRACT

At its type section near the village of Cow Head on the Great Northern Peninsula, Newfoundland, the Cow Head Group consists of carbonate breccias, micrites, graded bioclastic limestones and non-calcareous shales with minor sandstones, shaly limestones and non-calcareous siltstones. Many of the limestones are laminated and bioturbated, and some are partially to completely dolomitised. The section is only 300m. thick and ranges in age from Middle Cambrian to Middle Ordovician. It was transported westward by gravity sliding during the Middle Ordovician and it now overlies shelf facies limestones. The sequence was carefully logged and sampled for conodonts in order to determine the existence and extent of conodont zones, and to define the transition between the Cambrian and Ordovician Systems in terms of conodont biostratigraphy.

Yields of conodonts from the samples are generally sparse and the faunas are rarely diverse. The conodonts are classified using multielement taxonomy wherever possible, and those elements which do not fit into any known multielement species are listed under form taxonomy.

The Cow Head Group is divided into 14 Units primarily on the basis of conodonts. No conodonts were recovered from the Middle Cambrian and thus it is correlated on the basis of previously reported trilobite faunas. Reasonable correlation

can be made with the conodont zones of Balto-Scandia erected by Lindström and Bergström for the Lower Ordovician, however not all of these zones have been recognised. The zones erected by Lindström for the Volkhovian and Kundan Stages of the Baltic Shield (Baltoniodus triangularis Zone to the Amorphognathus variabilis Zone) are not recognised in the Cow Head sequence. Tentative correlations are likewise made with the Australian Lower Ordovician conodont zones. Only a very poor correlation of the Cow Head Group with the conodont zones of the mid-western United States exists, emphasising the difficulty of correlating cratonic and extra-cratonic conodont faunas.

The Cow Head Group was deposited near the base of the Lower Paleozoic continental slope of eastern North America. It was laid down as a series of mass gravity slides which flowed from the outer shelf and upper slope into an area of active deposition and redistribution of thin carbonate and non-calcareous muds.

TABLE OF CONTENTS

CHAPTER V

CORRELATION

CHAPTER VI

PALEOENVIRONMENT: THE COW HEAD GROUP AS A CONTINENTAL SLOPE DEPOSIT

CHAPTER VII

NOMENCLATURE

CHAPTER VIII

TAXONOMY

ILLUSTRATIONS

PHOTOGRAPHS

CHAPTER I

INTRODUCTION

(i) ACKNOWLEDGMENTS

Sincere thanks are due to Dr. Lars E. Fahraeus for providing excellent guidance and encouragement to the writer during the compilation of this thesis.

A scholarship from Chevron Oil (Canada), for field work and equipment, held during 1972, is gratefully acknowledged.

Thanks are also due to Ms. Diane England who processed most of the samples for conodonts.

Earl and Agnes Payne and family of Cow Head are to be thanked for providing such enjoyable living conditions in the field.

(ii) LOCATION OF STUDY AREA

The carbonate breccias of the Cow Head Group, western Newfoundland are world renowned for their extreme coarseness (Dunbar and Rogers 1957, p. 175). The type section of the Group occurs at the village of Cow Head, which is situated on the west coast of the Great Northern Peninsula, at latitude 50°N and longitude 57°45'W. Excellent exposures are easily accessible along the shores of the Cow Head Peninsula, just west of the village. At its type section, the Cow Head Group is about 300m. thick. It is exposed as a broad syncline. Other localities at St. Paul's Inlet, Broom Point and Martin Point, (see Fig. 2), were not sampled for conodonts in this study.

MAJOR GEOLOGICAL ELEMENTS OF W.NEWFOUNDLAND

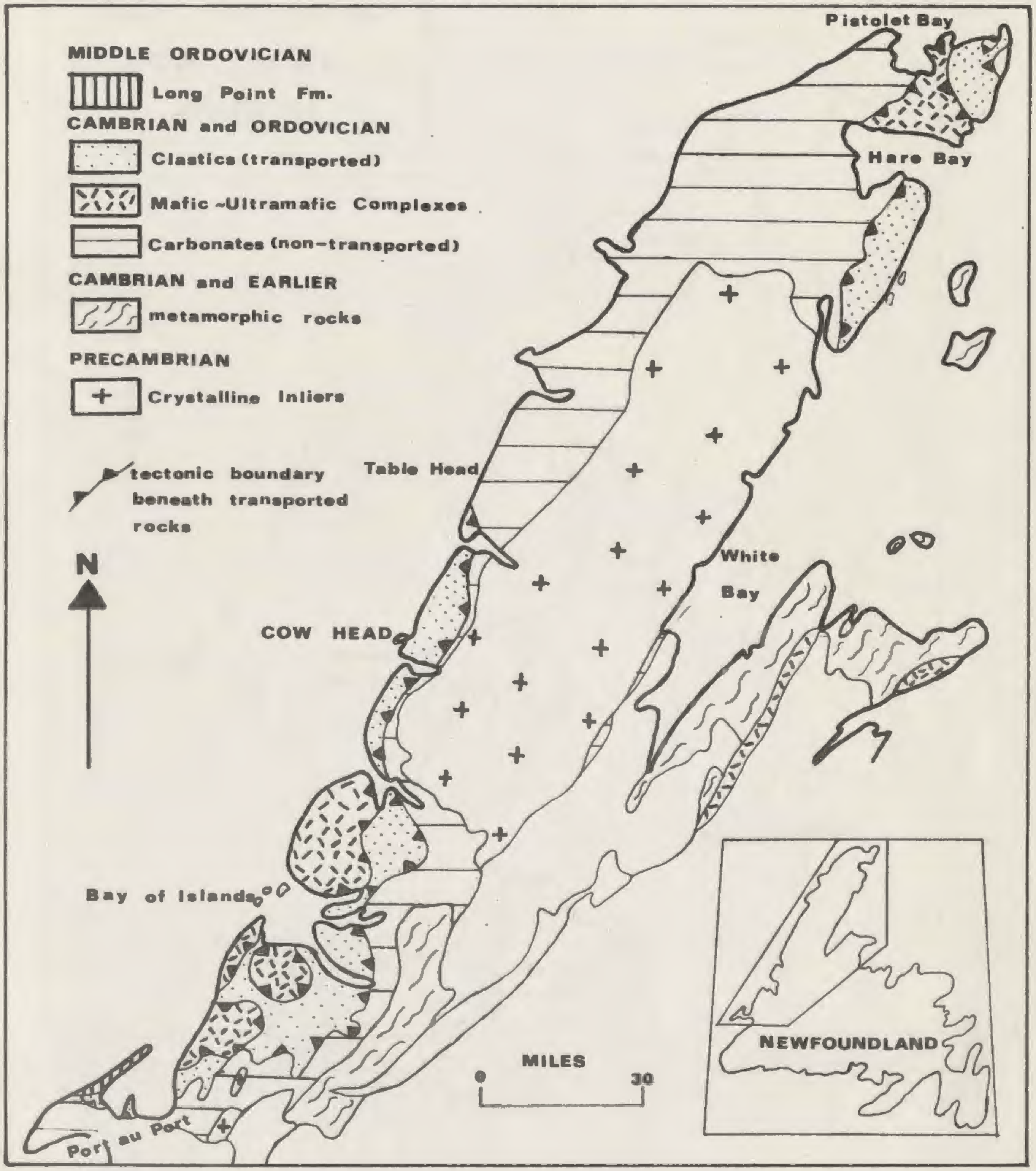


Fig.1

(After H. Williams 1971, Fig.1)

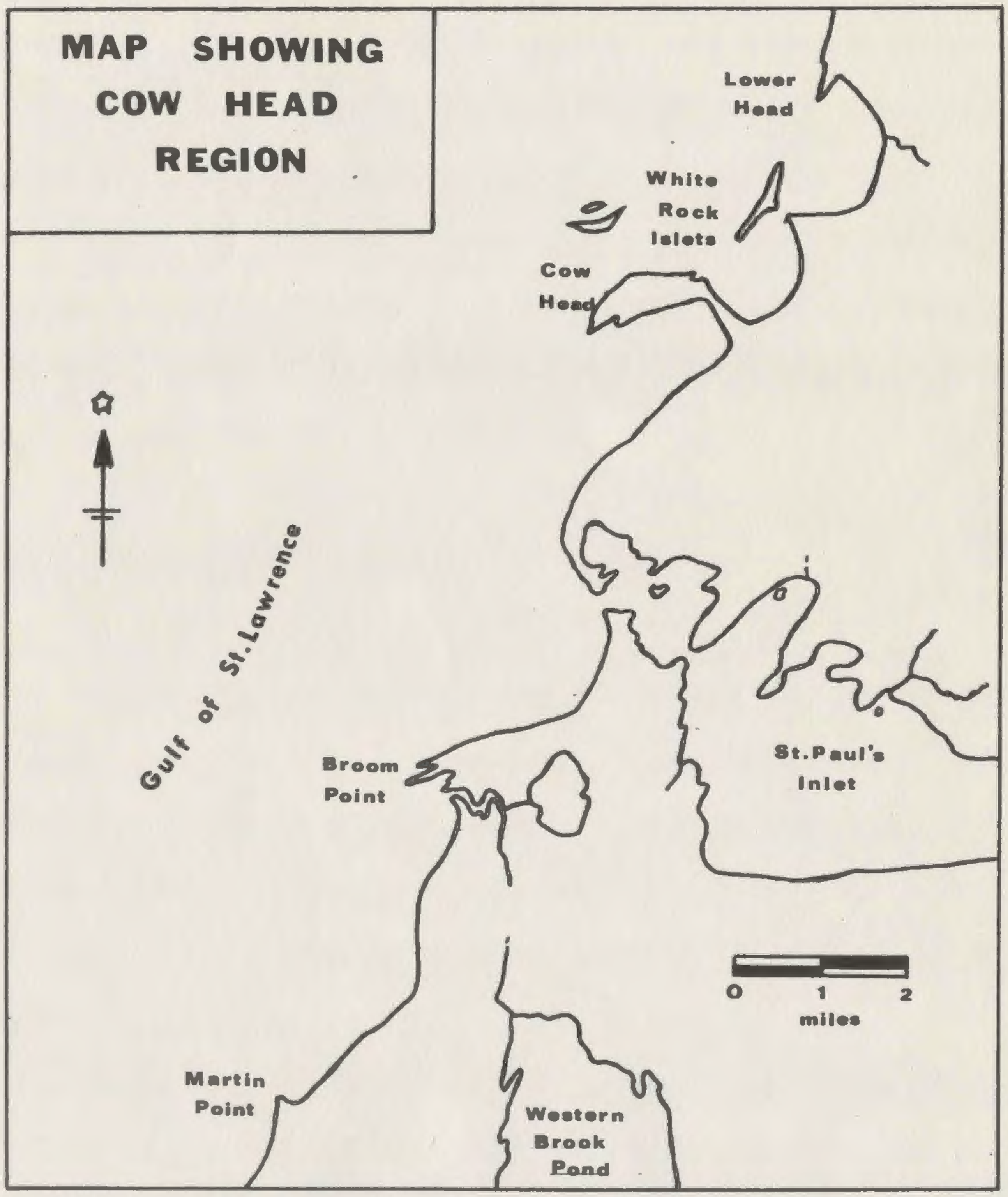

MAP SHOWING
COW HEAD
REGION
Lower
Head
White
Rock
Islets
Cow
Head
Gulf of St.Lawrence
Broom
Point
St.Paul's
Inlet
0
1
2
miles
Martin
Point
Western
Brook
Pond

Fig.2

(iii). PURPOSE

The purpose of the present study is to describe the conodont biostratigraphy of the Cow Head Group in detail. This involves determining the existence and extent of conodont zones within the sequence, and defining the transition between the Cambrian and the Ordovician Systems in terms of conodont biostratigraphy. Supplementary to this is a brief study of the sedimentology of the sequence, discussing the nature and origin of the unusual carbonate breccias and associated bedded limestones and shales. An explanation of the depositional environment is attempted.

(iv). PREVIOUS REGIONAL WORK:

The breccias were first described by Richardson (in Logan 1863, p. 291), but he did not account for their origin. Writing about some very large blocks in the breccia, he states: "....it is difficult to decide whether these are sediments deposited in the bed, or enclosed transported masses, notwithstanding that they are divided into beds with partings of black shale".

After four expeditions between 1910 and 1933, Schuchert and Dunbar (1934, p.84), described the breccias at Cow Head in some detail, and assigned a tectonic origin to them. They were: "forced to interpret these lenticular masses of coarse breccia as the material of talus and landslides formed along a fault scarp that came into existence during mid-Ordovician orogeny".

Oxley (1953) broadly accepted the view of Schuchert and Dunbar (1934) on the origin of the breccias, and pointed out the difficulty of correlating the breccias from place to place along the coast.

In the area of Portland Creek to the north, Nelson (1955) recognised that boulders in any one breccia horizon were largely made up of one rock type. He concluded that the breccias were the result of localised earthquakes affecting semi-consolidated muds. However, after reviewing the work of Schuchert and Dunbar (1934) and noting that they had studied exposures all along the coast, he felt "...inclined to the view that their hypothesis of origin is probably the best so far presented".

The first detailed paleontological study was made by Kindle and Whittington (1958) who recognised that the breccias were stratified sediments ranging in age from the Middle Cambrian to the Middle Ordovician. They studied trilobites in the boulders of the breccias, and graptolites in the interbedded shales to determine the biostratigraphic sequence. They state that, (Kindle and Whittington 1958, p.341): "with few exceptions the boulders of any conglomerate are approximately the same age as the immediately underlying strata". They regarded the Cow Head Group as a flysch sequence.

Baird (1960), in a comprehensive review of the carbonate breccias in western Newfoundland, concluded that both shallow and deep-water breccias occur. He suggested that some intraformational breccias were produced by wave and shore current action. He envisaged most of the Cow Head Group as forming in an embayment of the shelf, with slumping and sliding due to localised tectonic activity. He also suggested that "occasional fault scarps contributed to the formation of breccias throughout the basin."

Stevens (1970, p. 167), writing on sedimentation and tectonics in western Newfoundland, suggests that the possible origin of the clasts in the breccias is "....the over-steepened oceanward edge of a carbonate bank that provided detritus from middle Cambrian to Middle Ordovician."

The only previous research on conodonts from the Cow Head Group is reported by Fahraeus (1970). He studied a few samples from the Ordovician part of the Cow Head Group and compiled a correlation chart for the sequence. He found the faunas occurring in the succession to be BaltoScandian in content. The correlations made by Fahraeus (1970), with Balto-Scandian and British time-stratigraphic units based on conodonts from the Cow Head Group, entirely agree with the correlations suggested by Kindle and Whittington (1958).

Preliminary findings of the work presented in this thesis have been reported by Nowlan and Fahraeus (1972).

(v). PREVIOUS CONODONT RESEARCH

This section is a brief review of studies which have been published on conodonts of comparable age to those collected from the Cow Head Group.

Middle and Upper Cambrian:

Except for a few species described by Pander (1856), which may be of Cambrian age, the study of conodonts from the Cambrian is of recent date.

Müller (1959) reported several species of conodonts recovered from Cambrian rocks of Sweden and North Germany.

In 1961, Cambrian conodonts were reported from North America in a paper dealing with material from the Big Horn Mountains, Wyoming, U.S.A., (Koucky,Cygan and Rhodes, 1961).

Poulsen (1966) described a few middle Cambrian conodonts from unconsolidated clays on Bornholm Island in the Baltic Sea. Nogami (1966, 1967) has reported conodonts of Upper Cambrian age from the Kushan Beds of China. Unfortunately, I have not seen either of Nogami's papers, but they are reported here for completeness. Clark and Robison (1969), described a few middle Cambrian conodonts from the Emigrant Springs Limestone in Nevada, U.S.A. Clark and Miller, (1969), extended the lower ranges of some Cambrian conodonts described by Müller (1959).

Miller (1969) has published detailed conodont biostratigraphy of part of the Notch Peak Limestone, Utah, U.S.A. He described several new genera and species of Cambrian conodonts. Some of the forms reported by Miller (1969) occur in the Cow Head Group. Druce and Jones (1971) have recently reported Cambrian conodonts from the Burke River Structural Belt in eastern Australia. Miller and Rushton (1973) report natural conodont assemblages from the Upper Cambrian of

Warwickshire, Great Britain.

Tremadocian:

Pander (1856) described conodonts from Tremadocian beds in Estonia and the Leningrad region. Further studies by Viira (1966, 1967) detail more complete Estonian sequences. Similar conodonts have been reported from the Leningrad region (Sergeeva 1962, 1963) and from Sweden (Lindström 1955, 1960, 1964, 1971).

In the United States, Tremadocian conodonts have been recorded from the Prairie du Chien beds of the Upper Mississippi Valley (Furnish, 1938), the Stonehenge Limestone of Pennsylvania (Sando, 1958) and the Monocline Valley Formation of Nevada, (Longwell and Mound, 1957).

The Columbia Ice-Fields section in Alberta, Canada, has also yielded conodonts of Tremadocian age (Ethington and Clark, 1964). The studies of Druce and Jones (1971) and Miller (1969) also extend into the Tremadocian.

Arenigian:

The volume of literature on conodonts sharply increases in studies of Arenigian conodonts, and there are too many to discuss individually. Some of the publications more pertinent to this thesis are listed: Branson and Mehl (1933), Bergström (1968), Ethington (1959, 1972), Fahraeus (1966, 1970), Lindström (1955a, 1955b, 1957, 1960, 1964, 1971), Mound (1965, 1968), Sergeeva (1962, 1963), Viira (1966, 1967), Ethington and Clark (1971), and Sweet and Bergstrom (1966, 1972).

CHAPTER II

METHODS OF STUDY

(i) Collection of Samples

A total of 156 rock samples were collected at fairly closely spaced intervals. Each sample weighed approximately 5 kilos.

The Cow Head Group, in the study area, is folded into a broad syncline, exposing rocks of the same age on both the northern and southern shores. The Middle Cambrian is, however, exposed only on the north shore. Both limbs of this syncline were sampled for conodonts, thus giving two more or less correlative sections.

Samples were taken of both boulders and matrix of breccias, and also from the intervening limestones and shales. The sampling interval varied, but was never more than two metres or less than a few centimetres. As many lithologies as possible were sampled.

The samples were generally crushed to fragments with a diameter of about 4 cms., before being placed in a labelled bag.

During the collecting, the entire sequence was logged and mapped thus giving good lithological control above and below each sample.

For details of the sampled intervals and a map of the study area, see Fig. 3.

(ii). Processing of the Samples

The ready-crushed samples were brought back to the laboratory and placed in containers with a 15% solution of Glacial Acetic Acid. Occasionally, samples were dissolved in a 10% solution of Formic Acid. A small piece of each sample was retained for reference.

The residue from dissolution was passed through a 250-micron mesh sieve, and washed. The residue in the sieve was placed in an oven to dry. The dried residue was then separated in Tetrabromoethane (Sp. Gr.=2.92) and the heavy fraction was washed with alcohol and inspected for conodonts. Yields from the lower part of the sequence were generally low, but some larger faunas were recovered from the Ordovician part of the succession.

CHAPTER III

GEOLOGICAL SETTING

The west coast of Newfoundland constitutes the western portion of the tripartite division of the island proposed by Williams (1964). It forms the relatively stable western margin of the paleozoic orogen. More recently, in a discussion of the Appalachian Structural Province, Williams, Kennedy and Neale (1973) divide the island into a series of zones. Each zone has a distinct depositional and/or structural history. The west coast of Newfoundland is designated as Zone A, which is more or less equivalent to the western division of Williams (1964). For illustration of the main geological elements of the area, see Fig. 1. A brief description of the major components of the geology of western Newfoundland follows.

The basement of the western part of Newfoundland consists of complexly folded schists and gneisses, which are intruded by granites. These granites yield Rb-Sr whole rock and K-Ar ages of around 900my., thus indicating a Grenville age, (Pringle et al. 1971).

An autochthonous sequence overlies this basement. Three units are recognised within this sequence. The lower unit consists of conglomerates and quartzites overlain by volcanics and arkoses. The middle unit comprises a Cambro-Ordovician sedimentary sequence of limestones, dolomites, sandstones and shales. The lower part of this middle unit is the St. George Formation which is composed of light grey, evenly bedded dolomite and dolomitic limestone. This interval is interpreted as representing shallow water outer shelf facies (carbonate bank). The Table Head Formation is the upper part of the middle unit of the autochthon. This formation is about 335m. thick and rests with an erosional disconformity on the St. George Formation. It consists of a rubbly limestone at the base, which grades up into evenly bedded, locally dolomitic, limestone, which is in turn overlain by thinly bedded limestones and shales. The lower part of the Table Head Formation represents a continuation of outer shelf deposition. The middle and upper parts of the Table Head Formation are probably upper slope deposits, (Fahraeus pers. comm.).

The upper unit of the autochthonous succession is a clastic sequence which is fine-grained at the base and coarsens upwards. The sediments in this unit are derived from the east, which is in contrast to the lower and middle units in which the sediments were derived from the continental side to the west.

The Cow Head Group is one of the three allochthonous sequences recognised in western Newfoundland. Schuchert and Dunbar (1934) thought that the sediments of western Newfoundland were a single succession ranging in age from Cambrian to Silurian. Johnson (1941), Kay (1951), and Rodgers and Neale (1963) all proposed that much of the upper part of the section is not in place, but transported from a sedimentary basin to the east. Rodgers and Neale (1963) compared the allochthonoús rocks with the Taconic Klippe.

The transported sequences now recognised are (Stevens 1970): (i) The Cow Head Group consisting of a condensed succession of carbonate breccias, with intercalated thin beds of limestone and shale.

(ii) A clastic succession of the Humber Arm Group, which has a condensed sequence of carbonate breccias, limestone beds and shale in its middle portion, known as the Cook's Brook Formation (Stevens, 1970).

(iii) An ophiolite sequence.

The Cow Head Group is thought to be allochthonous on the basis of circumstantial evidence. The basal contact is not seen anywhere and no mélange zone has been noted in close proximity, thus the existence of a thrust cannot be established. However, it is suggested that the Cow Head Group is a sequence of deep-water limestones and carbonate breccias, and thus depositionally "out of place" on the shelf succession of the St. George and Table Head Formations. Stevens, (1970) related the Cooks Brook Formation of the Humber Arm Group to the Cow Head Group. He suggested that the Cook's Brook Formation is a more distal facies of the Cow Head Group, and this interpretation is followed here. The Cook's Brook Formation is transported, (Stevens 1970), and this may suggest a similar situation for the more proximal Cow Head Group.

Thus, the Cow Head Group was deposited in a basin to the east, and has been transported westward by gravity sliding in the Middle Ordovician. The Cow Head Group now lies on top of the largely shelf deposited St. George and Table Head Formations, from which the breccias may have been partially derived. (A later section in this thesis describes the paleoenvironment of deposition of the succession).

The Cow Head succession is overlain by un-named green sandstones (Kindle and Whittington, 1958), which crop out on the shores of St. Paul's Inlet, (Fig. 2). These green sandstones are part of the easterly derived clastics which make up the upper part of the autochthon. These clastics were probably derived from the ophiolites, which form the uppermost allochthonous slices, (Stevens, pers. comm.)..

CHAPTER IV

STRATIGRAPHY

(i). INTRODUCTION: PREVIOUS STRATIGRAPHIC INTERPRETATION

The earliest stratigraphical description of the Cow Head region is given in Schuchert and Dunbar (1934). As has been mentioned above, they considered the breccias at Cow Head to be talus and slides from a fault scarp. They recognised a sequence of shales, limestones, and limestone breccias occurring at Martin Point, Broom Point and St. Paul's Inlet (see Fig. 2) as the Green Point Series. These outcrops are interpreted as parts of the Cow Head Group (Kindle and Whittington, 1958).

Johnson (1941) includes the sequence at Cow Head as a different facies of the St. George and Table Head Formations, and describes two new groups for the rocks in the area: the Green Point Group and the Western Brook Pond Group.

Oxley (1953) recognised two different Lower Ordovician facies in the area, but considered the Cow Head sequence to be Middle Ordovician in age.

Kindle and Whittington (1958) first used the term Cow Head Group, and recognised the sequence as a sedimentary series ranging in age from Middle Cambrian to Middle Ordovician.

In this thesis the term Cow Head Group is used to refer to the succession on Cow Head Peninsula, and this sequence is herein considered to be the type-section. Other exposures of breccia occur above the lower Table Head Formation, from Pistolet Bay in the north to Capė Cormorant on the Port-au-Port Peninsula in the south (Fig.1). Stevens (1970, p. 170) considers these breccias to be of a different origin and generally younger than the Cow Head Group. The writer agrees.

The Cow Head Group is overlain by green sandstones in St. Paul's Inlet, but these do not occur at the type section and have not been studied in this thesis.

(ii). DESCRIPTION OF UNITS

Kindle and Whittington(1958) divided the Cow Head Group into a number of informal stratigraphic units termed beds. This subdivision has been found to be largely satisfactory for the present study, with a few exceptions (Table 1). For a map of the distribution of the Units see Fig. 3. No conodonts were found in the first five units of the sequence, and thus the age of these is based on the trilobites reported by Kindle and Whittington (1958).

UNIT 1

This is the oldest horizon on the peninsula. It is exposed on the north-east shore, on the point north-west of Tucker's Cove (Fig. 3). It is also exposed at low tide in the eastern corner of Beachy Cove. This Unit is a limestone breccia (Fig. 4), with some boulders up to 1m. in diameter. Most of the smaller fragments are micrites and of a flat

FIG. 4. CLOSE-UP OF THE LITHOLOGY OF UNIT 1, N.E. TIP OF COW HEAD PENINSULA.

FIG. 5. CLOSE-UP OF LITHOLOGY OF UNIT 2, N.E. TIP OF COW HEAD PENINSULA.

flaggy nature. Sporadic pebbles of calcarenite are present.

Between Units 1 and 2, there is about 15 cms. of thinly bedded micrites and shales.

UNIT 2

This unit is another breccia, distinctive in that it is entirely composed of flat pebbles which lie in the plane of bedding (Fig. 5). It is only about 2.5m. thick. It crops out on the northeastern point of the peninsula, and along the shore in Beachy Cove. (Fig. 3)

UNIT 3

This unit is also well exposed in Beachy Cove (Fig. 6), where it forms the cliff and part of the foreshore. In places it appears to consist entirely of bedded limestone and shale, but these deposits are actually enormous blocks up to 50m. in length, (Figs. 7 and 8). This breccia includes many such blocks of spectacularly folded, interbedded micrites and shales (Figs. 9 and 10). Many smaller flat pebbles are also present, and these are composed of the same material as the large folded blocks. Unit 3 is in fault contact with Unit 4 on the east side of Beachy Cove.

Intercalated between Units 3 and 4 is a thin (70 cms.) sequence of bedded calcareous siltstone which is rich in authigenic pyrite and seemingly rather siliceous.

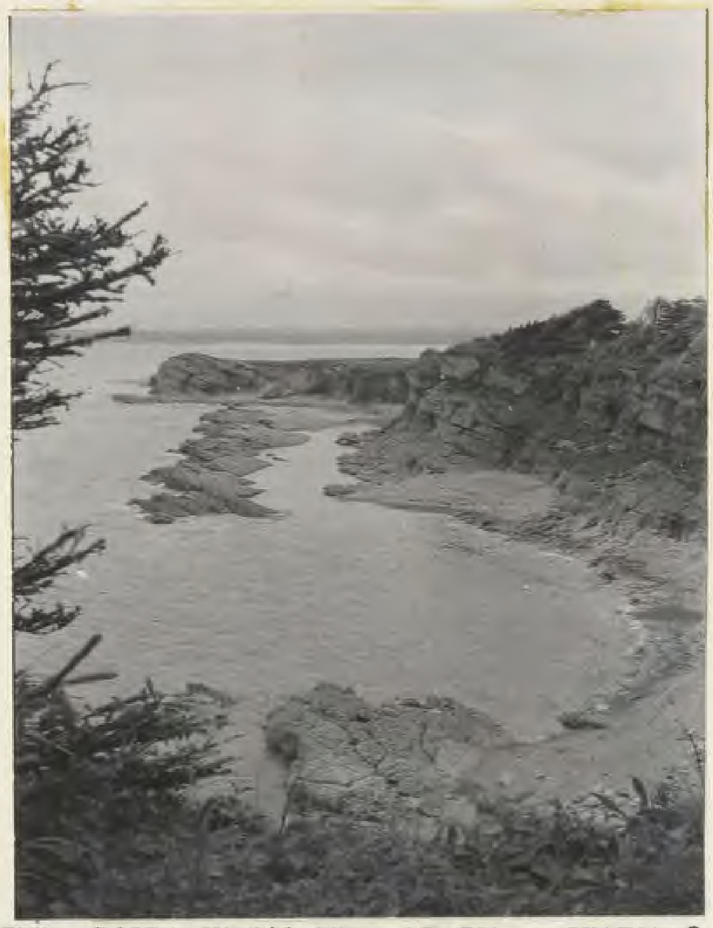


FIG. 6. BEACHY COVE FROM THE WEST: UNIT 2 CROPS OUT ALONG THE SHORE, AND UNIT 3 IS EXPOSED IN THE CLIFFS.

FIG. 7. DETAIL OF LARGE BLOCK OF BEDDED LIMESTONE IN UNIT 3, BEACHY COVE.

FIG. 8. CLOSE UP OF MARGIN OF THE BLOCK SHOWN IN FIG. 7.

FIG. 9. CONTORTED SLAB OF BEDDED LIMESTONE AND SHALE IN UNIT 3, BEACHY COVE.

UNIT 4

This unit exposed on the west side of Beachy Cove where the strike swings from east-west to north-south. It is a breccia with a maximum boulder size of about 1m. Several smaller boulders contain trilobite fragments. Most of the pebbles are of a flaggy nature.

A thin (30 cms.), interbed of calcareous siltstone and shale separates Unit 4 from Unit 5.

UNIT 5

This unit is largely a flat-pebble breccia (Fig. 11), with a few larger subrounded boulders (Fig. 12), some of which contain trilobite fragments. The smaller flat chips are mostly clean micrites, but coarser grained sandy calcarenites occur as well. Boulders of folded limestone are rare. The unit varies in thickness from 12m. at its eastern extremity to 20m. on the shore just east of the lighthouse. This unit forms a ridge running along the foreshore for about 400m.

UNIT 6

This is the first unit to yield conodonts. This unit forms the low ground all along the wave-cut platform which runs along the western part of the northern shoreline (Figs. 13a and b). It is largely a succession of interbedded micrites and shales with some lenticular limestone breccias. These breccias are mainly of the flat-pebble type, but coarser varieties do occur. Some of the lenses of breccia attain

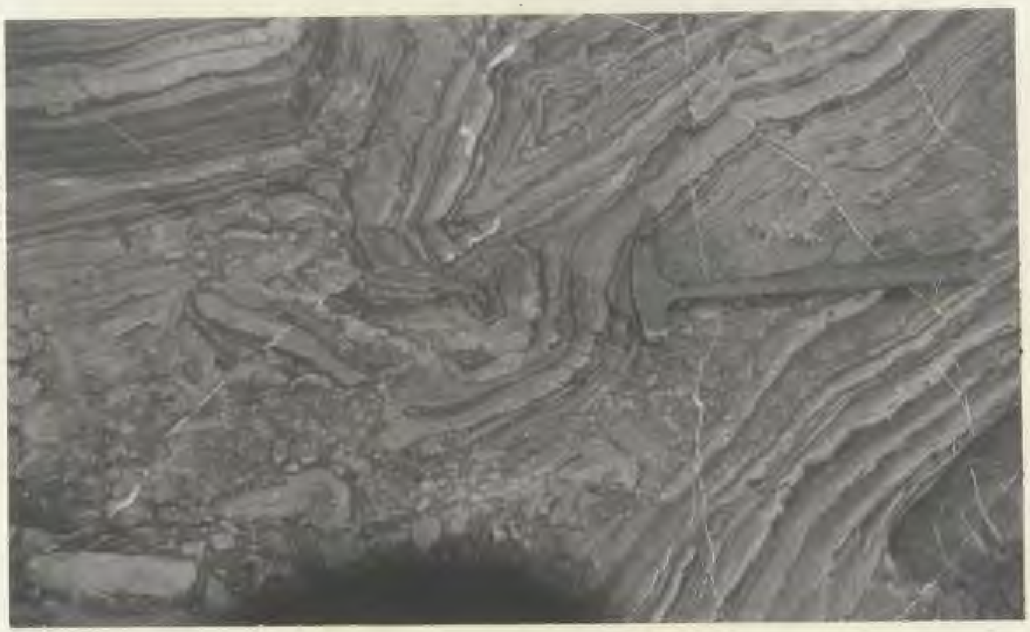


FIG. 10. CLOSE-UP OF A BRECCIATED PORTION OF A BEDDED BLOCK IN UNIT 3, BEACHY COVE.

FIG. 11. CLOSE-UP OF LITHOLOGY OF UNIT 5, CENTRAL PORTION OF NORTH SHORE OF THE PENINSULA.

FIG. 12. LARGE BOULDER IN UNIT 5, NORTH SHORE OF COW HEAD PENINSULA .

FIG. 13a. EXPOSURE OF UNIT 6 ALONG THE FORE—SHORE BELOW THE LIGHTHOUSE.

FIG. 13b. EXPOSURE OF UNIT 6 JUST WEST OF THE FAULTS ON THE NORTHERN SHORE.

FIG. 14. NOBBLY BEDDING SURFACE OF A BED OF LIMESTONE IN UNIT 6, NORTH SHORE OF COW HEAD PENINSULA.

optimum convex thicknesses of over 10m. The whole unit is 67.5m. thick.

The thin bedded micrites in most places exhibit peculiar uneven bedding surfaces, (Fig. 14), and may be folded in such a way as to suggest soft-sediment deformation (Fig. 15). These thin micrite beds are typically laminated, and many of them are dolomitic.

A 3m-thick layer of quartz sandstone is present about 35m. from the base of Unit 6 (Fig. 16). In its best development, this horizon consists almost exclusively of rounded and well sorted quartz grains in a calcite matrix. Many of the sand grains are coated with pyrite, giving the appearance of rounded pyrite grains. These quartz grains are common throughout Unit 6 but are particularly concentrated in this horizon. Crude cross-bedding has been noted in parts of this bed. Under the scanning electron microscope, these sand grains show characteristics of beach and dune sands, (R.M. Slatt pers. comm.).

About 5m. above this sandy layer, a few thin beds of finely interlaminated greenish mudstones and dolomites are present. These contain quite a large amount of pyrite. Similar mudstones mark the top of Unit 6, where they are broken up and thrown into folds and contortions beneath the coarse breccia of Unit 7 (Fig. 17). Several low angle faults which thrust and dip northwestwards at about 25°, confuse the

FIG. 15. SOFT SEDIMENT DEFORMATION IN BEDDED LIMESTONES AND SHALES OF UNIT 6, NORTH SHORE OF COW HEAD PENINSULA.

FIG. 16. COARSE PORTION OF QUARTZ SANDSTONE IN UNIT 6; THE FLAT PEBBLES DECREASE IN ABUNDANCE UPWARDS IN THE BED, NORTH SHORE OF COW HEAD PENINSULA.

FIG. 17. CONTORTED MUDSTONES OF UNIT 6, IMMEDIATELY BELOW THE BRECCIA OF UNIT 7, BENEATH THE CROW'S NEST.

FIG. 18. LOW ANGLE FAULT IN UNIT 6; THE DIP ON THE FAULT PLANE IS NORTHWARDS. THE DISPLACEMENT IS ABOUT 60 cms., (LEFT TO RIGHT), NORTH SHORE OF COW HEAD PENINSULA.

section a little, but their displacements are not very large (Fig. 18).

Unit 6 is traced to the north side of Tucker's Cove (Fig. 3), where it is patchily exposed north of the harbour and next to the fault on the north-east point of the peninsula (Fig. 19).

UNIT 7

This is a spectacular, prominent bed of breccia up to 20m. thick. This breccia contains boulders of white dolomitic limestone up to 4m. in diameter. The whiteness of the boulders makes Unit 7 very conspicuous along the shore. (It is a boulder in this bed which was shaped like a cow's head that provided the inspiration for the naming of the peninsula). Unit 7 crops out along the cliff on the western end of the north shore, and is very prominent at the Crow's Nest. The exposure swings inland just east of the lighthouse and Unit 7 probably forms the conspicuous scarp which runs some distance across the peninsula. It is interesting to note that this scarp is a beautifully preserved raised sea-cliff (Fig. 21). "Sub-fossil" Lithothamnion was found on the vertical surface. Unit 7 seems to thin markedly eastward and may crop out on the south-east side of Tucker's Cove, as a much less coarse breccia.

FIG. 19. A FAULT ON THE NORTH-EAST POINT OF THE PENINSULA, WHICH DOWNTHROWS UNIT 6 AGAINST UNIT 4. UNIT 6 IS ON THE LEFT AND UNIT 4 IS TO THE RIGHT IN THIS PHOTOGRAPH

FIG. 20. UNIT 7 NEAR THE POINT OF HEAD. UNIT 6 FORMS THE BEDDED MATERIAL BELOW. NOTE THE SLIGHTLY IRREGULAR BASE OF UNIT 7.

FIG. 21. UNIT 7 JUST BELOW THE LIGHTHOUSE. NOTE THE WAVE CUT SHAPE OF THE SCARP FACE.

FIG. 22. FLAT-PEBBLE BRECCIA OF BASAL UNIT 8 AT THE POINT OF HEAD. VIEW OF "BEDDING PLANE."

UNIT 8

The Point of Head (Fig.3) is partially made up of Unit 7, but it is largely formed by the overlying breccia sequence of Unit 8. At the base of Unit 8, there is about 35m. of what is mainly a flat-pebble or flaggy breccia (Fig. 22). This part also contains more or less lensoid bodies of coarser breccia with sub-rounded boulders. A few discontinuous layers of thin-bedded micrites are also present (Fig. 23). Most of the pebbles are brown or dark grey micrites. A few of the larger boulders in the lensoid bodies contain trilobite fragments and other macrofossil fragments.

The somewhat discontinuous thin-bedded horizons running through this part of the Unit demonstrate a considerable amount of faulting, which is not readily recognisable in the rather homogeneous breccia. The displacements of most of these north-west/south-east trending faults is minor, so that samples could be taken in stratigraphic order with a good degree of certainity. The low angle faults mentioned in the discussion of Unit 6 are also present here and it is very difficult to pick out the amount of displacements in this relatively homogeneous mass (Fig. 24).

Above this basal 35m. of breccia is about 18m. of intercalated flat-pebble breccias and thin-bedded micrites and shales (Fig. 25). The flat-pebble breccias contain pebbles of clean micrites, dolomites and calcarenites. Locally, rounded pebbles are present in some of the breccia

FIG. 23. OUTCROP PATTERN OF LOWER UNIT 8 AT THE POINT OF HEAD. NOTE THE THIN-BEDDED LIMESTONES AND SHALES, THESE PARALLEL BEDDING.

FIG. 24. LOW ANGLE FAULTING IN UNIT 8 AT THE POINT OF HEAD NOTE THE DISPLACEMENT OF THE JOINTS. BEDDING DIPS TO THE RIGHT (SOUTH-EAST).

FIG. 25. INTERBEDDED BRECCIAS, LIMESTONES AND SHALES OF THE UPPER PART OF UNIT 8 AT THE POINT OF HEAD. NOTE MAN STANDING AT CENTRE.

FIG. 26. "RIPPLED", UNEVEN BEDDING IN THE UPPER PART OF UNIT 8 AT THE POINT OF HEAD.

and these include dolomites, micrites, and chert.

The thin beds of micrite intercalated in this sequence have unusual lensoid and "rippled" appearances (Figs. 26 and 27). Many of these features are probably due to compaction causing bedding surfaces to warp somewhat. It is probable that $CaCO_3$ dissolution acted on some of the beds during and after deposition. This process tended to break the beds into a series of lenses. On some of these uneven bedding surfaces, mud fills the depressions. This mud is often poor in carbonate or completely noncalcareous. Vertical worm burrows are present in some of the thin micrite beds as well.

Unit 8 also crops out at the eastern end of the peninsula, on the point between Little Cove and Tucker's Cove. The character of the sequence changes considerably here, and a large proportion of it consists of thin bedded, laminated, graded limestones with intercalations of shale (Fig. 28). Several beds and lenses of flat-pebble breccias are present (Fig. 29) along with a few much coarser beds with boulders up to lm. across. This succession is well exposed in the cliff behind the powerhouse in Little Cove and all along the foreshore of the point. This complete change in proportions of breccia to bedded limestone between the Point of Head and Little Cove illustrates the very rapid lateral facies changes.

FIG. 27. LENSOID LIMESTONE BEDS IN UPPER UNIT 8 AT THE POINT OF HEAD. SUGGESTED SOLUTION SURFACES.

FIG. 28. UNIT 8 ON THE SHORE OF LITTLE COVE. NOTE RIPPLED AND LENSOID BEDDING FEATURES.

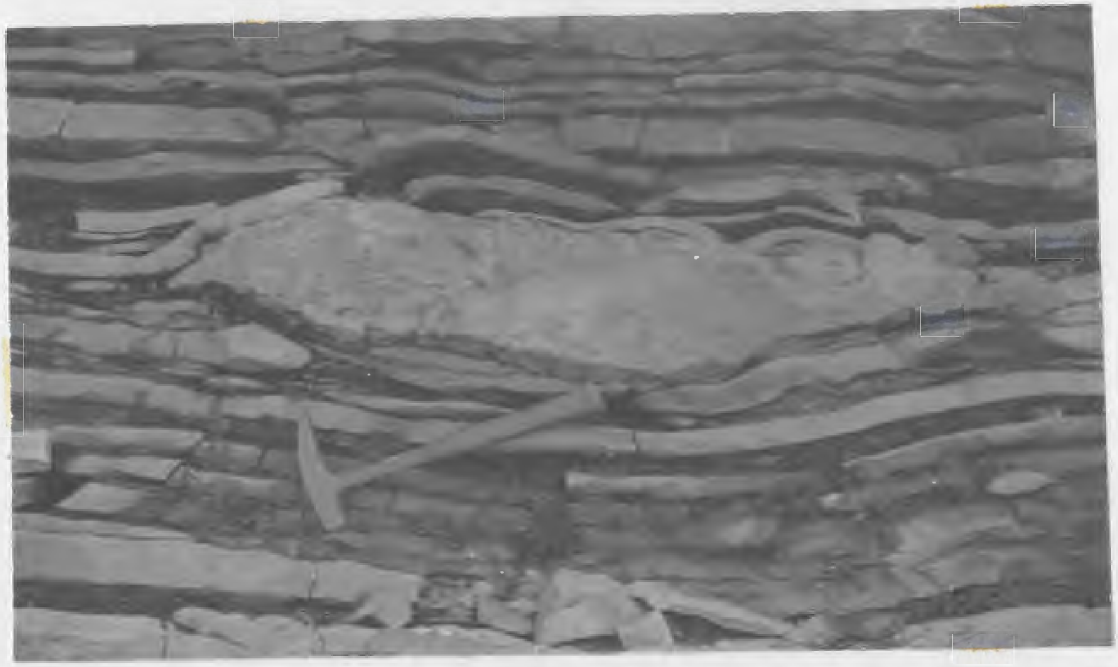


FIG. 29. SMALL LENS OF BRECCIA IN UNIT 8 IN TUCKERS COVE. THE BEDS ABOVE ARE DRAPED OVER THE IRREGULARITIES OF THE SURFACE OF THE BRECCIA LENS.

FIG. 30. THE INTERBEDDED LIMESTONES AND SHALES OF UNIT 9 AT THE POINT OF HEAD; THESE ARE OVERLAIN SUCCESSIVELY BY UNITS 10, 11 AND 12.

UNIT 9

Succeeding Unit 8 at the tip of the peninsula, is a sequence of thin-bedded, laminated micrites intercalated with shales which are locally graptolitic (Fig. 30). Lenses of flat-pebble breccia occur and one very coarse breccia about 25m. from the base. This sequence is referred to as Unit 9.

The shales in this sequence constitute a greater proportion of the thickness than in other units. The limestone beds consist of brownish micrites and very dense, dark grey micrites. Some of these beds are dolomitised. The limestones are very well laminated, and this may cause a single bed to look like a composite of a number of beds (Fig. 31). In most places they exhibit a mottled appearance; the darker patches are usually dolomitic. Vertical worm burrows are extremely common in some of these beds. These limestones also show the uneven bedding surfaces common in the upper part of Unit 8. The whole unit is about 27m. thick.

Unit 9 is also exposed to the west of the cabins on the west side of Shoal Cove, and also all along the southern shore from the east of Shoal Cove to the sand bar where it attains a similar thickness (32m.). Parts of the succession are repeated by a number of faults. There is a greater proportion of breccias in this exposure of Unit 9 (Fig. 32) than at the Point of the Head, and some are quite coarse, notably one with boulders up to 2.5m. in diameter which occurs at the base (Fig. 33). The thin bedded limestones are relatively less significant

FIG. 31. LAMINATED LIMESTONES OF UNIT 9 AT THE POINT OF HEAD. NOTE CHERT NODULE AT LOWER RIGHT AND LENSOID BEDS IN THE UPPER PORTION.

FIG. 32. BRECCIA AND THIN-BEDDED LIMESTONES IN UNIT 9 AT COW COVE. NOTE SMALL FAULT ON THE RIGHT.

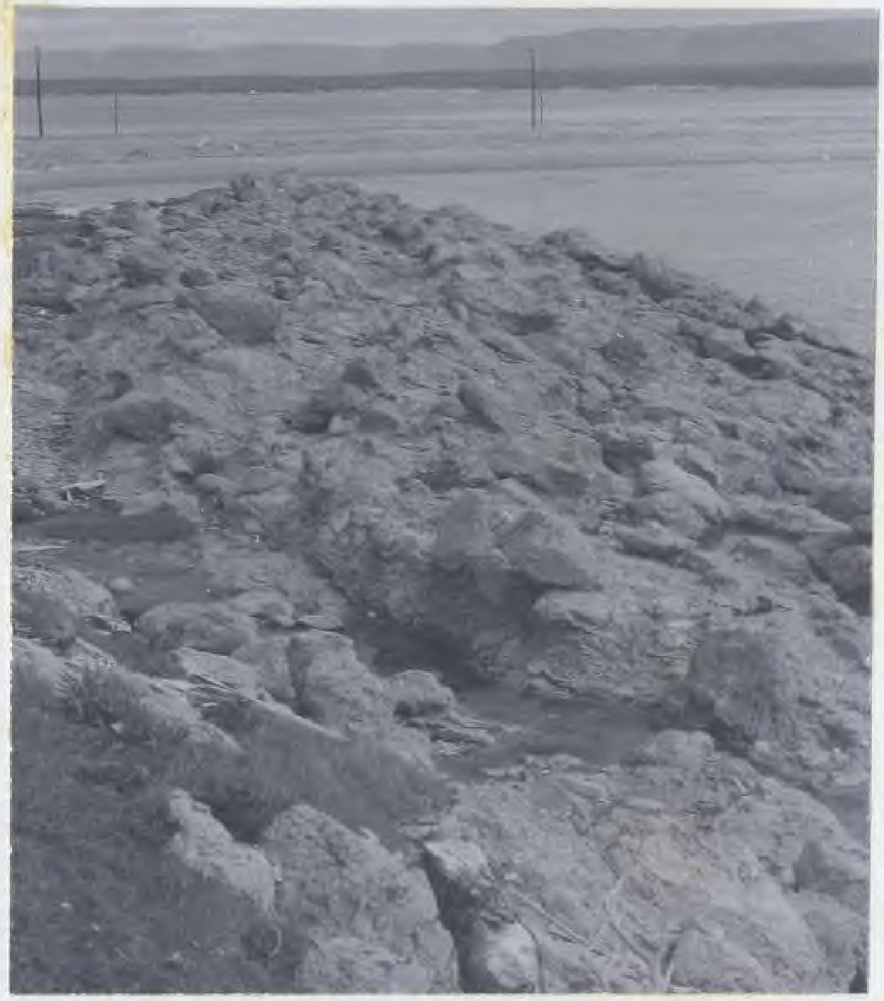


FIG. 33. COARSE BRECCIA AT THE BASE OF UNIT 9, IN COW COVE. THE SAND BAR IS IN THE BACKGROUND.

FIG. 34. UNIT 10 IN SHOAL COVE.

in this section. They are usually brown and grey micrites, but some graded bioclastic limestones occur as well. The limestones are locally burrowed, and exhibit the features attributed to solution and compaction in Unit 8, and the easterly outcrop of Unit 9. A number of samples from this unit yielded large faunas of conodonts. The contact with Unit 8 is not exposed on the south shore.

UNIT 10

At the Point of Head, an overlying breccia horizon, (Unit 10), downcuts about 1m. into Unit 9. This unit is only 2.2m. thick at the Point of Head, but it thickens westwards into Shoal Cove where it is about 5m. thick (Fig. 34). Several of the boulders in this breccia consist of interbedded micrites and shales which are haphazardly folded in places. Other boulders are commonly pale micrites with some macrofossils, usually gastropods. The top of the bed is covered by a layer of chert (Fig. 35).

UNIT 11

This unit is a sequence of thin-bedded limestones and shales, with rare beds and lenses of flat-pebble breccia (Fig. 36). It crops out along the Ledge and along the shore between Shoal Cove and Jim's Cove (Fig. 37). At the latter locality it is gently folded. The limestones at both localities are micrites which may be brown or dark grey and locally dolomitised. Some of the beds are lensoid with shale thickened

FIG. 35. THE TOP OF UNIT 10 AT THE LEDGE LOOKING SOUTH-WEST. UNIT 11 IS IN THE FOREGROUND.

FIG. 36. A LENS OF FLAT—PEBBLE BRECCIA IN UNIT 11 AT SHOAL COVE. NOTE THAT THE PEBBLES ALMOST ALL DIP TO THE RIGHT (i.e. NORTH), GIVING THE EFFECT OF CROSS-BEDDING.

FIG. 37. UNIT 11 EXPOSED FROM SHOAL COVE TO JIM'S COVE LOOKING WEST FROM THE WEST SIDE OF SHOAL COVE.

FIG. 38. CLOSE-UP OF UNIT 12 IN A CLIFF AT THE LEDGE

above and below the thin interconnections of the lenses. At The Ledge a few prominent beds of buff-weathering siltstone are present towards the top of the sequence. These distinctive units occur 13m. from the top of the sequence on the south shore. Unit 11 is about 13m. thick on The Ledge and thickens to over 30m. on the shore between Shoal Cove and Jim's Cove. This may suggest erosion of sediments or non-deposition at the easterly portion of outcrop. Beds at the base of Unit 11 at The Ledge are generally silicified, and entirely silicified lenses of microbreccia are to be seen. At The Ledge, an overlying coarse breccia (Unit 12) downcuts about 6m. into Unit 11 (Fig. 38).

UNIT 12

This unit is very resistant to erosion and forms the southern part of The Ledge, and the eastern headland of Jim's Cove (Fig. 3). It is about 9m. thick at the Ledge and thins to 3m. in Jim's Cove. In both localities boulders up to 2m. in diameter are found, and include buff-weathering siltstones like those of Unit 11, dolomites, breccias, micrites and rarely chert. At the base of this bed there are large slabs of bedded micrite and shale which give the appearance of having been ripped off underlying strata at the time of deposition of the breccia (Fig. 39). This unit is repeated by faulting on the headland east of Jim's Cove.

FIG. 39. LARGE SLABS OF BEDDED MICRITES AND SHALES IN THE BASE OF UNIT 12,JUST TO THE EAST OF JIM'S COVE. NOTE HAMMER AT CENTRE LEFT.

FIG. 40. BEDDING IN UNIT 13 AT THE POINT OF HEAD

UNIT 13

Overlying Unit 12 is a series of thin-bedded micrites, graded bioclastic limestones and shales (Fig. 40). In Deep Cove this series appears to have been laid down over an uneven surface of Unit 12. This Unit can be traced for only a short distance in Deep Cove. The Unit is 9m. thick at this exposure and it is broadly folded (Fig. 41). In Jim's Cove the exposure of Unit 13 is rather poor, but shales appear to be more dominant and the whole sequence is thicker. This thickness is probably accentuated by faulting (Fig. 42), but it may be as much as 12m. A single breccia unit within Unit 13 occurs in Jim's Cove, below which there are limestone shales with beautifully preserved graptolites. On the east side of Jim's Cove, there are thin-bedded limestones which strongly resemble those of Unit 13 in Deep Cove. It appears that more of Unit 13 was ripped up by Unit 14 in Deep Cove than in Jim's Cove and it is probable that this accounts for the difference in thickness between the two localities.

UNIT 14

This unit is a spectacularly coarse breccia (Figs. 43 and 44) with boulders up to 20m. in length. These larger boulders are mainly composed of white micrites but a great variety of lithologies is evident in the boulders. Several masses of bedded limestone and shale are included in the

FIG. 41. FOLD IN UNIT 13 AT THE POINT OF HEAD.

FIG. 42. FAULT IN UNIT 13 IN JIM'S COVE.

FIG. 43. UNIT 14 ON THE WEST SIDE OF DEEP COVE, CONTAINING VERY COARSE BOULDERS

FIG. 44. CLOSE-UP OF UNIT 14 ON THE WEST SIDE OF DEEP COVE.

breccia and they are often contorted and broken up (Figs. 45 and 46). Other lithologies incorporated as boulders in the breccia include micrites, (as smaller boulders and pebbles), calcarenites, bioclastic limestones, flat-pebble breccias, and rarely chert. A larger variety of macrofossils are present in the boulders in this breccia than in any other. One boulder with crinoid ossicles was noted, and several with gastropods, brachiopods and orthocone nautiloids were observed. This is the highest unit in the sequence.

FIG. 45. CONTORTED SLAB OF BEDDED LIMESTONES AND SHALES IN UNIT 14 ON THE WEST SIDE OF DEEP COVE.

FIG. 46. VERY LARGE UNFOLDED SLAB OF BEDDED, DOLOMITISED LIMESTONE IN UNIT 14 ON THE EAST SIDE OF DEEP COVE.

CHAPTER V

CORRELATION

(ii) Introduction - Comments to Correlation Chart (Table I

Correlations are made with the conodont zones of Balto-Scandia, the mid-western United States and Australia. Some explanatory comments on the correlation chart will be useful. The chart has numbered columns and these are discussed below.

1. The Arenigian and Tremadocian although described from Great Britain, are taken as being applicable to Balto-Scandia, since they have been used in correlation of that area (Jaanusson 1960).

2. The conodont zones are those of Lindström (1971) with the exception of the Paltodus inconstans Zone which was described and defined by Bergstrom (1968). The zones Baltoniodus triangularis to Amorphognathus variabilis are not represented by their zone fossils in the Cow Head sequence. This interval is filled entirely by species of the genus Periodon.

3. This column shows the units described in this study. The abbreviations are: S = Staurograptus; D = Dictyonema; I.c. = Isograptus caduceus; T.a. = Tetragraptus approximatus.

4&5. These show the beds described by Kindle and Whittington (1958) from the south and north shores of the Cow Head Peninsula respectively.

6. The Trempealauan is difficult to correlate precisely with the Cambro-Ordovician boundary of Balto-Scandia. It is thought, however, to extend somewhat into the Tremadocian (Clark and Miller 1969; Jones, Shergold and Druce 1971)

7. This column shows the possible correlation of the conodont zones in the mid-western United States defined by Ethington and Clark (1971). The difficulty of correlating cratonic and extracratonic faunas was pointed out by Ethington and Clark (1971), and this difficulty is evident in this study, because correlation with the mid-west faunas is very poor. A study of conodonts from the Pogonip Group of Nevada has, however, revealed faunas similar to those from Cow Head (Ethington 1972).

8. This column shows the stages set up by Jones, Shergold and Druce (1971). The correlations shown are based on the results of their study.

9. This column shows the conodont zones erected by Druce and Jones (1971). Correlation of these zones is based on that made by Jones, Shergold and Druce (1971).

Distinction of stratigraphic units on the Cow Head Peninsula is largely based on micro- and macro-faunas collected by the writer, or previously described in the literature and partly on lithological evidence.

(iii) <u>THE UNITS</u>

<u>UNITS 1-5</u>

Units 1 through 5 are lithologically distinct and can be traced in outcrop along the north shore of the Cow Head Peninsula. No conodonts were recovered from samples of these units. The age relationships are based on the trilobites reported by Kindle and Whittington (1958, Table 2, p. 319). Units 1-4 are Dresbachian in age and fall in the <u>Paradoxides forchammeri</u> Zone . Although this is the oldest date for the Cow Head Group at Cow Head, exposures at Broom Point and the White Rock Islets (Fig.2) indicate an earlier age which is equivalent to the <u>Paradoxides davidis</u> and <u>Paradoxides hicksi</u> Zones, (Kindle and Whittington 1958, Table 2, p. 319).

Unit 5 is placed in the <u>Taenicephalus</u> sub-zone of the Franconian, which Kindle and Whittington (1958) consider as a probable equivalent to Zone 4 of the Olenid Series in the Swedish succession.

<u>UNIT 6</u>

The oldest conodonts found in the Cow Head sequence occur a few metres above the base of Unit 6. The yields from these lowermost productive samples are, however, low and the taxonomic diversity of the fauna is rather poor. Characteristic elements of the fauna are four types of the genus <u>Hertzina</u>, distinguished by the presence or absence of anterior and/or posterior edges. Four form-species of the genus Proconodontus are recognised, viz: P. burkei, P. müleri müleri P. primitivus, and P. tricarinatus. These elements are common members of the Upper Cambrian fauna of Unit 6. P. müleri müleri is reported from the Notch Peak Limestone of Utah by Miller (1969). Druce and Jones (1971) note the occurrence of the other three Proconodontus species from the Chatsworth Limestone of Western Queensland, Australia.

The low yields from these Upper Cambrian horizons preclude a precise definition of the Cambrian-Ordovician boundary. Occurrences of graptolites belonging to the genera Dictyonema and Staurograptus noted by Kindle and Whittington (1958) close to the top of Unit 6 are in the Upper Cambrian, with the very top of the unit yielding Tremadocian graptolites.

Unit 6 faunas are found along the north shore (Fig. 3), and were also indentified from a sample (#71) from the north side of Tuckers Cove. This latter occurrence is noted from beds adjacent to a fault on the north-east point of the peninsula. On the other side of the fault are beds described as Middle Cambrian by Kindle and Whittington (1958), viz: Units 1, 2, 3, and 4. Thus, the Middle Cambrian is missing due to faulting on the southerly limb of the syncline at Cow Head.

Faunal correlations of Unit 6 between the north shore and the eastern shore of the peninsula are strengthened by the existence of beds of identical quartz sands at both locations.

UNIT 7

Unit 7 can be traced in outcrop from the Point of Head to the scarp in the central part of the peninsula, where it gradually disappears under drift. The tracing of the eastward extension of this unit is based upon conodonts. A thin breccia horizon crops out just south of the harbour (Fig. 3): above this are faunas characteristic of Unit 8, and below there is a fauna which occurs in Unit 6. This breccia is therefore in the stratigraphic position of Unit 7, but it is not necessarily the same breccia as that described as Unit 7 at the Point of Head.

At the Point of Head, Unit 7 yielded only specimens belonging to the genus *Hertzina*, (thus not allowing precise correlation) however, it is bounded below by the Tremadocian graptolites and above by a fauna characteristic of Unit 8 (see below).

Conodonts occurring in Units 6 and 7 are:

Hertzina spp. s.f.
Proconodontus *burkei* (Druce and Jones)s.f.
Proconodontus *müSlleri* *mülleri* Miller s.f.
Proconodontus *primitivus* (Müller) s.f.
Proconodontus *tricarinatus* (Nogami) s.f.

UNIT 8

The *Proconodontus* - *Hertzina* association continues up into the base of Unit 8, where it co-occurs with *Cordylodus proavus* s.f. This form species is regarded as the zone fossil of the lowermost Tremadocian in the Ninmaroo Formation of Queensland (Druce and Jones 1971). *Cordylodus proavus* is the only addition to the fauna in the lower part of Unit 8, and it appears quite suddenly, with no apparent evolutionary forerunner. Miller (1969) derives *C. proavus* from *Proconodontus notchpeakensis* but this species has not been found in the Cow Head Group.

The Balto-Scandian zone equivalent to this fauna in the lowermost Tremadocian is the *Cordylodus angulatus* zone (Lindström 1971) This species is not reported from the Cow Head Group. It is, however, recorded in the Middle Warendian (Table 1), in Australia, (Druce and Jones 1971), but here it occurs much higher in the sequence, at a level equivalent to the *Paltodus deltifer* Zone of Balto-Scandia.

The equivalent to this lower Unit 8 fauna in the mid-western United States is probably Faunas A and B of Ethington and Clark (1971). The correlation between the mid-western faunas and those of Balto-Scandia and Cow Head is very poor, however, because few forms occur in all the regions.

The upper part of the Tremadoc in Balto-Scandia is defined by the _Paltodus deltifer_ zone (Lindström 1971). No drepanodiform elements, and only very few oistodiform elements of this species occur in the Cow Head sequence. Other forms characteristic of, but not restricted to this zone do, however, occur, viz: _Oneotodus variabilis_ s.f. and _Paroistodus numarcuatus_.

Representatives of the zone fossils for the Upper Tremadoc of Australia established by Druce and Jones (1971), are not present in the Cow Head sequence, although a number of species recorded by them from this interval do occur.

The top of Unit 8 is marked by the first appearance of the Balto-Scandian zone fossil _Prioniodus elegans_ (Table 1). The top of Bed 8 (Kindle and Whittington 1958) is taken at the first appearance of the graptolite _Tetragraptus approximatus_. In this study _Prioniodus elegans_ is found within the _T. approximatus_ Zone and thus the boundary of bed 8/bed 9 (Kindle and Whittington 1958) is higher in the sequence than that of Units 8 and 9 in this study (Table 1).

It is interesting to note that _Drepanoistodus forceps_ is relatively abundant at this level, whereas Lindström (1971, Figs. 1 and 2) indicates a peak of abundance of this species at a higher level in the _Baltoniodus navis_ Zone (Table 1).

Quite a diverse scolopodid fauna is present (see list below). All the form-species collected at Cow Head were recorded by Druce and Jones (1971) from the upper part of the Warendian in Australia (Table 1), with the exception of Scolopodus filosus s.f. The forms from the Cow Head Group are quite persistent and extend higher than the Australian forms, i.e., into the Lower Arenig.

The top of Unit 8 probably lies in the Paltodus inconstans Zone (Bergstrom 1968), although no certain representative of the zone fossil has been noted. No drepanodiform elements and only very few oistodiform elements of this species are found. The boundary between Units 8 and 9 is defined on the first appearance of Prioniodus elegans. It follows, therefore that the upper part of Unit 8 must be equivalent to the Paltodus inconstans Zone. Thus, Unit 8 spans the Tremadoc-Arenig boundary.

Lithological correlations are impossible to make in this unit, because of the great lateral lithological variation.

The fauna contained in Unit 8 is listed below:

Acodus gratus Lindström s.f.
Cordylodus proavus Müller s.f.
Drepanodus acutus Pander s.f.
Drepanodus arcuatus Pander
Drepanodus simplex Branson and Mehl s.f.
Drepanodus tenuis Moskalenko s.f.

Drepanoistodus forceps Lindström

Hertzina spp.

Oneotodus variabilis Lindström s.f.

? Paltodus deltifer Lindström

? Paltodus inconstans Lindström

Paltodus n.sp.A. s.f.

Panderodus n.sp.

Paroistodus numarcuatus Lindström

Pronconodontus burkei (Druce and Jones) s.f.

Pronconodontus müller müller Miller s.f.

Proconodontus primitivus (Müller) s.f.

Proconodontus tricarinatus (Nogami) s.f.

Scolopodus bassleri (Furnish) s.f.

S. filosus Ethington and Clark s.f.

S. gracilis Ethington and Clark s.f.

S. iowensis (Furnish) s.f.

S. quadriplicatus Branson and Mehl s.f.

UNIT 9

Unit 9 lies entirely within the Prioniodus elegans Zone and its base is defined by the first appearance of that species. No formal stages or zones have been designated for this part of the sequence in Australia, so correlations on the basis of conodonts are impossible. P. elegans is reported from the

Pogonip Group, Nevada (Ethington 1972).

P. elegans extends down into the graptolite zone of Tetragraptus approximatus in the Cow Head sequence. This graptolite species is recorded from Unit 9 by Kindle and Whittington (1958) and the existence of the lower Arenig conodont P. elegans has been established several metres below their graptolite localities. Bergstrom and Cooper (1973, Fig. 6) extend the P. elegans Zone down into the equivalent of the T. approximatus zone, and this occurrence at Cow Head confirms that correlation.

Associated with Prioniodus elegans are a number of specimens of Prioniodus navis s.f. Much higher in the sequence this form species is considered to be an element of the multi-element species Baltoniodus navis (Lindström 1971). The form occurring in the Cow Head Group appears morphologically the same as the constituent element of Baltoniodus navis. The multielement association of Prioniodus navis s.f. is not known at this level, but it may perhaps be an evolutionary forerunner to Baltoniodus navis.

Paroistodus proteus is regarded by Lindström (1971), as a zone fossil immediately below Prioniodus elegans, equivalent to the Paltodus inconstans zone of Bergstrom (1968). In the Cow Head Group Paroistodus proteus is recovered from samples containing Prioniodus elegans and does not occur below this zone, except in one instance on the Point of Head (Sample 8B, Table 2). Thus, the Paroistodus proteus Zone (Lindstrom 1971) is not considered useful in correlation of the Cow Head Group. The P. proteus - P. elegans zonal boundary in the Balto-Scandian area is taken to coincide with the Tetragraptus phyllograptoides - Didymograptus batticus graptolite zones, and to be located in the lowermost part of the T. approximatus Zone (Bergstrom and Cooper 1973).

Beds 8a-g (Kindle and Whittington 1958) are here included in Unit 9 on the basis of the presence of Prioniodus elegans (Table 1). The base of Unit 9 is placed lower than the base of bed 9 (Kindle and Whittington 1958) on the same basis.

The fauna contained in Unit 9 is listed below:

Acodus gratus Lindström s.f.
Acontiodus arcuatus Lindström s.f.
Acontiodus reclinatus Lindström s.f.
Drepanodus arcuatus Lindström
Drepanoistodus forceps (Lindström)
Oistodus brevibasis Sergeeva s.f.
Oistodus lanceolatus Pander s.f.
Paracordylodus gracilis Lindström s.f.
Paroistodus numarcuatus (Lindström)
Paroistodus parallelus (Pander)

Paroistodus proteus (Lindström)

Prioniodus elegans Pander

Prioniodus navis Lindström s.f.

Scandodus furnishi Lindström s.f.

Scolopodus bassleri (Furnish) s.f.

Scolopodus filosus Ethington and Clark s.f.

UNIT 10

Unit 10 is entirely defined and correlated on lithological grounds. Only a few conodont specimens were recovered, but they clearly indicate the *Prioniodus elegans* zone.

The two multielement species identified are:

Drepanoistodus forceps (Lindström)

Prioniodus elegans Pander

UNIT 11

The next striking faunal change is the replacement of *Prioniodus elegans* by *Prioniodus evae*. This changeover takes place just above the base of Unit 11. This latter species is stratigraphically diagnostic in the Balto-Scandian area, (Lindström 1971) where conodont faunas of this type are currently best known (summarised by Lindström 1971). In the Cow Head sequence *P. evae* is associated with the graptolite *Tetragraptus fruticosus*. Bergstrom and Cooper (1973) report *P. evae* associated with the index graptolites *Phyllograptus densus* and *P. angustifolius elongatus* in the Marathon sequence in Texas are equivalent to the upper part of the *Didymograptus extensus* Zone, (Lindström 1971). Skevington (1963) correlates *D. extensus* with *T. fruticosus*, thus *P. evae* occurs at approximately the same level in the Cow Head Group as it does in the Balto-Scandian sequence and the Marathon sequence of the United States. *P. evae* is also reported from the Pogonip Group, Nevada (Ethington 1972).

A few specimens of *P. elegans* extend into the base of the *P. evae* Zone.

Unit 11 yielded the following species:

Acontiodus arcuatus Lindström s.f.
A. reclinatus Lindström s.f.
Drepanodus acutus Pander s.f.
Drepanodus arcuatus Lindström
Drepanodus simplex Branson and Mehl s.f.
Oistodus lanceolatus Pander s.f.
Pariostodus parallelus (Pander)
Prioniodus elegans Pander
Prioniodus evae Lindström
Scandodus furnishi Lindström s.f.

UNIT 12

This unit is within the *Prioniodus evae* Zone. A few probable elements of *Periodon flabellum* were recovered from a boulder in the breccia of Unit 12. Only two elements of the apparatus were found, so positive identification was not made.

The small fauna from Unit 12 consists of:

Drepanodus arcuatus Lindström

Drepanoistodus forceps (Lindström)

Paroistodus proteus (Lindström)

?Periodon flabellum (Lindström)

UNITS 13 and 14

Unit 13 is a distinct lithological entity between the breccia of Unit 12 and the spectacular and distinct Unit 14. The thinly bedded limestones and shales exposed in Jim's Cove yield beautifully preserved Isograptus caduceus. The character of the limestones in this unit is different to that in other, lower, bedded units. There is a much greater proportion of graded bioclastic limestones, some of which are quite coarse.

Unit 14, which is exposed on either side of Deep Cove (Fig. 3) is lithologically a very characteristic breccia and marks the top of the sequence.

The faunas recovered from these two units make correlation with the Balto-Scandian sequence rather difficult. None of the zones worked out by Lindström (1971) for the Volkhov Stage (Table 1) apply to the Cow Head sequence. The dominant elements in the faunas from Units 13 and 14 are representatives of the multielement species Periodon flabellum and P. aculeatus. Both of these species co-occur in samples from Unit 13, and intermediate forms of some of the elements are also present.

Lindström (1971) considers Periodon flabellum to be abundant from the time of the Prioniodus elegans Zone to the top of the Paroistodus originalis Zone. After which it becomes less abundant. Thus, this species has quite a long stratigraphic range and is of little use in correlation. Periodon aculeatus is not reported to occur below the Arenig-Llanvirn boundary (Fahraeus 1970; Bergstrom and Cooper 1973). At Cow Head the faunas immediately preceding this Periodon fauna are of middle Arenigian age (see above). Since no hiatus has been identified in the sequence the Periodon fauna must represent much, if not all of the remainder of the Arenigian and possibly some of the Llanvirnian. It is thus rather difficult to define the uppermost part of the Cow Head sequence chronostratigraphically, but it is probably very close to the Arenig-Llanvirn boundary.

The fauna contained in Units 13 and 14 consists of:

Acodus gratus Lindström s.f.

Acontiodus arcuatus Lindström s.f.

Acontiodus reclinatus Lindström s.f.

Belodella sp. A Fahraeus 1970 s.f.

Drepanodus acutus Pander s.f.

Drepanodus arcuatus Lindström

Drepanoistodus forceps (Lindström)

Oistodus triangularis Lindström s.f.

Paroistodus proteus (Lindström)

Periodon aculeatus Hadding

Periodon flabellum (Lindström)

Scandodus furnishi Lindström s.f.

Scolopodus gracilis Ethington and Clark s.f.

Spathognathodus n, sp. Lindström 1960. s.f.

CHAPTER VI

PALEOENVIRONMENT: THE COW HEAD GROUP AS A CONTINENTAL SLOPE DEPOSIT

(i) INTRODUCTION

The following discussion is based almost solely on field observation of lithologies and large-scale sedimentary structures. Only very cursory studies have been made of thin-sections and acetate peels. It is believed that large-scale sedimentary structures provide good evidence for the recognition of the paleoenvironment. Recognition of the environment of deposition will provide clues to the paleoecology of the conodonts.

The nature of the breccias and thin-bedded limestones is discussed, and an interpretation of the depositional environment is presented with respect to origin, made of transport and site of deposition. A brief section is devoted to conodont faunal changes and their possible environmental implications.

The lithologies have been described in a previous section, and so it will suffice to summarise here. The Cow Head Group is interpreted as a flysch sequence consisting of carbonate breccia, graded bioclastic limestones, micritic limestones and non-calcareous shales, with rare sandstones, shaly limestones and non-calcareous siltstones. Many of the limestones are laminated and some are partially to completely dolomitised.

(ii) THE BRECCIAS

The breccias are quite varied in form and provide many clues to the environment of deposition. All transitions occur from flat-lying undeformed micrite beds, to beds deformed into slump folds, to partially brecciated beds, to breccias. This illustrates the obvious instability of the site of deposition.

(a) General Characteristics

In general, the breccias form thin sheets, 3-20m thick, with some smaller scale lenses up to 15m across. They are contained in deep-water, thin-bedded limestones and shale. The breccias usually have planar bases, but some are seen to down-cut substantially. Those breccias that down-cut still have very even bases. Some of the breccias may exhibit an irregular upper surface because of boulders projecting above the general surface level (e.g. Unit 12).

Large pieces of bedded limestone and shale up to 50m. in length are locally included as boulders in the breccia, (Unit 3). Boulders of breccia are sometimes included as boulders in other breccias. Usually, several different lithologies are included as boulders in any one breccia, although one particular lithology may be dominant. In general, clasts range from silt and sand size to huge blocks several 10's of metres across. The most common clasts are flat, flaggy pebbles of micrite. The matrix generally consists of micrite, but matrices of sparry calcite are also present. No real grading is seen in the breccias although the tops of beds are often composed of generally finer material than the rest of the unit. No bedding planes are visible within any breccia: they all appear to represent more or less single events. A possible exception to this is Unit 8 at the Point of Head, where a generally homogeneous mass of breccia appears to have coarser lenses within it.

(b) Types of Breccia

Two main types of breccia can be distinguished:

1. Many of the breccias are of the so-called flat-pebble type. This implies that most or all of the pebbles are flat fragments derived from thinly bedded material. Usually, these pebbles are oriented parallel to the bedding plane, but sometimes they may be oriented in many planes.

2. The second type of breccia is much coarser, and contains large sub-rounded to sub-angular boulders. There are usually flat pebbles in these breccias as well, and they provide a "matrix" for the coarser fragments. The lithologies of the sub-rounded boulders and the flat pebbles are usually distinct from one another.

Gradations between these two types occur.

(iii) THE THIN-BEDDED LIMESTONES AND SHALES

The most common lithology in the thin-bedded limestones is micrite; many of these are laminated. Graded bioclastic limestones occur sporadically in the sequence. Many of these beds are partially to completely dolomitised; this is probably secondary, late dolomitisation which occurred along porosity routes opened up by solution and faulting.

Many beds show features of bioturbation. The most common are vertical or near vertical worm tubes which frequently occur in large numbers. Of secondary importance, are U-shaped worm tubes which occur in several beds. They are never present in as great numbers as the vertical worm burrows. These burrows are seen to disrupt laminations in the beds.

A peculiar feature of some of the thin beds, is a very uneven bedding surface (Fig. 14). The relief on these surfaces is of the order of a few centimetres. They are interpreted as being the result of dissolution. Non-calcareous muds have been deposited in the hollows of the surfaces. Dissolution seems to have had a significant effect on the structures in this sequence.

In places the beds have pronounced "pinch and swell" structures (Figs. 31, 40). In this case, the thin interconnections between the lenses are overlain by non-calcareous shale. In its most extreme form, this feature breaks the beds up into isolated individual lenses. This boundinage-like structure may be the result of compression or solution, or both.

(iv) INTERPRETATION OF DEPOSITIONAL ENVIRONMENT

(a) Introduction

It is proposed that the Cow Head breccias originated as gravity slides from the shelf and upper slope and were deposited on the lower continental slope. The thin bedded carbonates and non-calcareous shales are largely considered as lower continental slope deposits, some of which may have been laid down by turbidity currents. The action of bottom currents is thought to be considerable in terms of deposition and reworking of the lower slope sediments.

The depositional history of the Cow Head Group is discussed under three headings: (1) Detachment of blocks and initiation of movement; (2) Transport mechanisms; (3) Site of deposition.

(b) Origin and Deposition of the Cow Head Group

(1) Detachment of Blocks and Initiation of Movement

The breaking of blocks from the shelf edge was probably a result of earthquake shocks. The detachment mechanism is unlikely to have involved wave action, because none of the blocks show features of subaerial exposure. Evidence of the blocks being algal coated, bored or reworked extensively is also lacking. Collins and Smith (1972) suggest that the western platform was elevated above sea level, however there is nothing to suggest this in the blocks at Cow Head. Thus, response to earthquake movements is considered the most likely means of detachment of blocks from the shelf edge.

In many breccias there appear to be two distinct types of boulder (Chapter VI ii b);

(1) large subrounded or subangular boulders often containing macrofossils which are herein interpreted as shelf

lithologies (see below).

2. Flat pebbles (usually micrite) which are herein interpreted as slope lithologies (see below).

Other factors may have contributed to the initiation of movement as well as earthquake activity, e.g., slope material onto which the shelf blocks fell may have had increased pore pressure, and required little more than a trivial trigger to start movement downslope.

(2) Transport Mechanisms

With regard to transport, the weight of evidence points to the suggestion that the breccias are mass gravity flows. It is evident that large volumes of mud to boulder size debris have moved downslope, resulting in poorly sorted, ungraded, planar units. These characteristics are considered indicative of mass flow (Dott 1963; Mountjoy et al. 1972).

Dott (1963) divided submarine gravity movements into four intergradational types: 1. Rockfalls, 2. Slides and Slumps; 3. Mass Flows; and 4. Turbidity Flows. These types depend upon the behaviour of the mass in clastic, plastic or viscous fluid flow, and on the physical interaction between solids and fluids. All these types of motion are intricately related and provide a wide variety of types of deposits (Fig.51). In terms of the Cow Head sequence, mass flow is regarded as the most important type of transport process.

Mountjoy et al. (1972, p. 184) discuss the Devonian Ancient Wall megabreccias of Alberta and list features which they suggest are indicative of mass flow. These features are listed below and their applicability to the Cow Head breccias is obvious:

1. disoriented clasts surrounded by lime mud matrix (paraconglomerate texture);
2. wide variation in size of clasts from silt size to boulders up to 25 x 50m. and larger;
3. boulders and blocks are predominantly angular to subangular;
4. complete mixing of a wide variety of clasts during movement;
5. lack of stratification and sorting, except poor grading; which sometimes occurs at the top of a few deposits;
6. distinct boundaries and relatively planar lower boundaries;
7. lack of disruption of underlying strata;
8. transport over low slopes;
9. known lateral extent of a few kilometers.

The paraconglomerate texture is evident throughout the Cow Head sequence (e.g. Figs. 4, 5, 12, 22) and a wide variation in the size of clasts is common (e.g. Figs. 20, 22). Boulders in the breccias are dominantly subangular and there is often a wide variety of clasts, although one lithology is usually dominant. Grading is essentially absent in the breccias of the Cow Head Group, and boundaries are almost always planar (Fig. 32 and Fig. 43). The planar nature of the boundaries obviates a lack of disruption of underlying strata. The interpretation of the Cow Head breccias as lower slope deposits suggests that transport took place over low slopes. With regard to feature 9 in the above list, exposures of the Cow Head Group are known over a considerable lateral extent (Chapter III). In conclusion, it seems reasonable to interpret the Cow Head breccias as mass gravity slides.

The Cow Head Group is not a turbidite succession although turbidity currents, as such, were probably associated with the mass flows. There are extremely few flute casts or tool marks at Cow Head and cross bedding is rarely seen. More or less microscopic grading is present in several thin carbonate beds, and this may be the result of turbidity currents. The classic Bouma sequence (Bouma 1962) is never seen.

Submarine rockfall (Fig. 51), a process of rolling or freefall of individual clasts, may have contributed in a minor way as an agent of transportation, since, in some places, isolated boulders are seen within bedded limestones (Fig. 47). These must have rolled as individual blocks before or after a mass flow.

Mass gravity flows with associated minor turbidity flows are considered to be the volumetrically most important transportation agents in the Cow Head sequence.

The wide distribution of bottom currents at the present time suggests that they were probably active in the past as well. The importance of these bottom currents has been pointed out i.e. by Heezen (1968), Stanley and Kelling (1969) and Stanley and Unrug (1972). The latter authors (1972, p. 294) state: "bottom photographs and cores indicate that there are very few areas not in some fashion affected by the movement of water masses flowing above the bottom." Bottom currents are produced by differences in density of water masses or by differences in surface level or both. Velocities up to 1m. per second have been recorded (Heezen and Hollister 1964). Although the activity of bottom currents in the geological record has not really been documented, they may have been important sediment movers and redistributors in the Cow Head sequence in between mass flows. Evidence of their action may be suggested by the existence of extremely well sorted pseudopellets in the laminae of the thin bedded limestones, (Fahraeus et al. in press).

Thus, it is suggested that the Cow Head succession was transported by mass gravity slides, with relatively minor additions of sediment carried by turbidity and bottom currents. Knowledge of these transport mechanisms is still sketchy, but they appear to be the most likely processes active in the transport of the Cow Head sediments.

(3) Site of Deposition

The ungraded well sorted micrites present in the Cow Head sequence are interpreted as pelagic and hemipelagic sediments deposited along with non-calcareous shales in a lower continental slope environment.

Many of the thin bedded limestones exhibit uneven bedding surfaces which have been interpreted as surfaces of $CaCO_3$ dissolution (Chapter VI, iii). This suggests that deposition and consolidation took place close to the carbonate compensation depth (Berner 1971, p. 63), which represents the depth where $CaCO_3$ is dissolved as fast as it is deposited. The measured depth of the compensation point varies and often persists at depths far below that where the water becomes distinctly undersaturated (Berner 1971). Cold water currents may also inhibit deposition of carbonate.

The thin bedded limestones and shales lack macrofossils with the exception of graptolites. This may suggest that they were deposited in "deep water." Macrofossils are, however, quite abundant in some of the blocks in the breccias and a shallower water origin (possibly shelf) is invoked for these. It is suggested that the breccias are contained in "deep water" sediments.

The Cow Head sequence which is only about 300m. thick represents a long period of deposition (Middle Cambrian to Middly Ordovician). A depositional rate of this order is typical of the continental slope. Seismic reflection profiles show that the continental rise south-east of New England, for example, is a sedimentary sequence 1.6 kms. thick, whereas the slope is veneered by only 0.4 kms. of sediment. It seems obvious that the Cow Head Group cannot represent a rise deposit, and since it is contained within probable deep marine sediments, it seems likely that it is a continental slope deposit.

Further evidence that the sequence was deposited on a continental slope is provided by the thin bedded limestones. Lateral persistency of strata is regarded as being indicative of a lower slope environment, whereas the upper slope is dominated by channel deposits (Stanley and Unrug 1972). At Cow Head several dominantly thin bedded units can be traced across the peninsula. Shales containing the same graptolites as Unit 13 have been reported from St. Paul's Inlet (Fig. 2) by Kindle and Whittington (1958). Many of the breccias are also quite continuous, eg. Unit 7.

Stanley and Kelling (1969) found that core samples from the lower part of a modern slope commonly revealed lamination and bioturbation. Indeed, Stanley and Unrug (1972) consider bioturbate structures particularly common on the lower slope. A large proportion of the thin bedded limestones at Cow Head are laminated, and they locally exhibit burrows disrupting the laminae.

Gravity slides and slumps are most common on the lower slope (Stanley and Unrug 1972). The fact that much of the Cow Head Group was deposited by this mechanism further reinforces the lower slope as the site of deposition.

(c) Faunas and Environmental Change

Close to the top of the section, between Units 12 and 13, there is an abrupt change from a Prioniodus dominated fauna to an overwhelmingly rich Periodon fauna. This appears to reflect a shallowing of the depositional environment.

Barnes and Poplawski (1973) place Periodon forms in a shallower water environment than Prioniodus forms. A Periodon fauna occurs abundantly in the Table Head Formation (Fahraeus, 1970). This Formation is considered to be an upper slope deposit at the time of the abundant occurrence of Periodon (Fahraeus pers. comm.). Since the Cow Head Group is interpreted as a lower slope deposit it seems possible that the water-depth shallowed somewhat towards the top of the sequence, i.e. after Unit 12 was deposited.

Some evidence of shallowing can be seen in the lithologies of Units 13 and 14. Unit 13 contains a much greater proportion of bioclastic limestone than underlying thin bedded units. Boulders in Unit 14 yield a much larger number and a greater diversity of macrofossils than previous breccia units: crinoid stems, orthocone nautiloids, gastropods and trilobites have all been found. These two factors may indicate a greater proximity of the depositional environment to the shelf, and thus shallower water.

This change in the environment was probably associated with early tectonism involved with the start of the movement of the klippen. At the same time as this faunal change takes place at Cow Head, elsewhere, easterly derived flysch first appears. This flysch is associated with uplift of the ophiolite assemblages to the east (R.K. Stevens pers. comm.). Also, at this time, the disconformity between the St. George Formation and the Table Head Formation is evident. Although this is a diachronous disconformity, its earliest occurrence is in the late Arenig, (Fahraeus pers. comm.). Both ~~these~~ events suggest uplift, and since they are penecontemporaneous with the abrupt faunal change in the Cow Head sequence, it is suggested that uplift of the continental slope occurred in upper middle Arenig times, placing the sequence at Cow Head in shallower water. This situation persisted throughout the upper Arenig.

FIG. 47. ISOLATED BLOCK IN UNIT 6 ON THE NORTH SHORE.

FIG. 48. BRECCIA BOULDER WITHIN A BRECCIA, UNIT 8.

FIG. 49. BRECCIA BOULDER WITHIN A BRECCIA, UNIT 14.

FIG. 50. SLUMP FOLDING IN UNIT 6 ON THE NORTH SHORE.

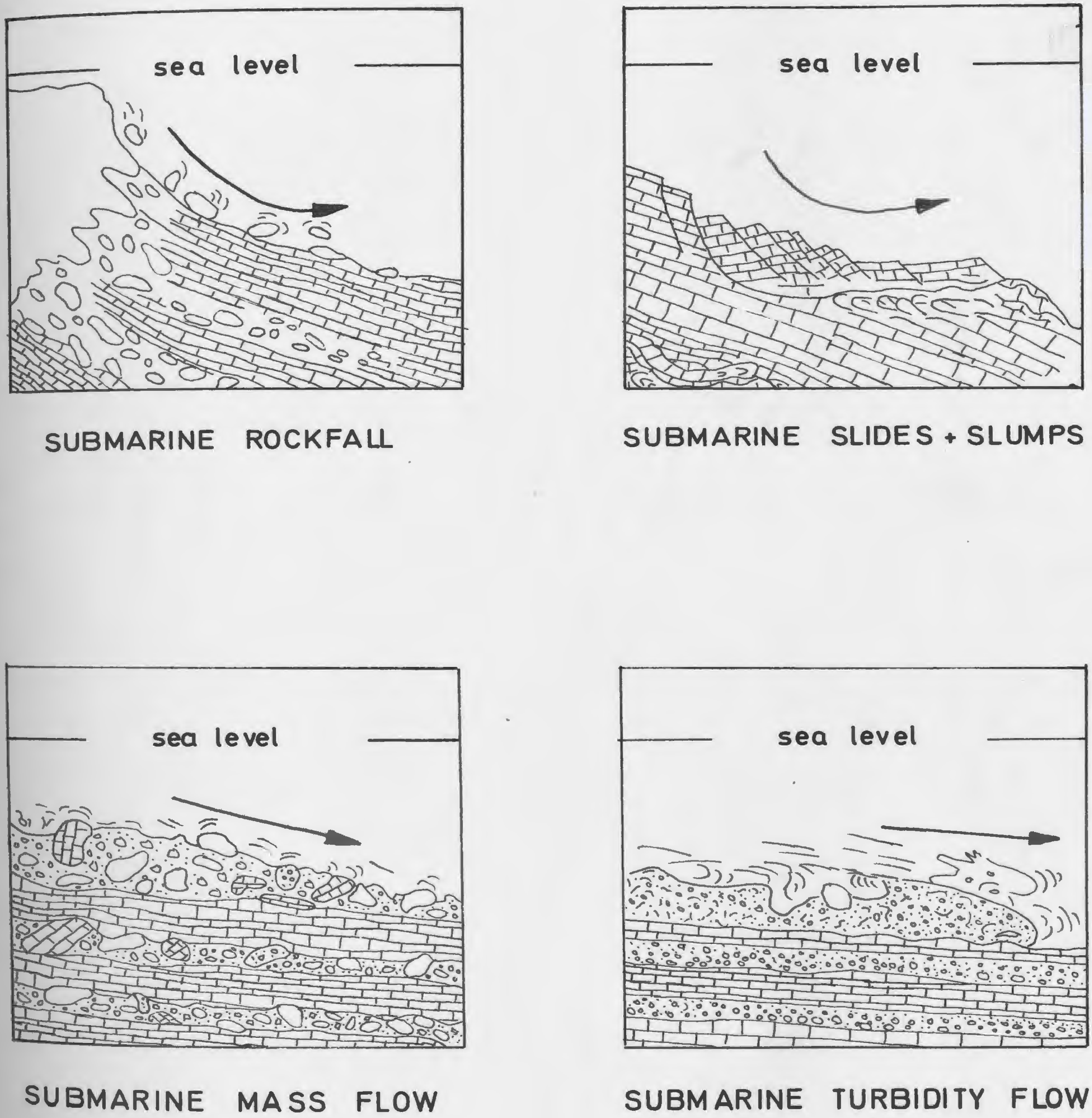


Fig. 51. Diagrammatic representations of the types of submarine gravity transport mechanisms which produced the Cow Head Group (After Mountjoy et al. 1972) Submarine mass flow is volumetrically the most important.

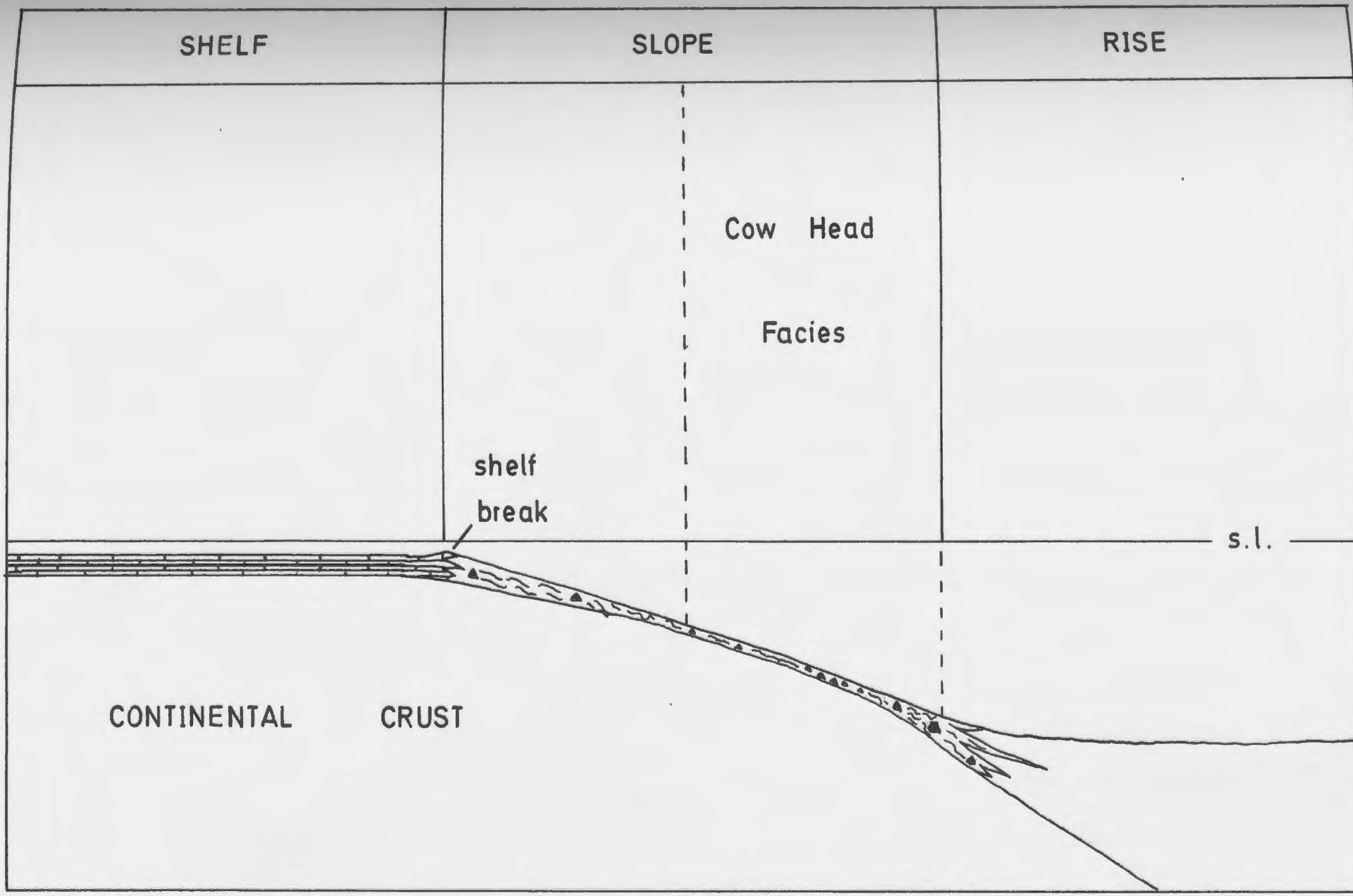


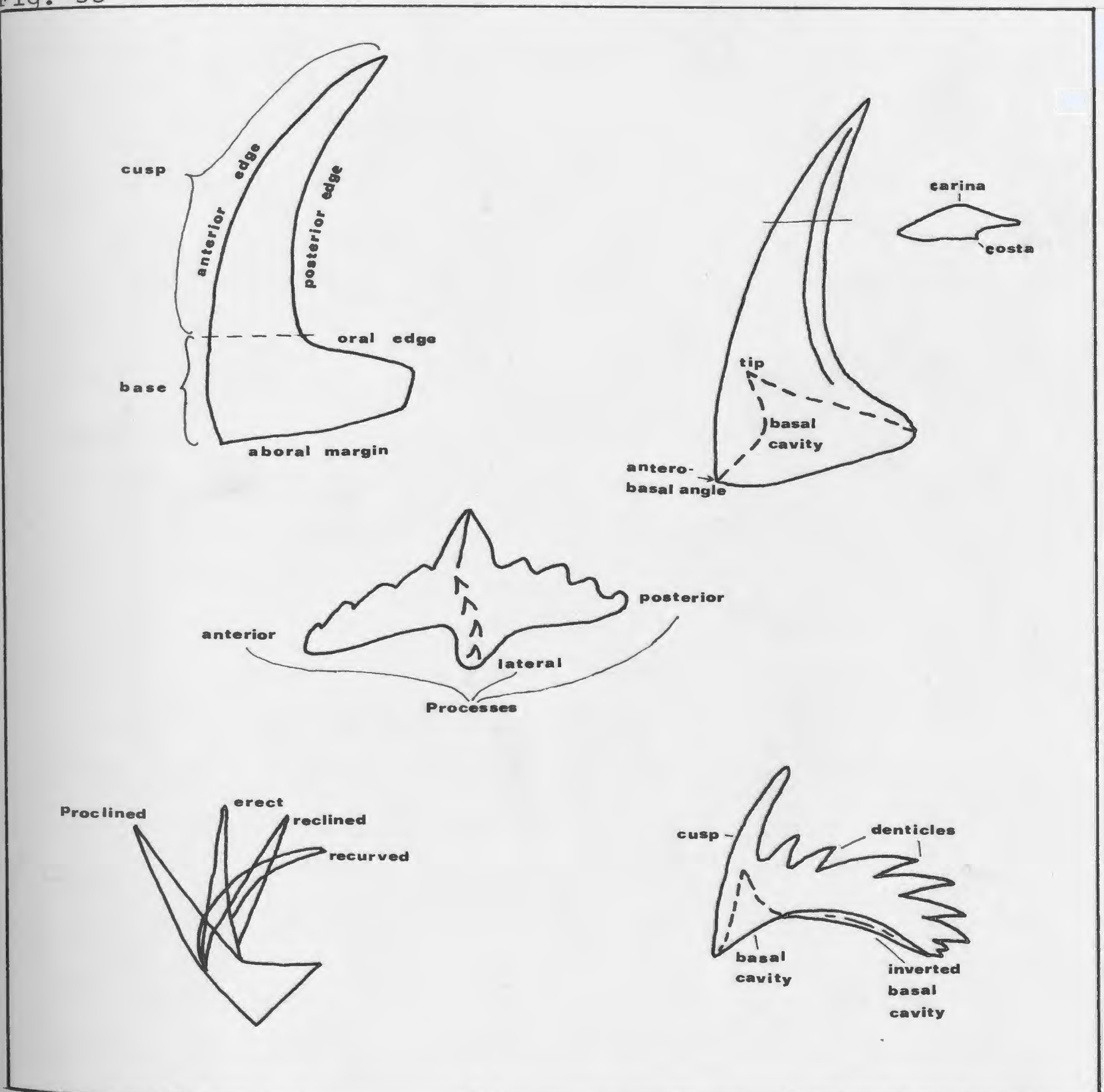
Fig. 52 Diagrammatic representation of depositional site of the Cow Head Group.

CHAPTER VII

NOMENCLATURE

A great variety of terms have been used in conodont literature for purposes of description. Those illustrated in Fig. 53, are used in the following descriptions. The terminology used is basically that of Lindström (1955a).

Fig. 53



CHAPTER VIII

TAXONOMY

(i) PREAMBLE

Conodonts are one of the largest and most important group of fossils about which the zoological affinities are unknown. Many suggestions have been made to rectify this, but so far, none has proved satisfactory. Pander (1856) and Ulrich and Bassler (1926) regarded conodonts as fish teeth. Other hypotheses have suggested affinities with annelid jaws (Scott 1934), components of a gastropod radula (Loomis 1936) and copulatory spicules of worms (Denham 1944). Lindström (1964) proposes a conodont supported organ which resembles a lophophore (feeding apparatus) such as exists in bryozoans, brachiopods and the hemichordates. It is known that conodonts had bilateral symmetry, that they were marine and that they were internally secreted by the conodontophorid, however, the exact biological affinities remain obscure.

One of the problems common in Paleontology is the question of how to classify parts or traces of organisms which are out of association with each other or with the whole organism. It has long been realised that conodonts occurred in complex assemblages or associations in an animal. Generally speaking, conodonts are, however, found as isolated elements and not as complete apparatuses, thus the classification has had to be based on these elements of unknown relationship. The inevitable result is that different "species" and "genera" are routinely based on what were parts of a single animal.

Pander (1856) believed conodonts to be teeth of an extinct group of fishes. The simple conical conodonts which he collected from the Ordovician do resemble fish teeth, and, since many modern fish have only one kind of tooth, he concluded that only conical teeth existed in one animal. He thought that the classification of conodonts would always be "precarious and arbitrary," because we might never know what the animal looked like.

Hinde (1879) proposed a multielement concept of a conodont species, which is that several isolated individuals were part of the same animal. He still named the individual elements in the species, but he grouped them together into a multielement species. Although Polygnathus dubius Hinde (1879), was the first multielement conodont species described, it had little influence on the subsequent schemes of taxonomy.

Later workers, such as Ulrich and Bassler (1926) believed that the genera and species they described were quite natural. Indeed, in 1925, Bassler had produced a classification of single conodont elements which he believed to be entirely natural. Somewhat more recently, it has been realised that the taxonomy used for isolated conodonts is a case of form-genera and form-species. In addition, assemblages have been described from several localities and, in classifying these, the authors regarded them as natural genera and species. Schmidt (1934), reported natural assemblages from the Upper Carboniferous of the Rhineland in Europe, and Scott (1934) reported them from a similar level in Montana, U.S.A. These reports of natural assemblages occurring on rock surfaces were not immediately accepted (Branson and Mehl, 1936), but they were subsequently reported frequently with the same elemental composition, and thus proven to be natural.

Presently, then, there exists a dual form of taxonomy for conodonts: firstly, those names which refer to isolated elements, which are form-genera and form-species, and secondly, those names referring to assemblages which are regarded as natural genera and species. Quite obviously, it is undesirable to have a dualism in the classification.

A natural classification is essentially a biological one, making allowance for the recognition of biological affinities and evolutionary trends. A simply utilitarian classification of conodonts is necessarily based on strict morphological criteria and, as such, it is less valuable in a biological sense. It is impossible to denote an evolutionary trend in a utilitarian classification except by the erection of sub-species, and this could become quite cumbersome.

This rather confused situation has been the case for several years and, during this time, many attempts have been made to rationalise it. It might be said that none of these attempts has been very successful, because the utilitarian and natural classifications are still being used side by side.

In naming a conodont assemblage, Rhodes (1952), used a new generic name for it, Scottognathus, which bore no relation to the conodont elements it contained. The precedent for this sort of procedure had been set by Scott (1942). The use of an entirely new name in this situation is a clear contravention of the International Rules of Zoological Nomenclature, and this opinion was expressed by Sinclair (1953). He voiced the view that it was desirable, indeed, necessary to abide by the Rules, and to use the name of the first-described species in that assemblage, according to the Law of Priority. This is legally the correct course to take and reduces Scottognathus to a junior synonym.

Rhodes (1953), in reply to Sinclair (1953), voiced his objections, although he did accept that Sinclair's (1953) proposals were theoretically preferable. He made the valid point that a single form-genus might be present in many different assemblages, and that confusion might arise from "double" use of well known form-genera. Despite Rhodes' objections, I think it is really undesirable to have nomenclatural rules for paleontologists which differ from those governing zoologists. It seems to me that it is better to attempt a natural classification by regarding conodont assemblages as natural taxa, and proceed with a natural classification from that assumption.

In the past, attempts have been made to preserve rather than to replace the duality in conodont taxonomy. Moore and Sylvester-Bradley (1957) submitted a proposal to the International Commission on Zoological Nomenclature, suggesting that units of nomenclature called "Parataxa" should be included in the Rules. In other words, they suggested a kind of special treatment for conodont workers. These parataxa exist in botanical nomenclature for such things as isolated spores. This proposal was rejected by the Commission.

Some quite wild suggestions have been made: a notable one by Moore (1962). He suggested that one should regard both taxonomic systems as "natural," but that one should keep the individual elements found in an assemblage taxonomically separate from known "isolated" species. This is purely dishonest and as Lindstrom, (1964) states: "...the seriousness of the situation is underlined when Moore, who is one of the most outstanding paleontologists of our time, should have to present a solution that is so desperate." It does seem that a natural system is the most desirable, and the present tendency is to attempt a natural classification as often as possible. It is also evident, however, that it may be difficult to erect a natural system because of the lack of much detailed knowledge, and the relatively few appearances of conodont assemblages.

In the erection of a natural system of classification criteria must be established and the intricate problems must be recognised. Several avenues of approach are available to us, and these include:

1. Extensive studies of avilable natural assemblages.
2. Reference to morphology of individual conodonts.
3. Reference to morphology of conodont assemblages as a whole.
4. Possible reconstruction of lines of evolution of individuals and assemblages.
5. Statistical reconstructions of related elements and assemblages.
6. Examination of detailed microstructure.

In any case, it should be a slow step-by-step progression from the utilitarian single element classification to the natural multielement classification. It would be best to let changes come gradually, and for any modifications to be based on extremely good and convincing research material. I do not think that there is need for official protection of the utilitarian approach, or a need for drastic and immediate changes to bring about a multielement classification. Sometimes material may be insufficient, or the approaches used may be wrongly based in the efforts to get a totally multielement system into operation quickly. Numbers of specimens must be large, and a biological approach must be employed.

With respect to material from the Cow Head Group, yields of conodonts are generally small, and so difinitive statements of multielement taxonomy are difficult to make. The multielement species erected by Lindstrom (1971), are followed, with reservations, wherever it is thought reasonable to account for their identification. The samples from Cow Head on the whole yield much too sparsely to make it possible to comment more than briefly on the species erected by Lindström (1971). However, I think it is worth commenting on the approaches used to arrive at these species.

Lindström (1971) used samples from the Volkhov and Kunda Stages of the Arenigian (see Table 1) which are very rich in conodonts. He first recognised that a "constant association could be established between certain form species present in greater numbers than 5 to 11 in the samples." It is after he reconstructs these numerical associations, that he recognises homologous elements recurring in apparently related apparatuses. After following these two steps, he erects taxonomic relationships. I feel this to be somewhat the reverse of the way in which these studies should be approached. Primary importance should be placed upon the symmetry and symmetry transitions of individual elements. An examination of symmetry will often reveal evolutionary lineages and associations. Subsequent to the study of morphology and symmetry, one should look for constant associations of elements, and compare these to previously established evolutionary lineages. Speciation is evolution, thus it is obvious that identification of natural species should be primarily concerned with evolutionary lineages. Simple co-occurrence in a series of samples does not necessarily indicate a biological relationship.

In addition, I believe that many of the multielement species described in the literature to date, may really be at the generic level. This may be so, because individual form-species showing a high degree of variability are grouped together into assemblages, thus making it possible that species exist within a multielement species. The variability of a single isolated element may thus be reflecting the existence of many more multielement species than we presently recognise. This factor is compounded when we group several variable individual elements together. It is, of course, realised that given presently available material, it is very difficult to work out many multielement species.

All this is not to say that multielement taxonomy should not be attempted, but the results and methods of such attempts should be carefully scrutinised.

In the present study as many of Lindstrom's (1971) multielement species as possible are recognised and remarked upon. The elements which do not fit into any known multielement species are listed under form taxonomy. Following

Lindstrom's taxonomy constituent elements are referred to by attaching the suffix "-form", to the name of the form-genus they resemble. The term s.f. (sensu formo), is used whenever referring to a form-species.

A chart showing the actual numbers of each species obtained from productive samples is provided as Table 2.

(ii) MULTIELEMENT TAXONOMY

DREPANODIDS:

According to Lindström (1971) the drepanodids are divisible into two groups viz. the Drepanodus Group and the Paltodus Group.

"The group represented by Drepanodus has a Scandodus-like oistodiform element. Representatives of this group have a less wide base than those of the other group. There is a tendency to develop postero-lateral costae. The other group, represented by Drepanoistodus, Paroistodus and Paltodus, has Oistodus-like oistodiform elements and wider base with a somewhat shallower basal cavity than that found in representatives of the first group." (Lindström 1971, p. 41).

Drepanodus Group

Genus Drepanodus Pander, 1856-Lindström, 1971

Type species: Drepanodus arcuatus Pander, 1856

DESCRIPTION:

The apparatus consists of a drepanodiform and an oistodiform element.

In the drepanodiform element the basal cavity is conical and deep. The axis is curved. The base is little wider than the cusp. It is sub-symmetrical with rounded lateral faces and sharp anterior and posterior edges. There may be a fold or a notch on one side of the base.

The oistodiform element is markedly asymmetrical. The base is offset from the cusp. The cusp is more or less straight, with an outer rounded face. The inner face has shallow rounded grooves along the margins. The cusp may have fine costae posteriorly.

The Genus Drepanodus contains some of the largest conodont elements known.

Drepanodus arcuatus Pander, 1856, Lindstrom, 1971
Pl. 2, Figs. 11-13, 17.

Lindstrom's (1971 description comprises the following form-species:

Drepanodus arcuatus Pander 1856, p. 20, Pl. 1, Figs. 2,4,5,17.
Lindström 1955a, p. 558, Pl. 2, Figs. 30-33;
Text: Fig. 3J.

Drepanodus cf. arcuatus Pander, Lindström, 1955a, p. 560, Pl.2, Figs. 45, 46; Text: Fig. 4c.

Drepanodus flexuosus Pander 1856, p. 20, Pl. 1, Figs. 6,7,8.

Scandodus pipa Lindström 1955a, p. 593, Pl. 4, Figs. 38-42; Text: Fig. 3P.

Drepanodus sculponea Lindström 1955a, p. 567, Pl. 2, Fig. 40; Text: Fig. 3L

This species includes acostate, simple elements with long and slowly tapering cusps. The lateral faces are well rounded. The cross-section is lanceolate to comma-shaped.

In the drepanodiform element, the basal cavity may be about as deep as it is wide antero-posteriorly. It is curved with its tip near the anterior margin. The base does not flare much, but forms a slightly bulging continuation of the smoothly recurved outline of the cusp. There may be a slight notch or undulation on one side of the margin of the basal cavity.

The oistodiform element Scandodus pipa s.f. is shaped like a smoking pipe with a slightly lateral twist. The cusp is nearly straight and markedly reclined. The base is subquadratic in lateral view. The width of the basal cavity is greater than the depth. It is deepest and widest posteriorly and ends as a shallow groove at the anterior basal angle.

The form-species Drepanodus sculponea is included in this species.

REMARKS:

The drepanodiform elements are well represented in the Cow Head material; largely by the form-species D. arcuatus.

The oistodiform element occurs concurrently with the drepanodiform elements in several samples.

Lindström (1971) is uncertain about the inclusion of the form-species D. sculponea in this assemblage. At Cow Head this form occurs in frequent association with the above forms and it seems likely that it made up part of the natural assemblage. The similarity of S. pipa to D. sculponea in symmetry also suggests a relationship.

OCCURRENCE:

Units 8, 9, 11, 12, 13.

MATERIAL:

51 drepanodiform elements

44 oistodiform elements.

Paltodus Group

"The basal cavity is larger in representatives of this group than in those of the Drepanodus Group. This is particularly evident in the oistodiform elements, which are further characterised by a sharp, pointed angle posteriorly at the base of the cusp. The drepanodiform elements may carry a sharp costa on either or both sides of the cusp." (Lindström 1971, p. 42)

Genus Drepanoistodus Lindström, 1971

Type species: Oistodus forceps Lindström, 1955

DESCRIPTION:

The apparatus consists of a drepanodiform and an oistodiform element.

Drepanodiform elements are unornamented except for a few specimens which bear a costa on one side. The base of oistodiform elements is extended antero-posteriorly. Cusp and base meet at a sharp angle posteriorly. A few specimens have inverted basal cavity anteriorly.

Lindström (1971) states that drepanodiform elements outnumber oistodiform elements by 2:1 or 4:1, but this is not the case in this study.

Drepanoistodus forceps Lindström 1955 --Lindström 1971.
Pl. 3, Figs. 11-15.

In his description Lindström includes the following form-species:

Oistodus forceps Lindström, 1955a, p. 574, Pl. 4, Figs. 9-13; Text: Fig. 3M.

<u>Acodus deltatus</u> Lindström, 1955a, p. 545, Pl. 2, Figs. 27-29

<u>Drepanodus homocurvatus</u> Lindström 1955a, p. 563, Pl. 2, Figs. 23, 24, 39. Text: Fig. 4d.

<u>Drepanodus planus</u> Lindström, 1955a, p. 565, Pl. 2, Figs. 35-37; Text: Fig. 4a

<u>Drepanodus suberectus</u> (Branson and Mehl, 1933), Lindström, 1955, p. 568, Pl. 2, Figs. 21, 22.

<u>DESCRIPTION</u>:

The drepanodiform elements are recurved, slender and have slender lanceolate cross-section. The antero-basal angle is 90 degrees or less. The aboral margin is curved. There is a short straight oral margin. A few specimens bear a costa on one side.

The oistodiform elements have a more or less straight anterior margin. A slight undulation sometimes occurs on the inner side of the basal margin. The cusp is long, strongly reclined, and slightly deflexed laterally.

<u>REMARKS</u>:

Lindstrom (1971) includes the form-species <u>Acodus deltatus</u> in this species, however, Cow Head material shows no occurrence of this form. The oistodiform element is only sparsely represented and specimens thus identified show a close relationship with the form-species <u>O.parallelus</u>.

The drepanodiform elements of this species are well represented, mainly by forms referred to the form-species <u>D. homocurvatus</u>.

OCCURRENCE:

Units 8, 9, 11, 12 and 13.

MATERIAL:

53 drepanodiform elements.

61 oistodiform elements.

8

Genus Paltodus (Pander, 1856)-Lindström 1971

Type species: Paltodus subaequalis Pander, 1856

DESCRIPTION:

Lindstrom (1971, p. 44) describes the members of this genus as follows:

"Drepanodiform elements of this genus have a triangular base and a suberect to moderately recurved cusp. There may be sharp, prominent costae on either or both sides.

In oistodiform elements the base extends about as far anteriorly as it does posteriorly. The basal cavity is wide and may flare towards the inner side."

Paltodus deltifer Lindström, 1955a--Lindström 1971, Pl. 2, Figs. 16, 20.

Drepanodus deltifer Lindström, 1955a, p. 562, Pl. 2, Figs. 42-43.

Oistodus inaequalis Pander, 1856; Lindström, 1955a, Pl. 3, Figs. 52, 55, 56, not 53, 54, 57.

DESCRIPTION:

The drepanodiform element of this species is thin and sharp-edged. The base is laterally compressed. In outline the basal cavity is an equilateral triangle with concave edges.

The oistodiform element has a basal cavity that is obtusely triangular in outline. It flares broadly to the inner side. The cusp is shorter than in the drepanodiform element. It is reclined and bent inwards at the base. The posterior angle between the base and the cusp may be either rounded or sharp.

REMARKS:

I am uncertain as to the existance of this species at Cow Head. The oistodiform element is found in four samples, but no specimens of the drepanodiform element are found. It is difficult to distinguish the oistodiform elements from those that occur in P. inconstans, but I think both forms occur in Cow Head.

OCCURRENCE:

Unit 8.

MATERIAL:

No drepanodiform element.

4 oistodiform elements.

?<u>Paltodus</u> <u>inconstans</u> Lindstrom, 1955a--Lindström 1971

Pl. 2, Figs. 16, 20

Lindström lists the following form-species as being present in <u>P. inconstans</u>.

<u>Paltodus</u> <u>inconstans</u> Lindström 1955a, p. 583, Pl. 4, Figs. 3-8

?<u>Oistodus</u> <u>inaequalis</u> Pander 1856, p. 27, Fig. 37.

<u>Oistodus</u> <u>inaequalis</u> Pander 1856; Lindström, 1955a, p. 576, Pl. 3, Figs. 53, 54, 57, not Figs. 52, 55, 56.

?<u>Paltodus</u> <u>subaequalis</u> Pander, 1856, p. 25, Pl. 1, Figs. 24.

?<u>Paltodus</u> <u>rotundatus</u> Pander, 1856 p. 25, Pl. 1, Figs. 33, 34.

?<u>Machairodus</u> <u>angustus</u> Pander, 1856, p. 23, Pl. 1, Fig. 35.

Note: Lindström (1971) notes that <u>P. inconstans</u> may well be junior synonym of at least one of Pander's species listed above. He is uncertain of their identifiaction and has chosen <u>P. inconstans</u>, realising also, that Pander's <u>O. inaequalis</u> may be a senior synonym of both <u>P. deltifer</u> and <u>P. inconstans</u>.

<u>DESCRIPTION</u>:

The drepanodiform element is assymmetrical. The inner face is flat with one or no median costa. The outer face is rounded and costate. The cusp is smoothly recurved. The oistodiform element is similar to that in <u>P. deltifer</u>. It has a rounded costa on the inner face, towards which the cusp is bent. The ratio of drepanodiform to oistodiform elements appears to be 1:1.

REMARKS:

The drepanodifrom element has not been identified with certainty in the Cow Head samples.

Oistodiform elements are found which may belong to either P. deltifer or P. inconstans, but at least some can be placed with certainty in this species, because they show a prominent rounded costa on the side towards which they are bent.

OCCURRENCE:

Unit 8.

MATERIAL:

No drepanodiform elements;

2 oistodiform elements.

Genus Paroistodus Lindström 1971

Type species: Oistodus parallelus Pander, 1856

According to Lindström (1971, p. 46) Paroistodus "includes drepanodid conodonts with drepanodiform and oistodiform elements. The basal cavity tends to become inverted anteriorly. Drepanodiform elements tend to develop a sharp, low costa on each side. Base of oistodiform elements is roughly square in side view and does not extend very far anteriorly.

The ratio between drepanodiform and oistodiform elements is about 2:1."

Paroistodus numarcuatus (Lindström, 1955a)--Lindström 1971 (p. 46,Fig. 8) Pl. 3, Figs. 2,3.

Lindstrom (1971) includes the following form-species in this species:

Drepanodus numarcuatus Lindström 1955, p. 564, Pl. 2, Figs. 48, 49; Text: Fig. 3I

Drepanodus amoenus Lindström, 1955, p. 558, Pl. 2, Figs. 25, 26; Text: Fig. 4b.

Oistodus parallelus Pander 1856 - Lindström 1955, Pl. 4, Figs. 27-29; Text: Fig. 3N. not Pl. 4, Figs. 26, 30, 31; Fig. 30.

DESCRIPTION:

The drepanodifrom element is not fully costate. It is recurved. The basal cavity may be shallow (Drepanodus numarcuatus s.f.)or rather deep (Drepanodus amoenus s.f.).

Neither the drepanodiform nor the oistodiform element has an inverted basal cavity anteriorly. Neither forms are really costate.

REMARKS:

The three form-species elements of this species are found to coexist in only one sample from Cow Head.

The drepanodiform element is poorly represented. Oistodus parallelus s.f. specimens are recognised without the partially inverted basal cavity and are thus included in this species.

OCCURRENCE:

Units 8 and 9.

MATERIAL:

16 drepanodiform elements;

19 oistodiform elements.

Paroistodus _proteus_ (Lindström, 1955a)--Lindström, 1971, p.46, Figs. 8, 10. Pl. 3, Figs. 8, 9.

Lindström includes the following form-species in this species:

Drepanodus _proteus_ Lindström, 1955a, p. 566, Pl. 3, Figs. 18-21; Text: Fig. 2a-fij.

Oistodus _parallelus_ Pander 1856; Lindström, 1955, p. 79, Pl. 4, Figs. 26, 30; Text: Fig. 30.

DESCRIPTION:

The drepanodiform element has recurved basal cavity posteriorly which is inverted anteriorly, or very shallow. The cusp is very long and slender, its lateral faces rounded and non-costate.

The oistodiform element is indistinguishable from that of _Paroistodus_ _parallelus_. The basal cavity is inverted anteriorly.

REMARKS:

Lindström's (1971, p. 46) description of this species refers indirectly and not formally to the form-species _O. parallelus_; it is included formally above.

This species only occurs very sparsely in the Cow Head sequence. Only a few specimens from scattered samples have been found.

OCCURRENCE:

Units 9, 11, 12 and 13.

MATERIAL:

32 drepanodiform elements.

21 oistodiform elements.

<u>Paroistodus parallelus</u> (Pander 1856); Lindström 1971,
Pl. 3, Figs. 5,6.

Lindstrom includes the following form-species in this species:

<u>Oistodus parallelus</u> Pander, 1856, p. 27, Pl. 2, Fig. 40.

<u>Oistodus parallelus</u> Pander, 1856; Lindström 1955, p. 579 Pl. 4, Figs. 26, 30, 21; Fig. 3-0

<u>Distacodus expansus</u> (Graves and Ellison 1941) Lindström, 1955, p. 555, Pl. 3, Figs. 13-17; Fig. 2 g-i.

<u>DESCRIPTION:</u>

On each lateral face of the drepanodiform element there is a posteriorly directed costa. The cusp is recurved or reclined, laterally compressed and slender. It is keeled anteriorly and posteriorly. The base is wide and flaring and not very high.

The oistodiform element is robust; the basal part is square in lateral view.

Both elements have zones of inverted basal cavity anteriorly.

<u>REMARKS:</u>

Four representatives of the form-species <u>Distacodus expansus</u> have been found. Oistodiform elements occur in the same samples so this species definitely exists in the Cow Head sequence.

OCCURRENCE:

Upper part of Unit 9 and in Unit 11.

MATERIAL:

4 drepanodiform elements;

3 oistodiform elements.

Panderodids

According to Lindström, (1971, p. 49), the panderodids are: "simple conodonts with symmetry transition and a sharply conical basal cavity. The surface, at least on the cusp, is ornamented by fine longitudinal striations. The cusp consists of white matter and is suberect or proclined." Herein, those panderodids with erect cusps are included also. Elements are usually sulcate or costate or both. The cross-section of the base may be either rounded or laterally compressed.

Panderodus n.sp.A

Pl. 2, Figs. 8, 9, Text: Fig..54.

DIAGNOSIS

A laterally compressed panderodid with a long base and a short erect cusp. The basal cavity is deep and conical. The anterior margin of the base is deflexed.

DESCRIPTION:

The basal cavity is very deep and reaches a little into the cusp. It is more or less triangular in lateral view. The cross-section is elliptical with a flexure at the anterior edge. The apex of the basal cavity is medially placed and extends to the point of flexure of the cusp.

The base is very long and compressed. The lower part of the anterior edge is deflexed so that a sulcus is formed on the inner side. The aboral edge is straight or gently convex in lateral view. The oral edge is sharp. It is straight to slightly concave in lateral view.

The cusp is short in relation to the base. The oral margin makes an angle of about 130° with the posterior edge. The sulcus on the anterior margin of the base extends onto the cusp but it is less pronounced.

Many specimens are very finely striated.

REMARKS:

It is probable that this is a component of single-type multielement species. It bears a resemblance to *Drepanodus altipes* Henningsmoen 1948, but differs in being more compressed and having a longer base.

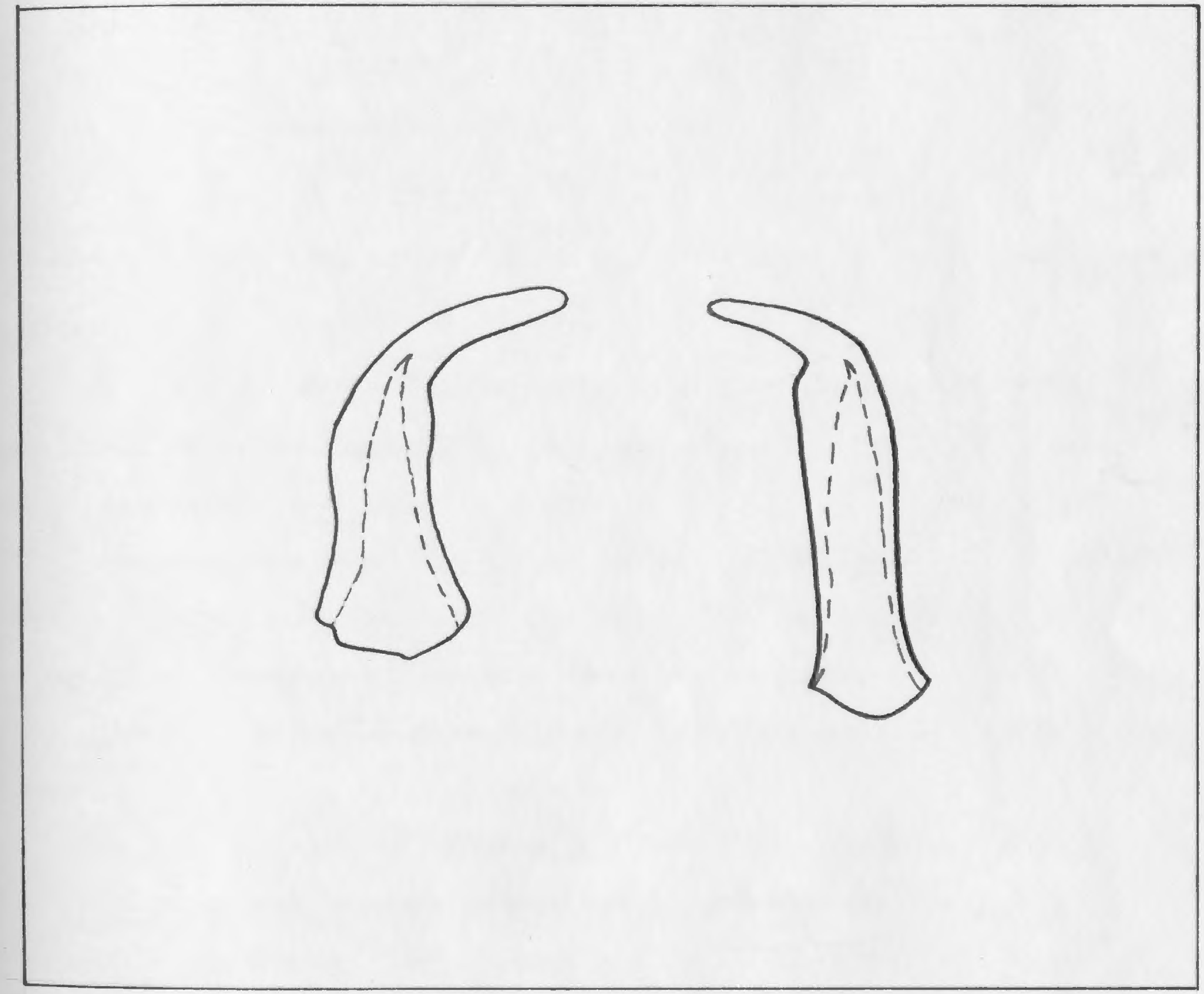
OCCURRENCE:

Unit 8.

MATERIAL:

13 specimens.

Fig. 54



Line drawings of specimens of *Panderodus* n.sp. A from the Cow Head Group.

Genus Stolodus Lindström, 1971.

Type species: Distacodus stola Lindström 1955

After Lindstrom, (1971, p. 51): "Stolodus includes conodonts with a wide and deep, thin-sheathed base, small suberect cusp, and prominent costae reaching the rim of the basal cavity.

Stolodus stola Lindström 1955

Pl. 2, Fig. 15

Distacodus stola Lindström, 1955a, p. 556, Pl. 3, Figs. 43-49.

DESCRIPTION:

The basal cavity extends a short distance into the cusp. The base is laterally compressed and long. The oral edge is straight.

The cusp is short. It is erect, proclined or slightly recurved. The lower part of the cusp is usually keeled, and these keels, together with the two costae extend to the aboral edge. The keels and costae become rather pronounced towards the base.

An intraspecific symmetry transition occurs: "As a rule the keels and costae are placed symmetrically. Either of the lateral faces may, however, fail to develop a costa. Then, the oral keel gradually curves over to the lateral face in question and the other lateral face develops an additional costa that may ultimately replace the oral keel towards the aboral margin," (Lindström, 1955a, p. 551). The specimens from Cow Head have the keels and costae placed symmetrically without exception.

OCCURRENCE:

Unit 9.

MATERIAL:

2 specimens.

Prioniodids

After Lindström (1971, p. 51): "The prioniodids are conodont species in which the main units, prioniodiform elements, have three main denticulate edges on the base, (anterior, outer lateral, and posterior), a wide base, and a relatively small stout erect cusp. The denticulate edges develop into processes that may branch. In addition to the main units, there are oistodiform elements and compound elements with a 2- to 4- branched base and a relatively long curved cusp."

The prioniodids are divisible into the Prioniodus Group and the Baltoniodus Group according to Lindström (1971). No representatives of the latter group have been found at Cow Head.

Prioniodus Group

There is no inner lateral flare of the posterior process in the prioniodiform elements of this group, which is in contrast to the Baltoniodus Group. The posterior process is unbranched. None of the elements has a particularly wide or deep basal cavity.

Compound elements are more or less pick-shaped, ("Oepikodus"), but this basic pattern is complicated by the development of trichonodelliform and tetraprioniodiform symmetry transition elements.

Oistodiform elements are present in this group as well, and they sometimes have denticulated extensions anteriorly.

Genus *Prioniodus* Pander, 1856

Type species: *Prioniodus elegans* Pander 1856

Prioniodus elegans Pander 1856 - sensu Sweet and Bergstrom 1972, Pl. 4, Figs. 1-8, Text: Fig. 55A.

The constituent form-species and their synonomies are:

Prioniodus elegans Pander 1856, p. 29, Pl. 2, Figs. 22,23.

Prioniodus elegans Pander 1856; Lindström 1955a, p. 589, Pl.5, Figs. 26-29; Text:Fig. 5a

Belodus gracilis Pander 1856, p. 30, Pl. 2, Fig. 21, Pl. 3, Fig. 8.

Falodus prodentatus (Graves and Ellison, 1941); Lindström 1955a p. 569, Pl. 5, Figs. 21, 22, 30.

Prioniodus carinatus Pander 1856, p. 30, Pl. 2, Fig. 25; Pl.3, Fig. 7.

Tetraprioniodus robustus Lindström 1955a, p. 597, Pl. 6, Figs. 13-15.

Gothodus costulatus Lindström 1955a, p. 569, Pl. 5, Figs. 23-25.

DESCRIPTION:

The prioniodiform element has a shallow and narrow basal cavity. The posterior process is straight, with stout denticles in one plane. The anterior and lateral processes are directed downwards, and make an angle of about 90° with each other. Both of them are denticulated.

The oepikodiform element, (Gothodus costulatus s.f.), has a stout, short denticulated bar posteriorly. The cusp is long and slender. The lateral processes are very poorly developed, especially on one side. Trichonodelliform and tetraprioniodiform elements occur, and may be parts of a transition series of the oepikodiform element. The tetraprioniodiform element has two lateral processes, one of which is more posteriorly placed than the other. The cusp is long and slender.

The oistodiform element is elongate and denticulated anteriorly. There may be up to seven small, low, notch-like denticles.

REMARKS:

This species seems to consist of five elements: a prioniodiform, an oepikodiform, a trichonodelliform, a tetraprioniodiform and oistodiform element.

Belodus gracilis Pander, 1856, s.f. is a senior synonym of Cordylodus multidentatus Graves and Ellison, 1941, s.f. which is a senior synonym of Oepikodus n.sp. Lindström, (1964, p. 38) s.f., and Gothodus costulatus Lindström, 1955, s.f. Lindstrom (1971) does not list this synonomy.

OCCURRENCE:

Units 9 and 10, with possible occurrence in Unit 11.

MATERIAL:

91 prioniodiform elements;

61 oepikodiform elements;

95 oistodiform elements;

60 tetra prioniodiform elements;

14 trichonodelliform elements.

Prioniodus evae Lindström

Pl. 4, Figs. 9-12; Text: Fig. 55B

The constituent form-species according to Lindström (1971) are:

Prioniodus evae Lindström 1955a, p. 589, Pl. 6, Figs. 4-10.

Oepikodus smithensis Lindström 1955a, p. 571, Pl. 5, Figs. 36, 37.

Oistodus longiramis Lindström 1955a, p. 579, Pl. 4, Figs. 35-37.

DESCRIPTION:

The prioniodiform element is slender. The posterior process is twisted so that the proximal denticles are upright and the distal denticles are horizontal or nearly so. The anterior and lateral processes are subequal in size. Median carinae are developed on both lateral sides of all the processes. The cusp is big, flattened and sharp-edged.

The oepikodiform element has no denticles on the anterior process and the lateral processes are but weakly developed.

The oistodiform element is elongate anteriorly and posteriorly. The posterior extension is curved downwards, thus the aboral margin is arched.

REMARKS:

No symmetry variants of the oepikodiform element have been found, and Lindström (1971), does not include any in his original description. This species is thus not directly derived from its predecessor, Prioniodus elegans. The phyllogeny of this species is not known.

In the Cow Head material, an oistodiform element has been found with both anterior and posterior extensions denticulated, (Pl. 4, Fig. 15).

OCCURRENCE:

Units 11 and 12.

MATERIAL:

61 prioniodiform elements;

14 oepikodiform elements;

8 oistodiform elements.

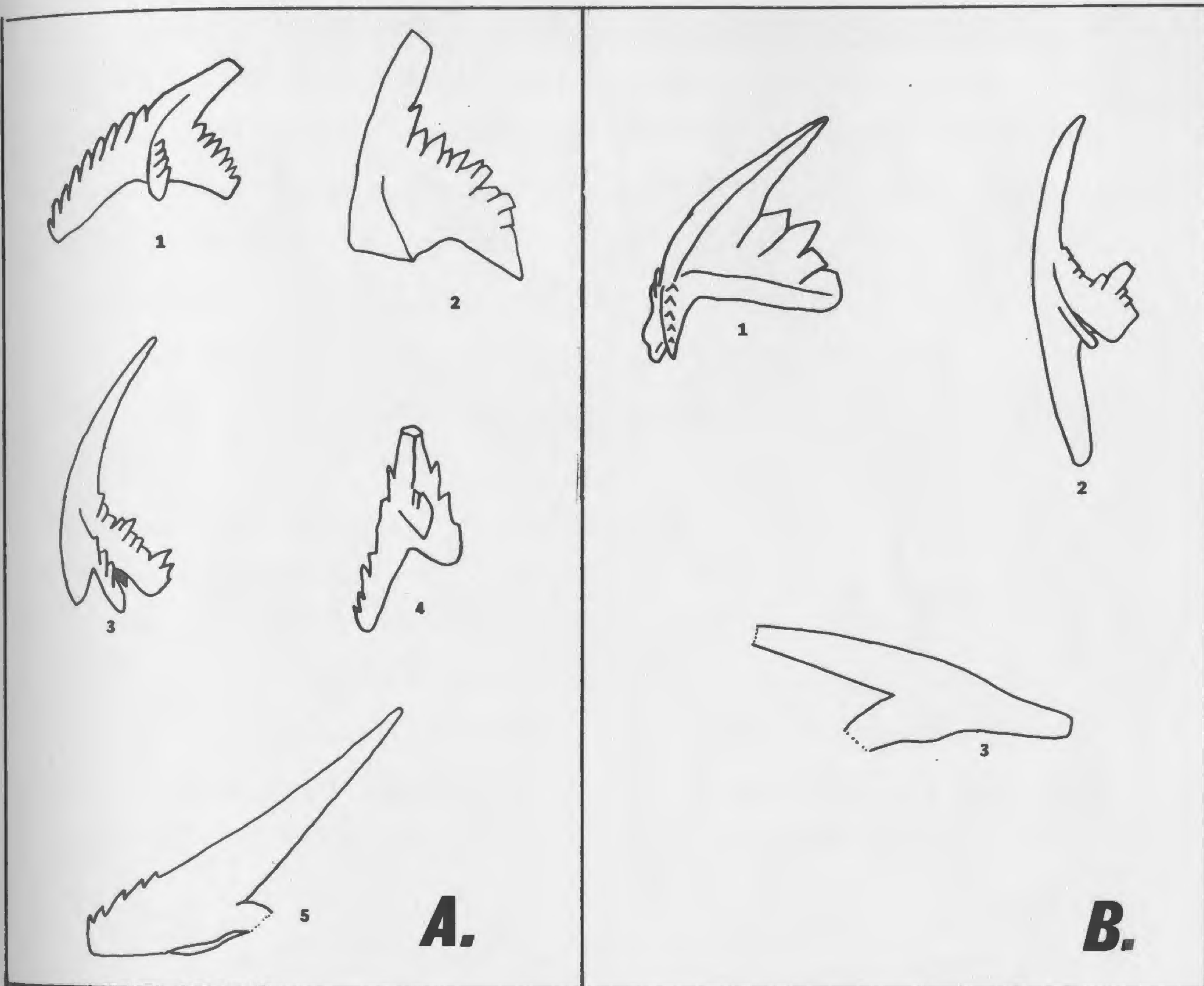


FIG. 55. A. Prioniodus elegans: - 1. Prioniodiform element. 2. Oepikodiform element. 3. Tetraprioniodiform element. 4. Trichonodelliform element. 5. Oistodiform element.

B. Prioniodus evae: - 1. Prioniodiform element. 2. Oepikodiform element. 3. Oistodiform element.

All drawings were made of specimens from the Cow Head sequence. No reconstruction of lost parts was made.

Periodontids

The periodontiform elements of this group are referred to as multiramiform elements. They show a cordylodiform-trichonodelliform symmetry transition series. These multiramiform elements have slender, recurved anterior cusps, and blade-like long multidenticulate posterior processes, that may be twisted out of the"vertical" plane. The aboral edge of the process is excavated anteriorly and is usually characterised by a prominent inverted basal cavity posteriorly. Denticles next to the cusp are small and increase in size and become more reclined posteriorly. Posteriorly, the denticles usually become small again.

The elements described by Lindström (1971) as ozarkodiniform elements are here split into prioniodiniform elements and ligonodiniform elements. These elements are blade-like and multidenticulate, with a prominent main cusp. The denticles are usually present both anteriorly and posteriorly.

An oistodiform element is present in this group as well.

Genus Periodon Hadding 1913

Type species: Periodon aculeatus Hadding 1913

Periodon flabellum Lindström 1955--Lindström 1971, Pl. 5, Figs. 1-6; Text Fig. 56.

Included in this species are the form-species:

Periodon flabellum (Lindström, 1955b)--Lindström 1964, p. 83
Fig. 28A - D

Trichonodella flabellum Lindström 1955a, p. 599, Pl. 6,
Figs. 28-30.

Prioniodina ? deflexa Lindström 1955a, p. 586, Pl. 6,
Figs. 3.-35.

Oulodus inflatus (Lindström)--Lindström 1964, p. 85, Fig. 30A.

Falodus prodentatus (Graves and Ellison 1941), sensu Sweet and
Bergstrom 1962, p. 1227, Pl. 170, Figs.
2,3; Text: Fig. 2B.

DESCRIPTION:

The multiramiform elements illustrate the classic cordylodiform - trichonodelliform symmetry transition series. They differ from those in _Periodon aculeatus_ in the lack of a strongly inverted basal cavity. In this species the length of the main cusp is greater than the length of the posterior process; in _P. aculeatus_ the ratio is closer to 1:1.

The ligonodiniform element ("_Oulodus inflatus_") has a few, slender denticles anteriorly. In the prioniodiniform element anterior denticles are either extremely small or else they are missing altogether. Both have denticulated posterior processes with upright to reclined denticles.

The oistodiform element is short anteriorly with 1-4 denticles reaching quite high on the anterior margin. The aboral margin is arched with a curved, posteriorly directed extension.

REMARKS:

This species is revised from Lindström (1971). An oistodiform element is included for the following reasons: firstly, there is common co-occurrence of an oistodiform element with Periodon flabellum in Cow Head samples. Secondly, it is difficult to see why P. flabellum should not have an oistodiform element when all other Periodon species are described as containing one, Periodon grandis Ethington - Sweet and Bergström (1966); Periodon aculeatus described informally by Webers (1966). Furthermore, elements of P. flabellum and its successor P. aculeatus occur in the same samples thus suggesting the presence of an oistodiform element in both species.

The oistodiform element is called Falodus prodentatus s.f. but it is not representative of the type described by Graves and Ellison (1941) or Lindström (1955a). The element present in this species is that described by Sweet and Bergstrom (1962, as listed in the synonomy). The element illustrated, but not described by Lindström (1960, Fig. 5, #17) is probably co-specific.

OCCURRENCE:

Unit 13 and possibly in Unit 12.

MATERIAL:

49 multiramiform elements;

49 ligonodiniform elements;

20 prioniodiniform elements;

46 oistodiform elements.

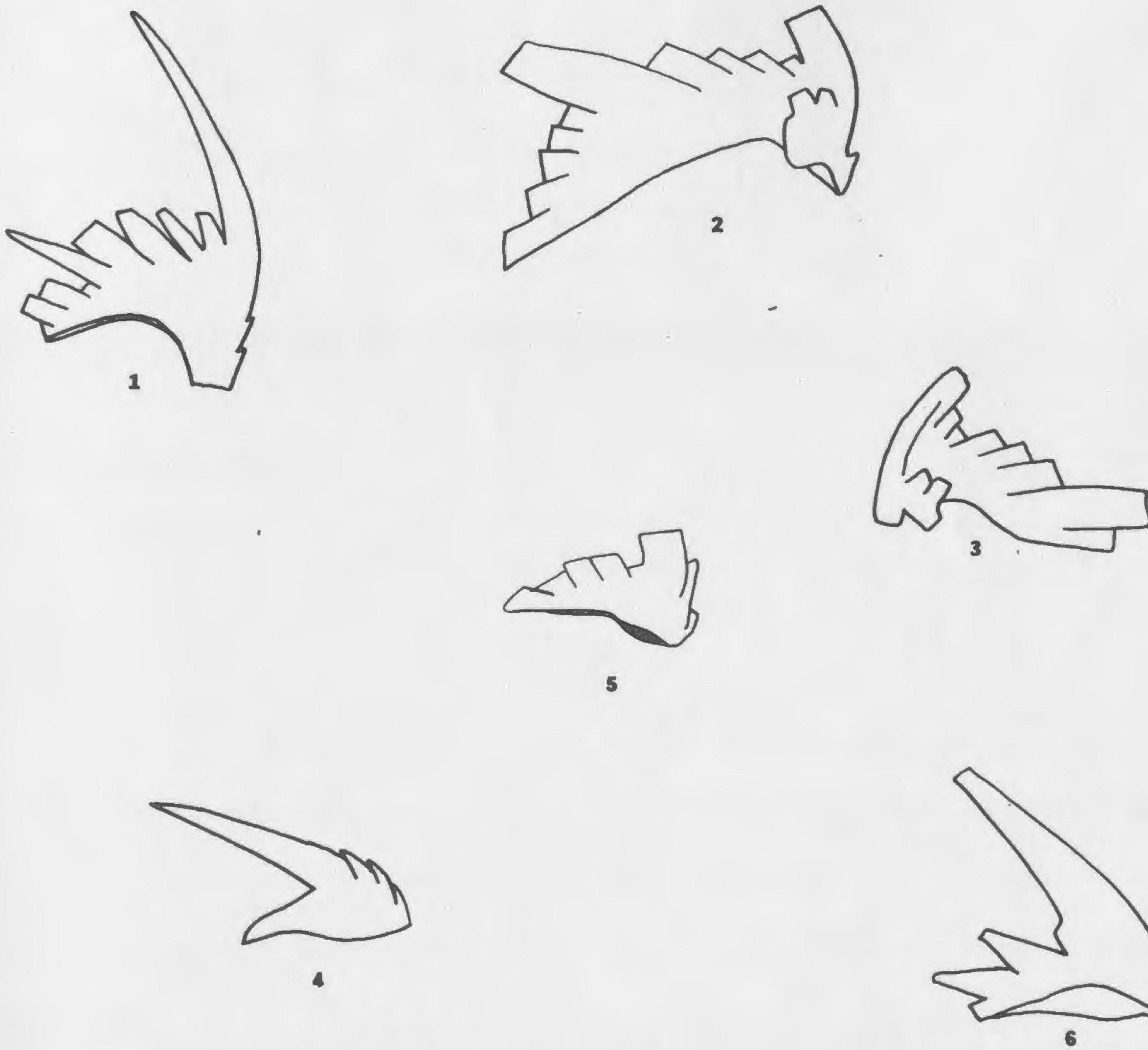


FIG. 56. Periodon flabellum. Drawings are of specimens from the Cow Head sequence. No reconstruction of lost parts has been made.

1. Multiramiform element, (cordylodiform symmetry)

2,3. Multiramiform elements, (cladognathiform symmetry).

4. Oistodiform element. 5. Ligonodiniform element.

6. Prionidoiniform element.

Periodon aculeatus Hadding 1913

Pl. 5, Figs. 7-14; Text: Fig.57

The constituent form-species are:

Periodon aculeatus Hadding 1913 - Lindström 1955b, p. 110 Pl. 22, Figs. 10, 11, 14-16 and 35.

Prioniodina macrodentata (Graves and Ellison 1941) - Sweet and Bergstrom 1962, p. 1240, Pl. 171, Figs. 7, 8.

Oulodus tortilis (Sweet and Bergstrom 1962) - Lindstrom 1964, p. 85, Fig. 30.

Falodus prodentatus (Graves and Ellison 1941) - sensu Sweet and Bergstrom 1962, p. 1227, Pl. 170, Figs. 2,3; Text: Fig. 2B.

DESCRIPTION:

As in Periodon flabellum, the multiramiform elements show a cordylodiform - trichonodelliform symmetry transition series. The basal cavity is broadly and strongly inverted posteriorly. The posterior process is more twisted than in P. flabellum.

The ligonodiniform element also has a twisted posterior process, so that the distal denticles are in a more or less horizontal plane. The anterior denticles are few in number and somewhat more slender than the posterior denticles.

The prioniodiniform element has stout, robust denticles which are well developed both anteriorly and posteriorly. The posterior process is only slightly twisted out of the "vertical"plane.

The oistodiform element is indistinguishable from that in Periodon flabellum.

REMARKS:

Intermediate, transitional forms between this species and Periodon flabellum are found in the Cow Head sequence. The ratios of the elements in both these species of Periodon are quite similar if one groups the ligonodiniform elements and the prioniodiniform elements in each species. It is approximately a 1:1:1 ratio.

OCCURRENCE:

Units 13 and 14.

MATERIAL:

50 multiramiform elements;

25 ligonodiniform elements;

53 prioniodiniform elements;

42 oistodiform elements.

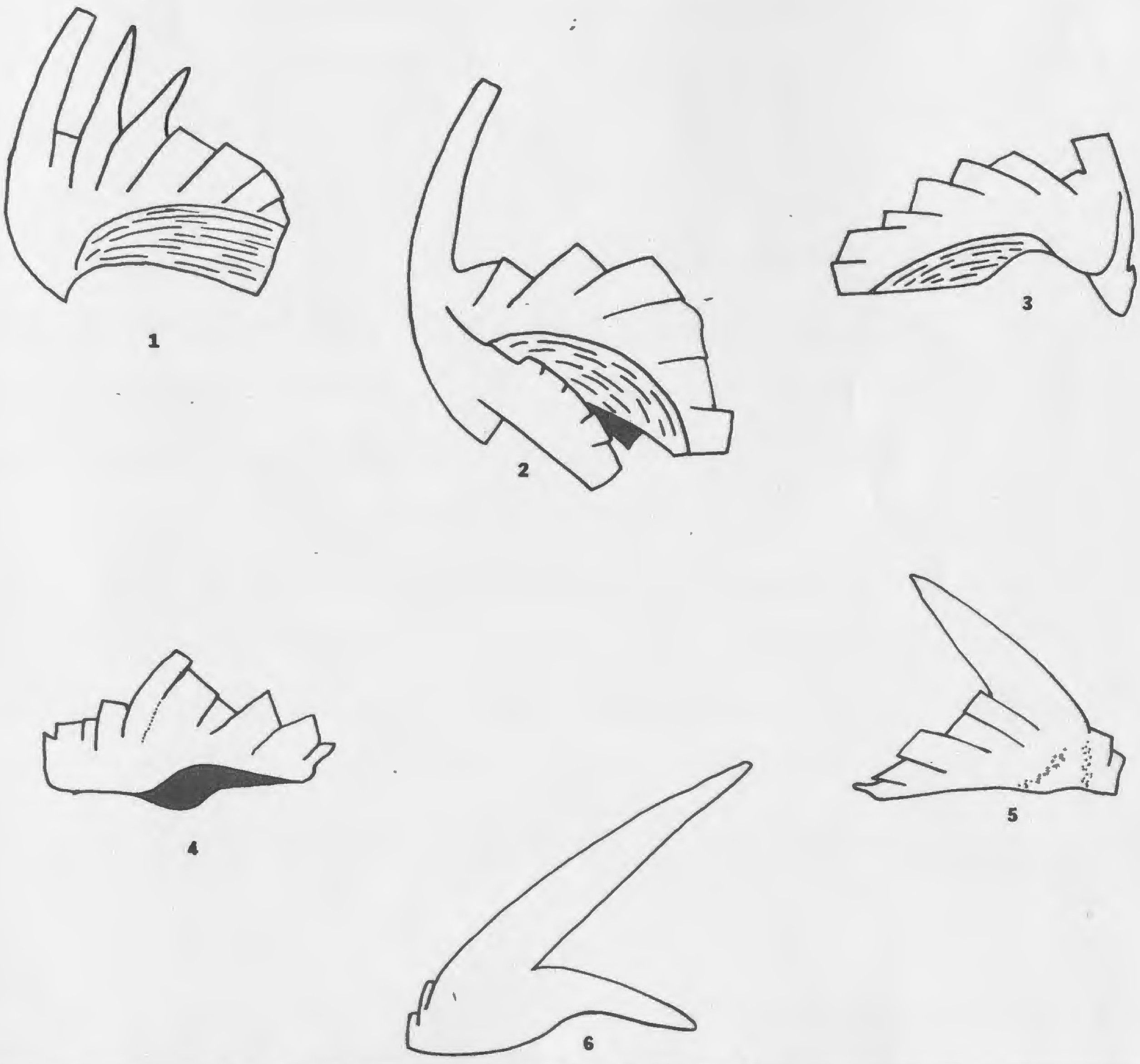


FIG. 57. <u>Periodon</u> <u>aculeatus</u>. Drawings are of specimens from the Cow Head sequence. No reconstruction of lost parts has been made.

1. Multiramiform element, (cordylodiform symmetry)
2. Multiramiform element, (trichonodelliform symmetry)
3. Multiramiform element, (incipient cladognathiform symmetry)
4. Prioniodiniform element
5. Ligonodiniform element.
6. Oistodiform element.

(iii) RESIDUAL SPECIES

Genus Acodus Pander, 1856

Type species: Acodus gratus Lindström, 1955

Acodus gratus

Pl. 2, Fig. 4

Acodus gratus Lindstrom, 1955a, p. 545, Pl. 2, Figs. 27-29

DESCRIPTION:

The basal cavity is more or less conical. The oral edge is short, keeled and almost straight. The aboral margin is convex in lateral view. Its rim may show an undulation. The angle between the basal anterior edge and the base is sharp.

The cusp is recurved with sharp edges. The anterior edge is deflexed laterally. To the side of the anterior edge there runs a thin costa that basally may replace the edge.

REMARKS:

Intermediate forms between A. gratus and D. homocurvatus occur.

OCCURRENCE:

Units 8, 9, 10 and 13.

MATERIAL:

12 specimens.

Genus *Acontiodus* Pander, 1856

Type species: *Acontiodus arcuatus* Lindstrom, 1955

Acontiodus arcuatus

Acontiodus arcuatus, Lindström 1955a, p. 547, Pl. 2,
Figs. 1-4; Text: Fig. 3A

DESCRIPTION:

The base is laterally compressed. It is roughly triangular in outline and curved aborally so that a "sickle shaped space is formed between its anterior margin and that of the tooth," (Lindström 1955a; P. 547). The basal cavity is deep.

The cusp is recurved. Two keels run the length of the cusp: one anterior and one posterior. On each side of the posterior keel there is a costa. On the base, several smaller costae may develop between the main costae and the oral edge.

REMARKS:

The specimens from Cow Head agree in all respects with those described and illustrated in Lindström (1955a).

OCCURRENCE:

Units 9, 11 and 13.

MATERIAL:

17 specimens.

Acontiodus reclinatus Lindström, 1955

Pl. 2, Figs. 10, 14

Acontiodus reclinatus Lindström, 1955a, p. 548, Pl. 2
Figs. 5, 6; Text: Fig. 3C

DESCRIPTION:

The basal cavity is laterally compressed and rounded in outline. It sends a shallow extension posteriorly. The aboral margin is evenly curved anteriorly, thus there is no antero-basal angle.

The cusp is slender. It is strongly recurved at the base and then is straight. The anterior and posterior edges are sharp. The posterior lateral costae are usually only weakly developed. The lateral faces are rounded.

REMARKS:

Specimens from Cow Head agree in all respects with Lindström's (1955a) description. This element bears a similarity with some specimens of Drepanodus proteus s.f. when the costae are poorly developed.

OCCURRENCE:

Units 9, 11 and 13.

MATERIAL:

4 specimens.

Belodella sp. A Fahraeus 1970

Pl. 4 Fig. 17

Belodella sp. A. Fahraeus 1970, Fig. 3.0

DESCRIPTION:

The basal cavity is deep and triangular in outline. The cross section is narrowly triangular.

The anterior edge is deflexed laterally, forming a sulcus on the inner side. The posterior edge is denticulated with basally fused denticles. The denticles become broader towards the cusp. The cusp bears lateral costae.

REMARKS:

Fahraeus (1970) regards this species as being commonly associated with Spathognathodus n.sp. Lindström 1960 in the Table Head sequence.

OCCURRENCE:

Unit 14

MATERIAL:

1 specimen.

Genus *Cordylodus* Pander, 1856

Type species: *Cordylodus angulatus* Pander, 1856

Cordylodus proavus, Müller, 1959

Pl. 1 Fig. 14, 15

Cordylodus proavus Muller, 1959, p. 448, Pl. 15, Figs. 11, 12 18; Text: Fig. 3B.

Cordylodus proavus Druce and Jones 1971, p. 70, Pl. 1, Figs. 1a-6; Text: Fig. 23 p, q, r.

DESCRIPTION:

The basal cavity is large and conical; the apex is medially situated. The base is extended posteriorly and the basal cavity runs along this extension. Posteriorly, the base is denticulated, with up to three discrete denticles which are parallel to the reclined part of the cusp.

The cusp is reclined at the tip of the basal cavity; above the basal cavity, the cusp is entirely filled with white matter.

OCCURRENCE:

Lower Part of Unit 8.

MATERIAL:

7 specimens.

Genus Drepanodus Pander, 1856

Type species: Drepanodus arcuatus Pander, 1856

Drepanodus acutus Pander, 1856.

Pl. 2, Fig. 3

Drepanodus acutus Pander, 1856, p. 21, Pl. 2, Fig. 9.

Drepanodus acutus Pander, Druce and Jones, 1971, p. 73, Pl. 20, Figs. 5a-7c; Text: Fig. 24a

DESCRIPTION:

The basal cavity is conical and large, similar to that in D. tenuis. The apex is medial, and may be recurved with the cusp. The base is large and oval in cross-section.

The cusp is at right angles to the base and is circular to laterally compressed in cross-section. The anterior face lies parallel to the aboral margin. A carina may be developed on the anterior face.

REMARKS:

The description of Druce and Jones (1971) states that the basal cavity is always recurved with the cusp, but this is not the case for many Cow Head specimens.

OCCURRENCE:

Units 8, 11, 13.

MATERIAL:

4 specimens.

Drepanodus simplex, Branson and Mehl 1933

Pl. 2, Fig. 2

Drepanodus simplex Branson and Mehl, 1933, p. 58, Pl. 4, Fig. 2

Oneotodus sp. indet. Müller, 1959, p. 458, Pl. 13, Fig. 15

Drepanodus simplex Branson and Mehl 1971; Druce and Jones, p. 74, Pl. 13, Figs. 1a-4c; Text: Fig. 24b.

DESCRIPTION:

The basal cavity is conical. Its apex is medial. The basal cavity is shallow and has a circular cross-section.

The cusp is reclined and long. The proximal half is circular to ellipsoidal in cross-section, but the distal half is extremely laterally compressed, with sharp anterior and posterior edges. The distal half may also be broader than the proximal half. The tip may be slightly bent anteriorly.

OCCURRENCE:

Units 8 and 11.

MATERIAL:

5 specimens.

Drepanodus tenuis, Moskalenko, 1967

Pl. 2, Fig. 1

Drepanodus tenuis, Moskalenko; 1967, p. 107, Pl. 23, Figs. 5-11.

Drepanodus tenuis, Moskalenko, Druce and Jones 1971, p. 75, Pl. 12, Figs. 8a-c; Text: Fig. 24e.

DESCRIPTION:

The basal cavity is conical and large. The apex is situated medially. The oral margin is rounded and it is straight in lateral view. The aboral margin is straight in lateral view also.

The cusp is slightly reclined and laterally compressed. The anterior and posterior edges are sharp and sometimes produced as low knife-edges. The lateral faces are rounded.

REMARKS:

Material from Cow Head is very similar to that illustrated by Druce and Jones (1971), except that in some specimens the apex of the basal cavity is anteriorly placed. I had thought of placing these as Drepanodus cf. D. tenuis s.f., but the resemblance is so great that I finally considered them identical to D. tenuis s.f.

OCCURRENCE:

Unit 8.

MATERIAL:

11 specimens.

Genus *Hertzina* Müller, 1959

Type species: *Hertzina americana* Müller, 1959

REMARKS:

In material from Cow Head, all specimens of this genus are broken, and only cusp fragments remain. In this situation four informal types have been recognised. No formal taxa are proposed. These types are distinguished on the basis of presence or absence of the anterior or posterior edges. The four types are:

(A). Those with rounded cross-sections.

(B). Those with an anterior edge.

(C). Those with a posterior edge.

(D). Those with anterior and posterior edges.

In all cases the cusp is very slender. (See Pl. 1, Figs. 5-7).

Lindström (1964, p. 139), places *Hertzina* Müller 1959 in synonomy with *Coelocerodontus* Ethington 1959 and suggests that *Belodella* Ethington 1959 may be a junior synonym. Druce and Jones (1971), also list *Hertzina* in synonomy with *Coelocerodontus*. It is here considered preferable to retain the genus *Hertzina* as a separate taxon for very slender and long simple cones, which may or may not be laterally compressed.

OCCURRENCE:

Units 6 and 7, and the lower part of Unit 8.

MATERIAL:

66 specimens.

Genus Oistodus Pander, 1856

Type species: Oistodus lanceolatus Pander 1856.

DESCRIPTION:

Elements belonging to Oistodus have a more or less wide basal cavity. The oral edge makes a sharp angle with the posterior edge. Sometimes one or both lateral faces bear carinae.

Oistodus brevibasis Sergeeva, 1963

Pl. 3, Fig. 1

Oistodus brevibasis, Sergeeva 1963, p. 95, Pl.Vll, Figs. 4,5.

DESCRIPTION:

The basal cavity is moderately deep with the apex pointing anteriorly. The whole base is laterally compressed. The aboral edge is more or less straight.

The cusp is somewhat recurved. It is laterally compressed with sharp anterior and posterior edges. The cusp is more rounded on one face than the other and it is thus slightly more asymmetrical. The anterior margin is evenly curved.

REMARKS:

Lindström (1971, p. 39) places this form species in the multi-element species Scandodus brevibasis, however, none of the other constituent form species are present, so I describe O. brevibasis here as a form species.

OCCURRENCE:

Unit 9.

MATERIAL:

9 specimens.

Oistodus lanceolatus Pander 1856

Pl. 3, Fig. 4

Oistodus lanceolatus Pander 1856, p. 27, Pl. 2, Figs. 17 18. (not 19).

Oistodus lanceolatus Pander 1856, Branson and Mehl 1944, pp. 239-240, Pl. 93, Fig. 23

Oistodus lanceolatus Pander 1856, Lindström 1955a, p. 577 Pl. 3, Figs. 58-60.

DESCRIPTION:

The basal cavity is shallow anteriorly; the apex is anterior and the basal cavity is deeper posteriorly. The base is laterally compressed. The oral margin is sharp. It is curved in lateral view. The aboral margin is slightly concave posteriorly, then convex centrally, becoming concave again towards the antero-basal angle.

The cusp is reclined and curved laterally. It is broad and laterally compressed. The edges are both sharp. The lateral faces are smooth.

REMARKS:

The specimens from Cow Head are very similar to those illustrated in the literature cited above. Lindström (1971, p. 38) includes this form-species in a multielement species of the same name. Other members of this multielement species are extremely rare or absent in the Cow Head Group and so *O. lanceolatus* is here described as a form-species.

OCCURRENCE:

Units 9 and 11

MATERIAL:

9 specimens.

Oistodus triangularis Lindström 1955

Pl. 3. Fig. 7

Oistodus triangularis Lindstrom 1955a, p. 581, Pl. 4; Figs. 14-18.

DESCRIPTION:

The basal cavity is deep and wide. The oral edge is sharp with a very high thin keel. The aboral margin is more or less straight.

The cusp is slightly recurved, long and slender. Both anterior and posterior edges are sharp. In addition to this, there is a very prominent lateral costa that reaches the aboral margin, causing the base to be extended to that side. Thus the cross-section is triangular.

REMARKS:

My single specimen concurs with material described and illustrated by Lindström (1955a).

This form species is placed in the multielement species Oistodus lanceolatus by Lindström (1971, p. 38), but since only one specimen was found in Cow Head, it is here described as a form-species.

The single specimen found is extremely beautifully preserved.

OCCURRENCE:

Unit 13.

MATERIAL:

1 specimen.

Genus *Oneotodus* Lindström 1955

Type species: *Oneotodus variabilis* Lindström, 1955

Pl. 1 Fig. 21

Oneotodus variabilis Lindström, 1955

Oneotodus variabilis Lindström, 1955, p. 582, Pl. 2, Figs. 14-18, 47, Pl. 5, Figs. 4,5; Text: Fig. 6.

Oneotodus variabilis Lindström, 1955a; Mound 1968, p. 414, Pl. 3 Figs. 59; Pl. 4, Figs. 1-8.

Oneotodus variabilis Lindström; Druce and Jones 1971, p. 84, Pl. 13, Figs. 5a-c; Text: Fig. 26m.

DESCRIPTION:

In lateral view the basal cavity is triangular with its apex close to the anterior margin. The Cow Head specimens always have an elliptical cross-section. Striae are not evident on any of the specimens.

OCCURRENCE:

Units 8 and 9.

MATERIAL:

5 specimens.

<u>Paltodus</u> new species A

Pl. 2, Figs. 5-7

DIAGNOSIS:

A laterally compressed paltodid with two strong lateral costae, one on each side, and variable number of other lateral costae and grooves.

DESCRIPTION:

The basal cavity is conical, partially filling the base. It sends a shallow anterior extension which does not reach the antero-basal angle. The apex of the basal cavity is medial but directed anteriorly. The oral edge is sharp and straight in lateral view. It may curve basally to meet the aboral edge. The basal outline is ellipsoidal.

The cusp is erect to proclined and laterally compressed. Two strong posteriorly directed median lateral costae are developed and these extend onto the base. Troughs may develop between these and the sharp posterior edge. The anterior edge is smoothly curved and may or may not be laterally deflexed. The lateral faces may be subequally broadly rounded, or else the inner face is flat and the other face is convex. Several smaller costae may be developed on the lateral faces. In the case of a more symmetrical species there may be four on either side, but in cases of assymmetry the costae may occur only on the outer face.

REMARKS:

In its symmetrical form this species resembles Scolopodus much more than Paltodus and so it is difficult to place it satisfactorily in one or other genus. Besides the symmetry variables, the other dimensions remain exactly the same.

OCCURRENCE:

Units 8, 9 and possibly 14.

MATERIAL:

7 specimens.

Genus *Paracordylodus* Lindström 1955

Type species: *Paracodylodus gracilis* Lindström 1955

Paracordylodus gracilis

Pl. 3, Fig. 10

Paracordylodus gracilis Lindström 1955a, p. 584, Pl. 6, Figs. 11, 12.

DESCRIPTION:

According to Lindström (1955a) the species has a "very shallow and narrow basal cavity, slightly deepened beneath the cusp.

The posterior process is broadly arched. The denticles are big and reclined, bigger and more strongly reclined the farther posteriorly. They are laterally flattened, straight-edged and sharply pointed.

The cusp is smoothly recurved, with one thin costa on each side. These costae do not get near the aboral margin. The anterior process is rather big, straight and directed obliquely backwards, in continuation of the basal part of the cusp.

The whole unit may be slightly curved sideways.

REMARKS:

I chose to follow Lindström's (1955a) description to the letter because I have only one representative of this species and it agrees in all respects with the description. My specimen from Cow Head is very similar to Lindström's(1955a) Pl. 6, Fig. 11.

OCCURRENCE:

Unit 9.

MATERIAL:

1 specimen only.

Genus *Prioniodus* Pander 1856

Type species: *Prioniodus elegans* Pander 1856

Prioniodus navis Lindström 1955

Pl. 4, Figs. 13, 14

Prioniodus alatus Hadding, Lindström 1955b, p. 111, Pl. 22, Fig. 32 (not 26, 28 29, 30, 31, 33, 34).

Prioniodus navis Lindström 1955a, p. 590, Pl. 5, Figs. 31-35.

DESCRIPTION:

The basal cavity is deep and extends along all the processes. It projects into the cusp. The basal sheath is folded inward between the anterior and lateral processes, and undulated between the lateral and posterior processes.

The posterior process is straight with small erect denticles. The anterior process is curved making an angle of less than 90 degrees with the posterior process. The lateral process is straight and makes an angle of 30 degrees with the anterior process. Both the anterior and lateral processes are denticulated with small erect denticles.

The cusp is slender, erect and bears three ridges: one to each process.

REMARKS:

This form-species is placed in the multielement species *Baltoniodus navis* and *Baltoniodus triangularis* by Lindström (1971, p. 55-56). Both of these species occur higher in the sequence than the form-species *P. navis* at Cow Head. *P. navis* occurs in the Prioniodus elegans Zone at Cow Head and must be a forerunner to the element in both the multielement species above. The relatively large numbers and fairly consistent occurrence of P. navis in the Cow Head Group suggests that it is not derived but that it is truly in place. The multi-element species association of this element is not known but it may possibly have occurred in some variant of Prioniodus elegans. Peculiarly none have been found associated with the Prioniodus evae Zone.

OCCURRENCE:

Unit 9 only.

MATERIAL:

18 specimens.

Genus Proconodontus Miller 1969

Type species : Proconodontus mülleri Miller 1969

Miller (1969) described this genus as "very large simple cones, erect to reclined, laterally compressed, including symmetrical and assymetrical species." The most distinctive feature of the genus is the very deep basal cavity which may extend to the tip of the cusp.

Ethington (1959) proposed a new genus, Coelocerodontus, for Ordovician conodonts from the upper part of the Galena Formation in Iowa and Minnesota, U.S.A. These forms are also simple, hollow cones with deep basal cavities. Ethington (1959) identified species on the basis of the shape of the cross-section. The Upper Cambrian representatives of this genus bear remarkable similarity to the genus Proconodontus.

Druce and Jones (1971) stretch Ethington's definition to include simple, horn-shaped cones without keels, by including C. rotundatus in the genus.

The genus Proconodontus, Miller 1969, needs little or no revision in order to include the Upper Cambrian, C. burkei Druce and Jones 1971), C. primitivus (Müller, 1959), C.Rotundatus Druce and Jones, 1971, and C.tricarinatus (Nogami, 1967).

Thus a redescription of the genus Proconodontus is necessary:

Simple cones usually laterally compressed, including symmetrical and assymetrical species.

The basal cavity is very deep and large and may extend to the tip of the basal cavity. Some species are somewhat twisted and/or bent over to one side: these assymetrical forms may have a carina on the concave side. The anterior and/or posterior edges may be sharp and bear a costa, or both may occasionally be smoothly rounded.

Proconodontus burkei (Druce and Jones, 1971)

Pl. 1, Fig. 4

Coeloceredontus burkei Druce and Jones, 1971, Pl.11, Figs. 5a–12b; Text: Fig. 22a,e.

DESCRIPTION:

A simple hollow cone; erect to gently reclined and is elliptical in cross-section. The anterior and posterior edges are sharp, often produced as thin flanges. In some specimens the posterior oral part of the edge breaks down to form denticles.

The basal cavity is very deep and possesses a basal filling which is commonly opaque and white. The cusp is very small.

OCCURRENCE:

Lower part of unit 8.

MATERIAL:

2 specimens.

Proconodontus müllери müllери Miller 1969

Pl. 1, Figs. 8, 9

Scandodus n.sp. Müller 1959, p. 464, Pl. 12, Fig. 11.

Proconodontus mülleri mülleri Miller 1969, p. 437, Pl. 66, Text: Fig. 5H.

DESCRIPTION:

The basal cavity is extremely deep and large, extending to the tip of the cusp. The cusp is reclined or erect, and laterally compressed. It is usually asymmetrical. Anterior and posterior carinae exist and extend almost to the basal edges.

REMARKS:

No lateral carinae are present in Cow Head specimens: these are described as weak and occasional occurrences by Miller (1969).

OCCURRENCE:

Units 6, 7 and the lower part of Unit 8.

MATERIAL:

10 specimens.

<u>Proconodontus primitivus</u> (Müller, 1959).

Pl. 1, Figs. 1, 2

<u>Furnishina primitiva</u> Müller, 1959, p. 453, pl.11, Figs. 1-4

<u>Coelocerodontus primitivus</u> Druce and Jones 1971, Pl. 9, Figs. 5a-6c, 8a-c.

DESCRIPTION:

A simple, hollow cone. The base is conical with an elliptical cross-section and flaring edges. The cusp is short and proclined. The basal cavity extends the length of the cone. The walls are thin.

OCCURRENCE:

Units 6, 7 and the lower part of Unit 8.

MATERIAL:

23 specimens.

<u>Proconodontus</u> <u>tricarinatus</u> (Nogami 1967)

Pl. 1, Fig. 3

<u>Hertzina</u> <u>tricarinata</u> Nogami, 1967, Pl. 6, Figs. 5-8;
Text: Fig. 2A, B, C, D,

<u>Acodus</u> <u>cambricus</u> Nogami, 1967 (part) Pl. 6, Fig. 2;
Text: Fig. 1C,D. only.

<u>Coelocerodontus</u> <u>tricarinatus</u> Druce and Jones, 1971, Pl. 11,
Figs. 1a-4c.

<u>DESCRIPTION</u>:

A simple hollow cone with a short cusp. The walls are corrugated with one or two broad rounded, lateral carinae on either side. The basal cavity is conical, large and deep.

<u>OCCURRENCE</u>:

Lowest part of Unit 8.

<u>MATERIAL</u>:

2 specimens.

Genus <u>Scandodus</u> Lindström 1955a

Type species: <u>Scandodus</u> <u>furnishi</u> Lindström 1955a

<u>Scandodus</u> <u>furnishi</u>

Pl. 2, Fig. 19

<u>Scandodus</u> <u>furnishi</u> Lindström (1955a) p. 592, Pl. 5, Fig. 3

DESCRIPTION:

The basal cavity is shallow and its apex points anteriorly. It opens to the inner side. The outer side of the base is cut off from the inner side by a sharp oral edge. "The aboral outline is roughly trapezoidal " (Lindström 1955a, p. 592).

The cusp is erect and blade-like. It has a prominent growth axis which is straight and white. The edges are sharp and the posterior edge runs at right angles to the oral edge. Costae may be seen to be weakly developed above the base on some specimens.

REMARKS:

My specimens from Cow Head agree with the description of Lindström (1955a).

OCCURRENCE:

Units 8, 9, 11 and 13.

MATERIAL:

5 specimens.

Genus Scolopodus Pander, 1856

Type species: Scolopodus sublaevis Pander 1856

Redefined Lindstrom 1955 p. 594-5: "multicostate, symmetrical simple conodonts with or without posterior and anterior keels."

Scolopodus bassleri, (Furnish, 1938).

Pl. 1, Fig. 13

Paltodus bassleri Furnish 1938, p. 331, Pl. 42, Fig. 1

Paltodus variabilis Furnish 1938, p. 331, Pl. 42, Figs. 9, 10; Text: Fig. 1E.

Scolopodus n.sp.2 Lindström 1960 p. 93, Fig. 5, Nos. 6 and 7

Paltodus variabilis Mound, non 1965, Pl. 4, Figs 13, 14.

Paltodus variabilis Mound 1968, Pl. 4, Figs. 18-38.

Scolopodus bassleri Druce and Jones 1971, p. 91, Pl. 17, Figs. 1a-4d; Text: Fig. 30b.

DESCRIPTION:

The base is shallow and is completely excavated by a conical basal cavity. The apex of the cavity is close to the anterior margin near the point of flexure.

The cusp is long and needle-like. It is either erect or reclined. It has two lateral costae which are separated by broadly rounded anterior and posterior faces. These may or may not be symmetrically placed.

REMARKS:

Mound's (1968) specimens are too badly photographed to be sure of their affinity.

OCCURRENCE:

Units 8 and 9.

MATERIAL:

22 specimens.

Scolopodus filosus Ethington and Clark 1964

Pl. 1, Figs. 10, 11

Scolopodus filosus Ethington and Clark, 1964, p. 699, Pl. 114, Figs. 12, 17, 18, 19; Text: Fig. 2E.

Scolopodus filosus Ethington and Clark, Mound, 1968, p. 418, Pl. 5, Figs. 16, 20, 25, 28, 33, 39, 45-46, 59.

DESCRIPTION:

The basal cavity is conical and deep. The apex of the basal cavity is directed anteriorly upward. The base is unexpanded and circular or elliptical in cross-section.

The cusp is circular in cross-section. It is usually reclined and may be slightly curved.

The surface is ornamented by several hair-like costae which extend almost to the aboral edge.

REMARKS:

The description of Ethington and Clark (1964) refers to the species as being recurved, but all Cow Head specimens are reclined.

OCCURRENCE:

Units 8 and 9.

MATERIAL:

22 specimens.

Scolopodus _gracilis_ Ethington and Clark, 1964

Pl. 1, Figs. 18, 19

Scolopodus _gracilis_ Ethington and Clark, 1964, p. 699, Pl. 115, Figs. 2-4, 8, 9; Text: Figs. 2D,G.

Scolopodus _gracilis_ Ethington and Clark, Mound, 1968, p. 418, Pl. 5, Figs. 29-31, 34-38, 40, 42-44, 52-53.

Scolopodus _gracilis_ Ethington and Clark, Druce and Jones, 1971, p. 92, Pl. 17, Figs. 5a-7d; Pl. 18. Figs. 5a-d; Text: Fig. 30C.

DESCRIPTION:

The basal cavity is large. Its apex is close to the anterior margin at the point of curvature. The basal cavity excavates a shallow base, which is slightly expanded posteriorly.

The cusp is erect to reclined, and has a deep groove in the posterior margin, which is deepest basally.

REMARKS:

Mound's (1968) illustrations are not clear as to the nature of his _Scolopodus_ _gracilis_ specimens.

OCCURRENCE:

Units 8, 9 and 13.

MATERIAL:

17 specimens.

Scolopodus iowensis (Furnish 1938)

Pl. 1, Fig. 20

Acontiodus iowensis Furnish 1938, p. 325, Pl. 4, Fig. 16 not Fig. 17.

Scolopodus iowensis Furnish, Druce and Jones, 1971, p. 93, Pl. 16, Figs. 1a-7e; Text: Fig. 30d,e

DESCRIPTION:

The basal cavity is shallow. The base itself is short and unornamented. The cross-section is elliptical.

The cusp is proclined and is antero-posteriorly compressed, giving sharp lateral edges. The anterior face is smoothly convex and unornamented. The posterior face bears a broad, rounded costa, with troughs on either side extending to the lateral edges. The cusp is triangular in outline, looking posteriorly.

REMARKS:

The single specimen recovered from Cow Head fits the Druce and Jones (1971) description. It resembles only Fig. 16 on Plate 4 of Furnish's (1938) illustrations.

OCCURRENCE:

Unit 8.

MATERIAL:

1 specimen.

Scolopodus quadriplicatus Branson and Mehl 1933

Pl. 1, Fig. 12

Scolopodus quadriplicatus Branson and Mehl 1933, p. 63, Pl. 4 Figs. 14, 15.

Scolopodus quadriplicatus Branson and Mehl; Furnish 1938, p. 332, Pl. 41, Figs. 1-12.

Scolopodus quadriplicatus Branson and Mehl; Graves and Ellison 1941, Pl.1, Fig. 10; Pl. 3, Figs. 2,5.

Scolopodus quadriplicatus Branson and Mehl, Sands; 1958, p. 842, Pl. 2, Fig. 21.

Scolopodus quadriplicatus Branson and Mehl; Ethington and Clark 1964, p. 699, Pl. 115, Figs. 12,25

Scolopodus quadriplicatus Branson and Mehl; Mound 1965, p. 34, Pl. 4, Figs. 26, 30.

Scolopodus quadriplicatus Branson and Mehl; Druce and Jones 1971, p. 93, Pl. 18, Figs. 6a-7c; Text: Fig. 30f.

DESCRIPTION:

The basal cavity is not very deep and it is conical. The base is short. The cross-section is subcircular to elliptical. The base may be extended slightly posteriorly.

The cusp is erect to proclined. It is compressed antero-posteriorly, with two lateral costae. Two costae also occur posteriorly, close together. The two sets of costae are separated by postero-lateral broad troughs. The lateral costae extend almost to the aboral margin. The posterior costae extend as far as the oral margin.

OCCURRENCE:

Unit 8 only.

MATERIAL:

8 specimens.

Genus Spathognathodus Branson and Mehl 1941.

Type species: Spathognathodus primus Branson and Mehl 1933

Spathognathodus n.sp. Lindström

Pl. 4, Fig. 16

Spathognathodus n.sp. Lindström 1960, p. 93, Fig. 5, no. 3.

The short robust blade is about twice as long as high. It bears about sixteen denticles which are laterally compressed. The denticles at the posterior end are small and basally fused. Only a small part of the denticle is free. Anteriorly the denticles are larger and less fused at the base. They are pointed.

The basal cavity is widest centrally. It flares broadly to one side and sharply to the other. The posterior portion, aborally, is eccentric. The basal cavity reaches almost to the antero-basal angle. Thus the aboral section of the base is asymmetrical.

REMARKS:

Only one specimen has been found in the Cow Head sequence. Several have been found in the Table Head Limestone in Western Newfoundland, (Fahraeus pers. comm.), and these have been used as comparative material. Only Cow Head material is illustrated.

It seems likely that this element is the only element in a multielement species, because nothing is added to the fauna when this element comes in.

The specimen here may be from a fragment of shelf facies limestone included in the graded limestone from which it came.

OCCURENCE:

Unit 13.

MATERIAL:

1 specimen only.

EXPLANATION OF PLATE 1

All specimens X30.

Figs. 1,2	Proconodontus primitivus (Müller, 1959) s.f.; CH-10D; lateral view.
Fig. 3	Proconodontus tricarinatus (Nogami, 1967) s.f.; CH-10D; lateral view.
Fig. 4	Proconodontus burkei (Druce and Jones, 1971) s.f.; CH-10D; lateral view.
Figs. 5-7	Hertzina spp.
Figs. 8,9	Proconodontus mülleri mülleri Miller,1969 s.f.; CH-10D; lateral views.
Figs. 10,11	Scolopodus filosus Ethington and Clark 1964 CH-9E; lateral views.
Fig. 12	Scolopodus quadriplicatus Branson and Mehl, 1933 s.f.; CH-6472; lateral and postero-lateral views.
Figs. 13,16,17	Scolopodus bassleri (Furnish 1938) s.f. CH-6472; lateral and postero-lateral views.
Figs. 14, 15	Cordylodus proavus Müller 1959; CH-loD s.f.; lateral views.
Figs. 18,19	Scolopodus gracilis Ethington and Clark 1964 CH-577a; lateral and posterolateral views.
Fig. 20	Scolopodus iowensis (Furnish 1938); CH-5772 s.f.; posterior view.
Fig. 21	Oneotodus variabilis Lindstrom 1955; CH-6172 s.f.; lateral view.

PLATE 1

EXPLANATION OF PLATE 2

All specimens X30, unless otherwise stated.

Fig. 1	Drepanodus tenuis Moskalenko, 1967 s.f.; CH-5772; lateral view.
Fig. 2	Drepanodus simplex Branson and Mehl 1933 s.f.; CH-5772; lateral view.
Fig. 3	Drepanodus acutus Pander 1856 s.f.; CH-2C; lateral view.
Fig. 4	Acodus gratus Lindström 1955 s.f.; CH-9E; lateral view.
Figs. 5-7	Paltodus n. sp. A (X25), CH-5972; fig. 6 is the symmetrical variant; figs; figs. 5, 7 are the assymetrical variants.
Figs. 8,9	Panderodus n. sp. A, Fig. 8, (CH-5772); Fig. 9, (CH-5972; lateral views.
Figs. 10,14	Acontiodus reclinatus Lindstrom 1955 s.f.; CH-1072; lateral view; X25
Figs. 11-13,17	Drepanodus arcuatus Lindström 1955, Figs. 11 and 17: oistodiform elements, (X25), lateral views, Figs. 12, 13: drepanodiform elements, lateral views, all from CH-6172.
Fig. 15	Stolodus stola (Lindström, 1955); Ch-3472; lateral view.
Fig. 16, 20	?Paltodus deltifer or ?Paltodus inconstans Lindström 1955; oistodiform element only. Fig. 16, (CH-9A), outer lateral view; Fig. 20, (CH-6372), inner lateral view.

EXPLANATION OF PLATE 2 (CONTINUED)

Fig. 18 Acontiodus arcuatus Lindstrom 1955 s.f.; CH-3572B; lateral view.

Fig. 19 Scandodus furnishi Lindström 1955 s.f. CH-1072; lateral view; X25.

PLATE 2

EXPLANATION OF PLATE 3

All specimens X30, unless otherwise stated.

Fig. 1	Oistodus brevibasis Serveeva 1963 s.f.; CH-4072; inner lateral view.
Figs. 2,3	Paroistodus numarcuatus (Lindström, 1955); CH-8B; Fig. 2: oistodiform element, lateral view; Fig. 3: drepanodiform element, lateral view; both X25.
Fig. 4	Oistodus lanceolatus Pander 1856 s.f.; CH-4C; lateral view
Figs. 5,6	Paroistodus parallelus (Pander, 1856); CH-8B; Fig. 5: oistodiform element, lateral view; Fig. 6: drepanodiform element, lateral view; both X25.
Fig. 7	Oistodus triangularis Lindström 1955 s.f.; CH-0972; lateral view.
Figs. 8,9	Paroistodus proteus (Lindström, 1955); CH-8B; Fig. 8: drepanodiform element, lateral view; Fig. 9: oistodiform element, lateral view; both X25.
Fig. 10	Paracordylodus gracilis Lindström 1955 s.f. CH-4772; lateral view.
Figs. 11-15	Drepanoistodus forceps (Lindstrom, 1955); CH-3572B; Figs. 11, 13-15: drepanodiform element variants, lateral views; Fig. 12; oistodiform element, lateral view.

PLATE 3

EXPLANATION OF PLATE 4

All specimens X30, unless otherwise stated.

Fig. 1-8 — Prioniodus elegans Pander 1856; CH-3572B and CH-4072. Figs. 1-3: prioniodiform elements, lateral views; Fig. 4: oistodiform element, lateral view; Fig. 5: trichonodelliform element, lateral view; Fig. 6: trichonodelliform element, posterior view; Fig. 7: oepikodiform element, lateral view; Fig. 8: tetraprioniodiform element, postero-lateral view; all X25.

Figs. 9-12 — Prioniodus evae Lindström 1955; CH-4C; Fig. 9: prioniodiform element, lateral view; Figs. 10 and 11: oepikodiform element, lateral views; Fig. 12: oistodiform element; All X25.

Figs. 13, 14 — Prioniodus navis Lindström 1955 s.f. Fig. 13, (CH-4372), antero-lateral view; Fig. 14, (CH-3572B), postero-lateral view.

Fig. 15 — "Falodus" new form; CH-4072; lateral view; specimen photographed on slide. It was not moved for fear of breakage.

Fig. 16 — Spathognathodus n.sp. Lindström, 1960 s.f. CH-2C; lateral view.

Fig. 17 — Belodella sp. A Fahraeus 1970 s.f. CH-0572; lateral view.

PLATE 4

EXPLANATION OF PLATE 5

All specimens X30.

Figs. 1-6 — Periodon flabellum Lindström 1955; CH-2B; and 2C; Fig. 1: Multiramiform element, (cordylodiform symmetry), lateral view; Fig. 2: multiramiform element, (cladognathiform symmetry), lateral view; Fig. 3: prioniodiniform element, lateral view; Fig. 4: ligonodiniform element, lateral view; Figs. 5 and 6: oistodiform elements, lateral view.

Figs. 7-14 — Periodon aculeatus hadding 1913; CH-2B and 1072; Fig. 7: multiramiform element, (cordylodiform symmetry), lateral view; Figs. 8 and 9: multiramiform element, (trichonodelliform element), lateral and posterior view respectively; Fig. 10: multiramiform element intermediate between P. flabellum and P. aculeatus, (inverted basal cavity less pronounced); Fig. 11: ligonodiniform element, lateral view; Fig. 12: ligonodiniform element, a variant of Fig. 12; Fig. 13 prioniodiniform element, lateral view; Fig. 14 oistodiform element, lateral view.

PLATE 5

BIBLIOGRAPHY

Abbate E., Bortolotti V., and Passerini P., (1970)

Olistostrome and olistoliths; Sed. Geol. Vol. 4, pp. 521-557.

Baird D.M. (1960)

Observations on the nature and origin of the Cow Head Breccias of Newfoundland; Geol. Surv. Can. paper 60-3, 26 pp.

Barnes C.R. and Poplawski M.L.S. (1973)

Lower and Middle Ordovician Conodonts from the Mystic Formation, Quebec, Canada; J. Paleont. V. 47, No. 4, p. 760-790, 5 Pl.

Bergström S.M. (1968)

Biostratigraphy of the Lower Ordovician sequence at Skattungbyn, Dalarna (abs.) in VIII Nordiska Geologiska Vintermötet, Abstract: Geol. Fören. Stockholm. Förh., Vol. 90, p. 454.

Bergström S.M. and Sweet W.C. (1966)

Conodonts from the Lexington Limestone (Middle Ordovician of Kentucky and its lateral equivalents in Ohio and Indiana; Am. Paleontology Bull., Vol. 50 no. 229, p. 271-441, Pls. 28-35, 13 figs.

Bergström S.M. and Cooper R.A. (1973)

Didymograptus bifidus and the trans-Atlantic correlation of the Lower Ordovician; Lethaia, Vol. 6, pp. 309-336.

Berner R.A. (1971)

Principles of Chemical Sedimentology. McGraw-Hill, 229 p.

Berry W.B.N. (1960)

Correlation of Ordovician Graptolite-bearing sequences; 21st. Internat. Geol. Congr. Pt. 7, pp. 97-108.

Bouma A.H. (1962)

Sedimentology of some flysch deposits: Elsevier, Amsterdam, 168 pp.

Clark D.L. and Miller J.F. (1969)

Early Evolution of Conodonts; Geol. Soc. Am. Bull., V. 80, p. 125-134, 8 figs.

Clark D.L. and Robinson R.A. (1969)

Oldest Conodonts in North America: J. Paleont. Vol. 43, No. 4, pp. 1044-1046.

Denham R.L. (1944)

Conodonts: J. Paleont., v. 18, pp. 133-140.

Dott R.H. Jr. (1963)

Dynamics of subaequous gravity depositional processes; Am. Assoc. Pet. Geol. Bull., Vol. 47, p. 104-128.

Druce E.C. and Jones P.J. (1971)

Cambro-Ordovician Conodonts from the Burke River Structural Belt, Queensland, Bureau Min. Res. Bull. 110, 158 pp., 33 text-figs., 20 Pls.

Ethington R.L. (1959)

Conodonts of the Ordovician Galena Formation: J. Paleont. v. 33, p. 257-292, Pls. 39-41, 2 figs.

Ethington R.L. (1972

Lower Ordovician (Arenigian) Conodonts from the Pogonip Group, Central Nevada; Geologica et Palaeontologica SB, pp. 17-28, 1 Pl.

Ethington R.L. and Clark D.L. (1964)

Conodonts from the El Paso Formation (Ordovician) of Texas and Arizona: J. Paleont. 38, p. 685-704, Pl. 113-115.

Ethington R.L. and Clark D.L. (1965)

Lower Ordovician Conodonts and other microfossils from the Columbia Ice Fields Section, Alberta, Canada; Brigham Young Univ. Research Studies Geology Ser., v. 12, p. 185-205, 2 Pls.

Ethington R.L. and Clark D.L. (1971)

Lower Ordovician Conodonts in North America: Geol Soc. Amer., Mem, 127, pp. 63-82, Pl. 1 and 2

Erdtmann B.D. (1971)

Ordovician Graptolite Zones of Western Newfoundland in Relation to Palaeogeography of the North Atlantic: Geol. Soc. Am. Bull. Vol. 82 pp. 1509-1528, 2 figs.

Fahraeus L.E. (1966)

Lower Viruan (Middle Ordovician) Conodonts from the Gullhögen quarry, Southern Central Sweden: Sveriges Geol. Undersökning Arsb., Ser. C., Nr. 610, 40 p.

Fahraeus L.E. (1970)

Conodont-Based Correlations of Lower and Middle Ordovician Strata in Western Newfoundland: Geol. Soc. Amer. Bull. Vol. 81, p. 2061-2076, 4 figs.

Fahraeus L.E., Slatt R.M. and Nowlan G.S. (in press)

"Origin of Carbonate Pseudopellets." Jour. Sed. Pet.

Folk R.L. (1962)

Spectral subdivisions of Limestone Types: Am. Assoc. Pet. Geol., Mem. 7, pp. 62-84, ed. Ham W.E.

Furnish W.M. (1938)

Conodonts from the Prairie du Chien Beds of the Upper Mississippi Valley: J. Paleot. Vol. 12, No. 4, pp. 318-340.

Garrison R.E. and Fischer A.G. (1969)

Deep-water Limestones and Radiolarities of the Alpine Jurassic; Depositional Environments in Carbonate Rocks, a Symposium, ed. G.M. Friedman. S.E.P.M. Spec. Pub. 14.

Graves R.W. Jr. and Ellison S. (1941)

Ordovician Conodonts of the Marathon Basin, Texas: Univ. Missouri. School of Mines and Metall. Bull. Vol. 14, No. 2, pp. 1-26.

Hadding A.R. (1913)

Undre Dicellograptus-skiffern i Skane: Lunds. Univ. Arsskr., N.F., Afd. 2, Bd. 9, No. 15.

Heezen B.C. (1968)

The Atlantic Continental Margin: Univ. Missouri Rolla Jour., p. 5-25.

Heezen B.C. and Hollister C.D. (1964)

Deep-sea current evidence from abyssal sediments. Marine Geol. v. 1, pp. 141-174.

Hinde G.J. (1879)

On Conodonts from the Chazy and Cincinnatti Group of the Cambro-Silurian, and from the Hamilton and Genesce-Shale divisions of the Devonian, in Canada and the United States: Geol. Soc. Lond. Quart. Jour. Vol. 35. p. 161-178, pl. 1, 2 figs.

Hoskins H. (1967)

Seismic observations on the Atlantic continental shelf, slope and rise, southeast of New England: Jour. Geol. Vol. 75, p. 598-611.

Igo H. and Koike T. (1967)

Ordovician and Silurian Conodonts from the Langkani Islands, Malaya: Geology and Palaeont. of S.E. Asia, Vol. 111, pp. 1-29, Pl. 1-111.

Jaanvsson V. (1960)

On the series of the Ordovician System: 21 st. Internat. Geol. Congr. Repts., Pt. 7, p. 70-81.

Johnson H. (1941)

Palaeozoic Lowlands of North Western Newfoundland: N.Y. Acad. sci. Trans., Ser. 2, Vol. 3, No. 6, p. 141-145.

Jones P.J. (1971)

Lower Ordovician Conodonts from the Bonaparte Gulf Basin and the Daly River Basin, North Western Australia: Bur. Min. Res., Geol. and Beophys. Bulletin 117.

Jones P.J., Shergold J.H. and Druce E.C. (1971)

Late Cambrian and Early Ordovician Stages in Western Queensland: Jour. Geol. Soc. Austral., Vol. 18, pp. 1-32:7 Text figs.

Kay M. (1951)

North American Geosynclines: Geol. Soc. Amer. Mem. 48.

Kindle C.H. and Whittington H.B. (1958)

Stratigraphy of the Cow Head Region, Western Newfoundland: Geol. Soc. Amer, Bull., Vol. 69, pp. 315-342, 8 figs, 8 Pls.

Koucky F.L., Cygan N.E. and Rhodes R.H.T. (1961)

Conodonts from the eastern flank of the central part of the Big Horn Mountains, Wyoming: J. Paleont., Vol. 35, pp. 877-879.

Krumbein W.C. and Sloss L.L. (1963)

Stratigraphy and Sedimentation: Second Ed. Freeman and Co., San Francisco, 660 p.

Lindström M. (1955a)

Conodonts from the lowermost Ordovician Strata of South-Central Sweden: Geol. Fören. Stockholm. Förh. bd. 76, p. 517-614, Pl. 1-10, 6 figs.

----------- (1955b)

The Conodonts described by A.R. Hadding 1913: J. Paleont., Vol. 29, p. 105-111, Pl. 22, 1 fig.

----------- (1957)

Two Ordovician Conodont Faunas found with zonal graptolites: Geol. Fören. Stockholm Förh. bd. 79, p. 161-178, Pl. 1, 2 figs.

----------- (1960)

A Lower-Middle Ordovician Succession of Conodont Faunas: 21st. Internat. Geol. Congr. Repts., Pt. 7, p. 88-96, 8 figs.

----------- (1964)

Conodonts: Amsterdam, Elsevier Publishings Co. 196 pp.

----------- (1971)

Lower Ordovician Conodonts of Europe: Geol. Soc. Amer. Mem. 127, pp. 21-61, Pl. 1, 20 figs.

Logan W.E., (1863)

Geology of Canada: Geol. Surv. Canada, 983 pp.

Longwell C.R. and Mound M.C. (1967)

A new Ordovician Formation in Nevada, dated by conodonts: Geol. Soc. Amer. Bull., Vol. 78, p. 405-412, 1 Pl., 2 figs.

Miller J.F. (1969)

Conodont Fauna of the Notch Peak Limestone (Cambro-Ordovician), House Range, Utah: J. Paleont., Vol. 43, No. 2, pp. 413-439, Pls. 63-66, 5 text-figs.

Loomis F.B. (1936)

Are conodonts gastropods? J. Paleont., vol. 10, pp. 663-664.

Moore R.C. (1962)

Conodont classification and nomenclature. In R.C. Moore (Ed.) Treatise on Invertebrate Palaeontology. W. Miscellanea: Conodonts, Concoidal shells of uncertain affinities, Worms, Trace Fossils and Problematica: Geol. Soc. Amer., New York and Univ. Kansas Press, Lawrence (Kansas) pp. 92-98.

Moore R.C. and Sylvester-Bradley P.C. (1957)

Proposed insertion in the "Regles of provisions recognising 'Parataxa" as a special category for the classification and nomenclature of discrete fragments of life-stages of animals which are inadequate for identification of whole-animal taxa, with proposals of procedure for the nomenclature of 'Parataxa' Bull. Zool. Nomenclature, 15:5-13.

Mound M.C. (1965)

A conodont fauna from the Joins Formation (Ordovician), Oklahoma: Tulane Univ., Studies in Geol., Vol. 4, No. 1, pp. 1-45, Pls. 1-4, text-figs. 1-2, Table 1.

-------- (1968)

Conodonts and biostratigraphy of the lower Arbuckle Group (Ordovician), Arbuckle Mountains, Oklahoma: Micropalao. Vol. 14, no. 4, pp. 393-434, Pls. 1-6.

Mountjoy E.W., Cook H.E., Pray L.C. and McDaniel P.N. (1972)

Allochthonous Carbonate Debris Flows-Worldwide Indicators of Reef Complexes, Banks or Whelf Margins. 24th Internat. Geol. Congr. Repts. Sect. 6 pp. 172-189.

Müller K.J. (1959)

Kambrische Conodonten: Deutsche geol. Gesell., Zeitschr., V. 111, p. 434-485, Pls. 11-15.

Murray R.C. and Pray L.C. (1965)

Dolomitization and Limestone Diagenesis: an introduction. S.E.P.M. spec. Pub. No. 13.

Nelson S.J. (1955)

Geology of Portland Creek - Port Saunders Area, West Coast, Newfoundland: Geol. Survey, Rept. no. 7, 57 pp.

Nogami Y. (1966)

Kambrische Conodonten von China, Teil I: Kyoto Univ., College Sci. Mem., Ser. Br. V. 32, p. 351-366, Pls. 9, 10.

----------- (1967)

Kambrische Conodonten von China, Teil 2: Ibid, V. 33, p. 211-218, Pl. 1.

Nowlan, G.S. and Fahraeus L.E. (1972)

Conodont biostratigraphy of the Ordovician part of the Cow Head Group, Western Newfoundland (abstract): Geol. Soc. Amer. Abstracts with programs 4, 5, 341, Boulder, Colorado.

Oxley P. (1953)

Geology of Parsons Pond - St. Paul's area, West Coast: Newfoundland: Geol. Survey, Rept. 5, 53 pp.

Pander C.H. (1856)

Monographie der Fossilen Fische des silurischen Systems der russisch-baltischen Gouvernements: Königl. Anad. Wiss, St. Petersburg. 91 pp.

Poulsen V. (1966)

Early Cambrian distacodontid conodonts from Bornholm: Biol. Medd. Danske Vidensk. Selsk., v. 23, p. 1-11, Pl. 1.

Pringle I.R., Miller J.A. and Warrell D.M. (1971)

Radiometric Age Determinations from the Long Range Mountains, Newfoundland. Can. Jour. Earth Sci. Vol. 8, pp. 1325-1330.

Rodgers J. and Neale E.R.W. (1963)

Possible "Taconic" klippen in Western Newfoundland: Amer. Jour. Sci., Vol. 261, pp. 713-730.

Rhodes F.H.T. (1953)

Nomenclature of Conodont Assemblages: J. Paleont. Vol. 27, no. 4, pp. 610-612.

Sando W.J. (1958)

Lower Ordovician section near Chambersburg, Pennsylvania: Geol. Soc. Amer. Bull., Vol. 69, pp. 837-854.

Schmidt (1943)

Conodonten-Funde in ursprünglichen Zusammenhang: Paläontol. zo, v. 16, pp. 76-85.

Scholle P.A. (1971)

Sedimentology of fine-grained deep-water Carbonate turbidites, Monte Antola Flysch (Upper Cretaceous), Northern Appenines, Italy: Geol. Soc. Amer. Bull. Vol. 82, p. 629-658, 19 figs.

Schopf J,J.M. (1966)

Conodonts at the Trenton Group (Ordovician) in New York, Southern Ontario and Quebec: N.Y. State Mus. and Science Service Bull. no. 405, pp. 1-105, 6 Pls.

Schuchert C. and Dunbar C.O. (1934)

Stratigraphy of Western Newfoundland: Geol. Soc. Amer. Mem. 1.

Scott H.W. (1934)

The Zoological Relationships of the Conodonts: J. Paleont Vol. 8, pp. 448-455.

----------- (1942)

Conodont assemblages from the Heath Formation, Montana: J. Paleont, Vol. 16, pp. 293-300.

Sergeeva S.P. (1962)

Stratigraphic distribution of conodonts in the Lower Ordovician of the Leningrad Region: Akad. Nauk. S.S.S.R., Doklady, tom, 146, p. 1393-1395. (in Russian).

----------- (1963a)

Conodonts from the Lower Ordovician of the Leningrad Region: Akad. Nauk. S.S.S.R., Paleont, Jour., 1963, p. 93-108, Pls. 7, 8, 11 figs.

Sinclair G.W. (1953)

The naming of Conodont Assemblages: J. Paleont, Vol. 27, No. 3, pp. 489-491.

Skevington D. (1963)

A correlation of Ordovician Graptolite-bearing sequences: Geol. Fören. Stockholm. Förh. v. 85, pp. 298-319.

----------- (1966)

The Lower Boundary of the Ordovician System: Norsk. Geol. Tidsskr. pp. 111-119.

Stanley D.J. (1970)

Bioturbation and sediment failure in some submarine canyons: In IIIrd. European Symposium on Marine Biology, Vie et Milieu, Supplement 22, v. 2, p. 541-555.

Stanley D.J. and Kelling G. (1969)

Photographic investigation of sediment texture, bottom current activity and benthonic organisms in the Wilimington submarine canyon: U.S. Coast Guard Oceanogr. Rept. 22, 95 pp.

Stanley D.J. and Unrug R. (1973)

Submarine Channel Deposits, Fluxoturbidites and other indicators of Slope and Base of Slope environments in modern and ancient marine basins: S.E.P.M. Spec. Pub. 16, pp. 287-340.

Stevens R.K. (1970)

Cambro-Ordovician flysch sedimentation and tectonics in Western Newfoundland and their possible bearing on a Proto-Atlantic Ocean: Geol. Assoc. Can. Spec. Paper, No. 7, pp. 165-177.

Sweet W.C. and Bergström S.M. (1962)

Conodonts from the Pratt Ferry Formation (Middle Ordovician) of Alberta: J. Paleont, Vol. 36, no. 6, P. 1214-1252.

---------------------------- (1969)

The Generic Concept in Conodont taxonomy: North-Amer. Paleontol. Convention, 1969, Proc. C, pp. 157-173.

Viira V. (1966)

Distribution of conodonts in the Lower Ordovician sequence of Sukhrumägi (Tallinn): Eesti. Nsv Tead. Akad. Toimetised, Koide 15, pp. 150-155. (In Russian with English abstract).

----------- (1967)

Ordovician conodont succession in the Ohesaare Core: Eesti NSV Tead. Akad. Toimetised, Koide 16, pp. 319-329, 5 figs. (In Russian with English abstract).

Williams H. (1964)

The Appalachians in North Eastern Newfoundland - A two-sided symmetrical system: Amer. Jour. Sci., Vol. 262, pp. 1137-1158.

----------- (1971)

Mafic-Ultramafic Complexes in Western Newfoundland Appalachians and the Evidence for their Transportation: A Review and Interim Report: Geol. Assoc. Can. Proc. Vol. 24, pp. 9-25.

Williams H., Kennedy M.J. and Neale E.R.W. (1972)

The Appalachian Structural province: In Variations in tectonic styles in Canada, Eds. Price R.A. and Douglas J.W.: Geol. Assoc. Can. Spec. Paper. No. 11, pp. 182-261.

Webers G.F. (1966)

The Middle and Upper Ordovician Conodont Faunas of Minnesota: Minnesota Geol. Surv. Spec. Publ. 4, 123 pp. 15 Pls.

TABLE I

BALTO-SCANDIA: SERIES AND STAGES		BALTO-SCANDIA: CONODONT ZONES	COW HEAD NFLD: UNITS (THIS STUDY)	COW HEAD NFLD: BEDS KINDLE and WHITTINGTON (1958) south	COW HEAD NFLD: BEDS KINDLE and WHITTINGTON (1958) north	NORTH AMERICA: SERIES	NORTH AMERICA: MID-WEST U.S. ZONES	AUSTRALIA: STAGES	AUSTRALIA: CONODO
LLANVIRNIAN						CHAMPLAINIAN			
	KUNDAN	Amorphognathus variabilis	? 14	14	14	CANADIAN		NO FORMAL STAGE NAMES	N ZO
	VOLKHOVIAN	Microzarkodina parva	Ic 13	13	13				
		Paraistodus originalis							
		Baltoniodus navis							
		Baltoniodus triangularis							
ARENIGIAN		Prioniodus evae	12	12	12				
			11	11	11				
		Prioniodus elegans	10	10	10				
			9 Ta	9 8a	9				
		Paltodus inconstans	8	8	8		E		
TREMADOCIAN		Paltodus deltifer					D	WARENDIAN	Chosonodina - Acod
							C		Cordylodus ro Cordylodus a
							B		Cordylodus - Scolopod
		Cordylodus angulatus					A	DATSONIAN	Cordylodus ok -Cordylodus l
									Oneotodus b -Drepanodus
			7	7	7	?			Cordylodu
	Acerocare		SD			REMPEALEAUAN		PAYNTONIAN	

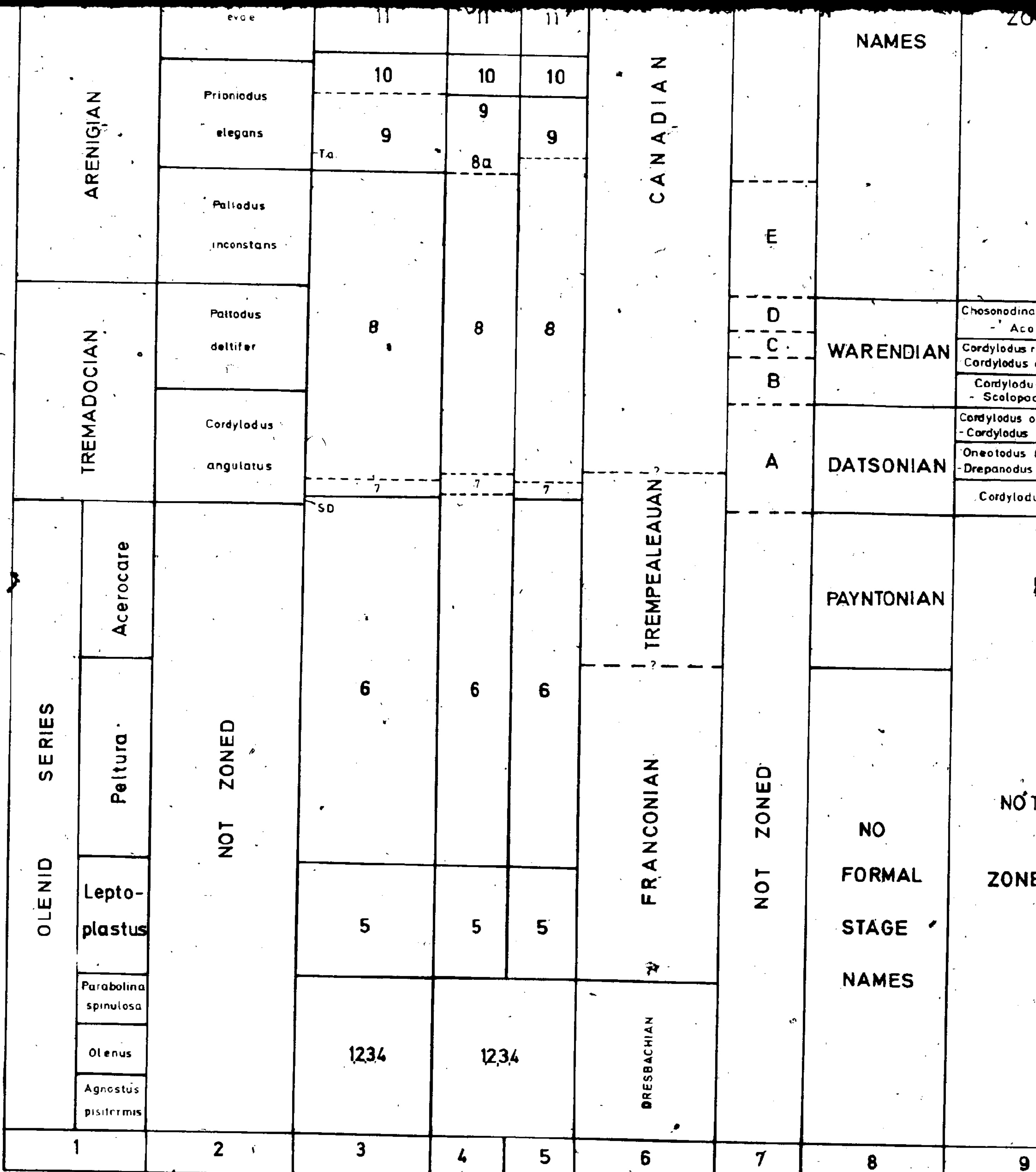
AUSTRALIA	
STAGES	CONODONT ZONES
NO ORMAL TAGE AMES	NOT ZONED
RENDIAN	Chosonodina herfurthi - Acodus
	Cordylodus rotundatus - Cordylodus angulatus
	Cordylodus prion - Scolopodus
TSONIAN	Cordylodus oklahomensis - Cordylodus lindströmi
	Oneotodus bicuspatus - Drepanodus simplex
	Cordylodus proavus
NTONIAN	

TABLE II

MULTIELEMENT SPECIES \ SAMPLE NOS		CH6-4	CH6-3	CH6-2	12C	12A	11C	10E	10D	10B	9K	9J	9I	9E	9D	9A	8D	8B	6E	6D	6B	5C	5B	4C	3D	2C	2B	1A	71	67	65	64	63	62
Drepanodus arcuatus	D										2		1			1	2	4	1	2				1		1						3	3	
	Oi												2			2	1	2		2				3	1	2	2							
Drepanoistodus forceps	D										2		2				1	2		5			1								1	3	2	
	Oi										2						2	1						10		5	1					1	1	1
? Paltodus deltifer	D																																	
	Oi															3																1		
? Paltodus inconstans	D																																	
	Oi																																1	1
Panderodus n.sp. A																																	2	
Paroistodus numarcuatus	D												3				1	6																
	Oi																3	1		2														
Paroistodus proteus	D																	4	1							1	1							
	Oi																									1								
Paroistodus parallelus	D																																	
	Oi																																	
Periodon aculeatus	Pd																									5	18	1						
	M																									2	28	2						
	Oi																									9	18	1						
	L																									7	12							
Periodon flabellum	Pd																									3	2							
	M																									14	24							
	F																									9	17							
	L																									15	15							
Prioniodus elegans	Pn																			3			5											
	Oe																		1	8		1	3	1										
	Oi																			7			2											
	Tet																		1	9	1	1	5	1										
	Tri																			1														
Prioniodus evae	Pn																							40	12									
	Oe																							3	10									
Stolodus stola	Oi																							6	1									
RESIDUAL SPECIES																																		
Acodus gratus														1		1								1							1	1		
Acontiodus arcuatus																	1							1		1								
Acontiodus reclinatus																																		
Bellodella sp A Fahraeus 1970																																		
Cordylodus pracvus									7																									
Drepanodus acutus																										1								1
Drepanodus simplex																								1										
Drepanodus tenuis											1																						1	3
Hertzina spp.		12	1	1	8	11		6	17	1	.		4																4	1				
Oistodus brevibasis																				1														
Oistodus lanceolatus																								4										
Oistodus triangularis																																		
Oneotodus variabilis																		2														2		
Paltodus n.sp. A										1																								
Paracordylodus gracilis																																		
Prioniodus navis																				4														

TABLE II

9.	91	9E	9D	9A	8D	8B	6E	6D	6B	5C	5B	4C	3D	2C	2B	1A	71	67	65	64	63	62	61	60	59	57	56	55	50	49	48	47	46	43	42	41	40	39	38	35B	34	32	27B	22	19	17	14	13	12	11	10	9	6	5	4	TOTALS
	1			1	2	4	1	2				1		1						3	3		4		1	12	2													10	1															51
	2			2	1	2		2				3	1	2	2								3		1	4	6			1	1	1					2			6						1	1					1				44
	2				1	2		5			1								1	3	2		6	2	2	3	1												1	16				1			1				1					53
					2	1						10		5	1					1	1	1	2			2		1									1			12	5	1	1			3	1		5		1	2				61
																																																								0
				3																1																																				4
																					1	1																																		2
																					2		2	2	2	5																														13
	3				1	6																	2																	4																16
					3	1		2															2			2		1												8																19
						4	1							1	1															1										21							1			1	1					32
														1																										20																21
																																							1	1	2															4
																																								2				1												3
														5	18	1																																			20	9				53
														2	26	2																																		4	8	8				50
														9	18	1																																		3	6	5				42
														7	12																																				3	2			1	25
														3	2																														1	3			1	3	1	6				20
														14	24																															5			1	1	2	2				49
														9	17																															10			3	2	3	2				46
														15	15																									1					1	6			4	1	5	1				49
								3			5																					1	2				1		10			57	11		1													91
							1	8		1	3	1																				2	1			1	1		10		2	23	6		1													61
								7			2																					1	1						5			64	12		2		1											95
							1	9	1	1	5	1																		1	1		1			1	11			23	4															60
								1																											1		3		1	6	2															14
												40	12																															4	1		4									61
												3	10																																		1									14
												6	1																															1												8
																																									1		1													2
		1		1								1							1	1			2																	4											1					12
					1							1		1																	2					1				7	1										2	1				17
																																						1						2							1					4
																																																						1		1
																																																								7
														1								1				1																		1												4
												1												1		1	2																													5
																					1	3		2	2	2																														11
	4																4	1																																						66
								1																							2									4	2	2														9
												4																												2				1		2										9
																																																				1				1
						2														2			1																																	5
																							1		1															2	1												1			7
																																1																								1
								4																										1			1			15	1															18
																																																								2



CORRELATION OF THE COW HEAD GROUP

G.S.Nowlan M.Sc. th

4 of |

8	9
ENDIAN	Chosonodina herfurthi - Acodus
	Cordylodus rotundatus - Cordylodus angulatus
	Cordylodus prion - Scolopodus
ONIAN	Cordylodus oklahomensis - Cordylodus lindströmi
	Oneotodus bicuspatus - Drepanodus simplex
	Cordylodus proavus
TONIAN	NOT ZONED
NO RMAL TAGE AMES	

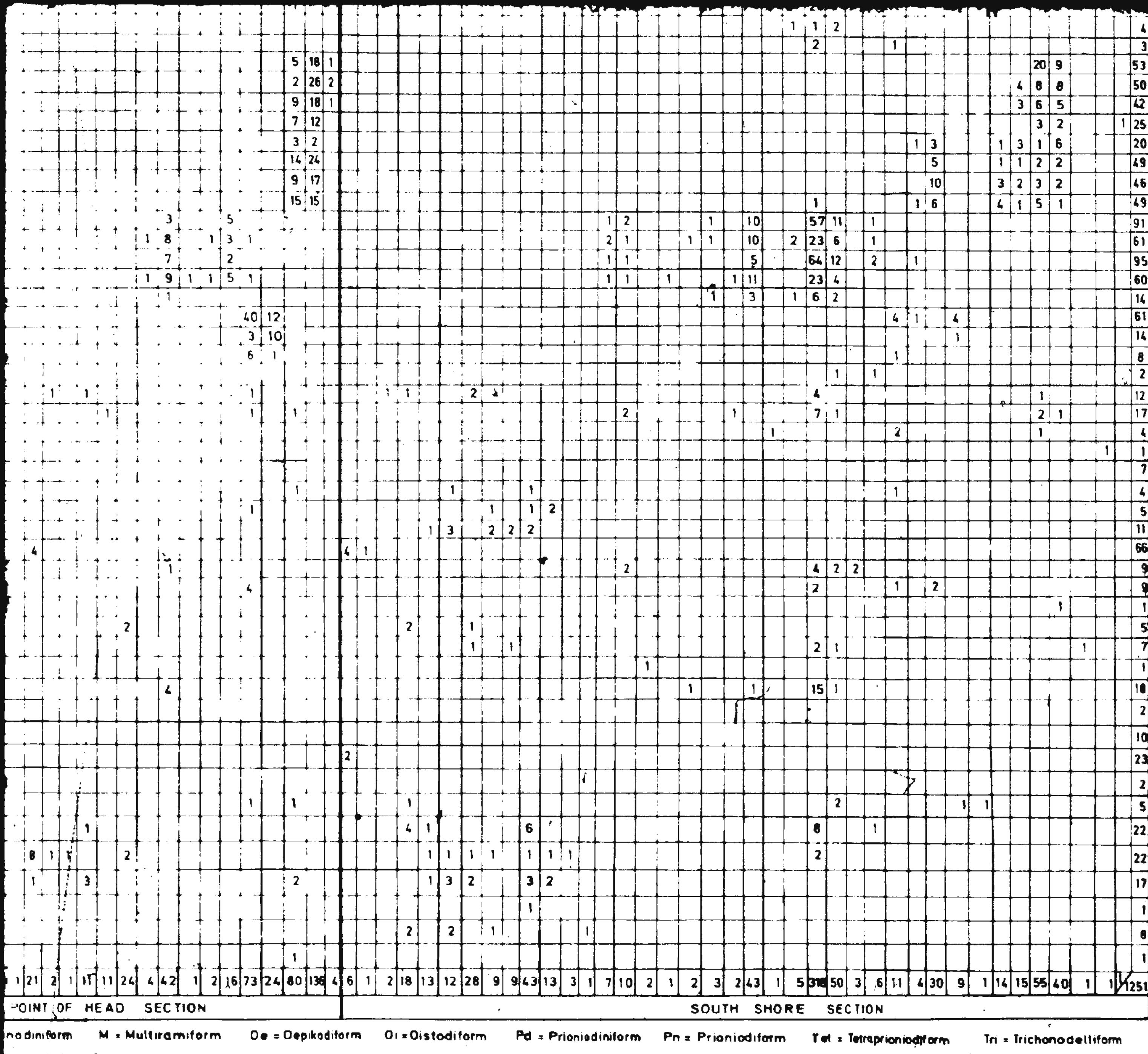
G.S.Nowlan M.Sc. thesis M.U.N. 1973

Species	Element	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27							
Paroistodus parallelus	D																																		
	Oi																																		
Periodon aculeatus	Pd																									5	18	1							
	M																									2	26	2							
	Oi																									9	18	1							
	L																									7	12								
Periodon flabellum	Pd																									3	2								
	M																									14	24								
	F																									9	17								
	L																									15	15								
Prioniodus elegans	Pn																			3			5												
	Oe																		1	8		1	3	1											
	Oi																			7			2												
	Tet																		1	9	1	1	5	1											
	Tri																			1															
Prioniodus evae	Pn																							40	12										
	Oe																							3	10										
Stolodus stola	Oi																							6	1										
RESIDUAL SPECIES																																			
Acodus gratus														1		1								1							1	1			2
Acontiodus arcuatus																	1							1		1									
Acontiodus reclinatus																																			
Belladella sp A Fahraeus 1970																																			
Cordylodus proavus									7																										
Drepanodus acutus																										1								1	
Drepanodus simplex																								1											
Drepanodus tenuis											1																						1	3	
Hertzina spp		12	1	1	8	11		6	17	1			4																4	1					
Oistodus brevibasis																				1															
Oistodus lanceolatus																								4											
Oistodus triangularis																																			
Oneotodus variabilis																		2														2			
Paltodus n sp A										1																									
Paracordylodus gracilis																																			
Prioniodus navis																				4															
Proconodontus burkei									2																										
Proconodontus mülleri mülleri		1					3	1	5																										
Proconodontus primitivus		3	1	2		1			14																				2						
Proconodontus tricarinatus									2																										
Scandodus furnishi																								1		1						1			
Scolopodus bassleri												1				1																4	1		
Scolopodus filosus											1		8	1	1			2															1	1	
Scolopodus gracilis													1			3										2							1	3	
Scolopodus iowensis																																			
Scolopodus quadriplicatus																																2		2	
Spathognathodus n sp																										1									
Lindström (1960)		16	2	3	8	12	3	7	47	2	8	1	21	2	1	11	11	24	4	42	1	2	16	73	24	80	136	4	6	1	2	18	13	12	2
		NORTH SHORE - POINT OF HEAD SECTION																																	

KEY TO ABBREVIATIONS: D = Drepanodiform L = Ligonodiniform M = Multiramiform Oe = Oepikodiform Oi = Oistodifo

CONODONT · DISTRIBUTION IN THE COW

5 of



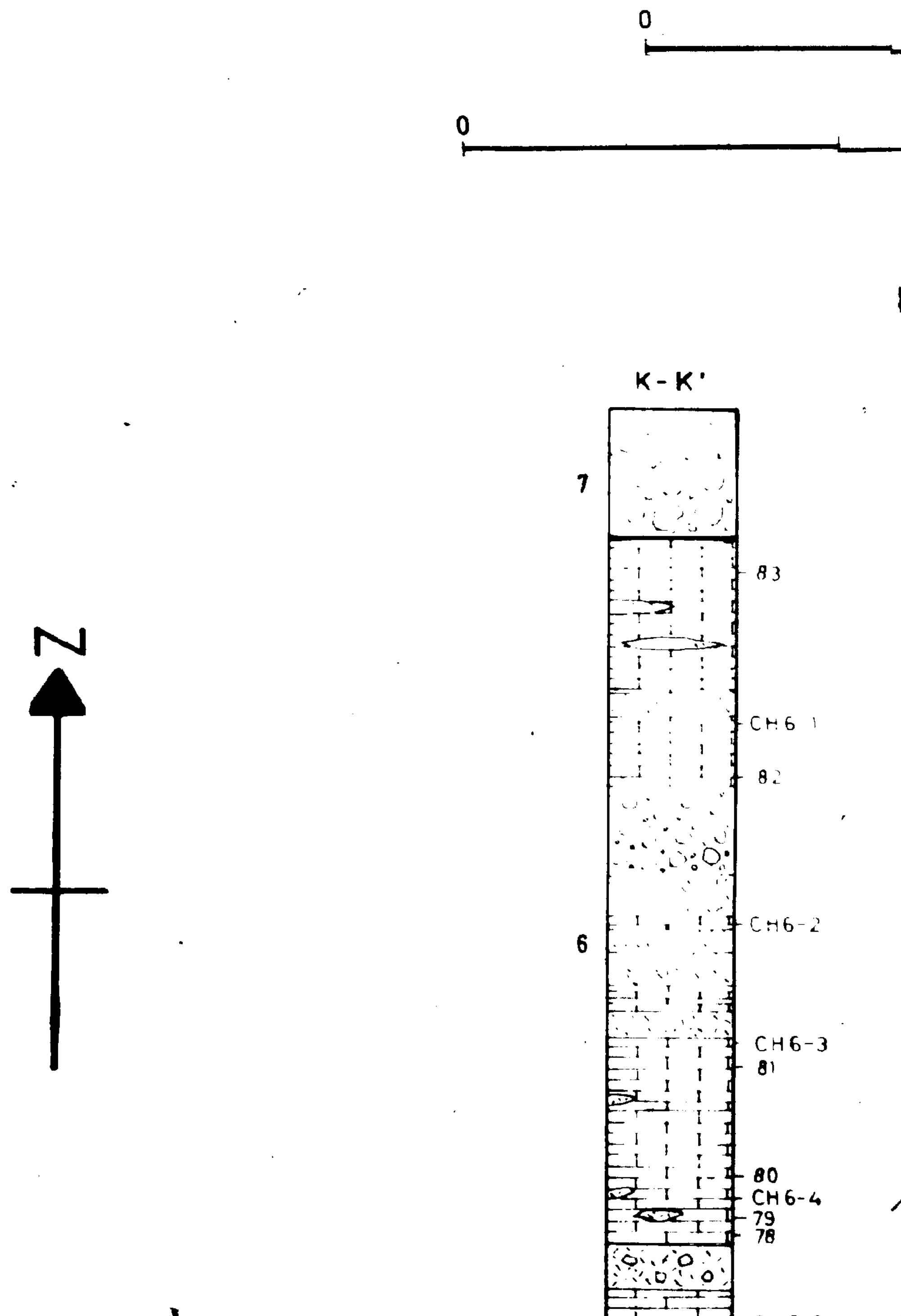
G.S. Nowlan M.Sc. thesis M.U.N. 1973

ONODONT DISTRIBUTION IN THE COW HEAD GROUP

GEOLOGICAL MAP OF THE COW

WITH STRATIGRAPHIC CO

1 of



THE COW HEAD PENINSULA, NEWFOUNDL

RAPHIC COLUMNS AND SAMPLE LOCATIONS -

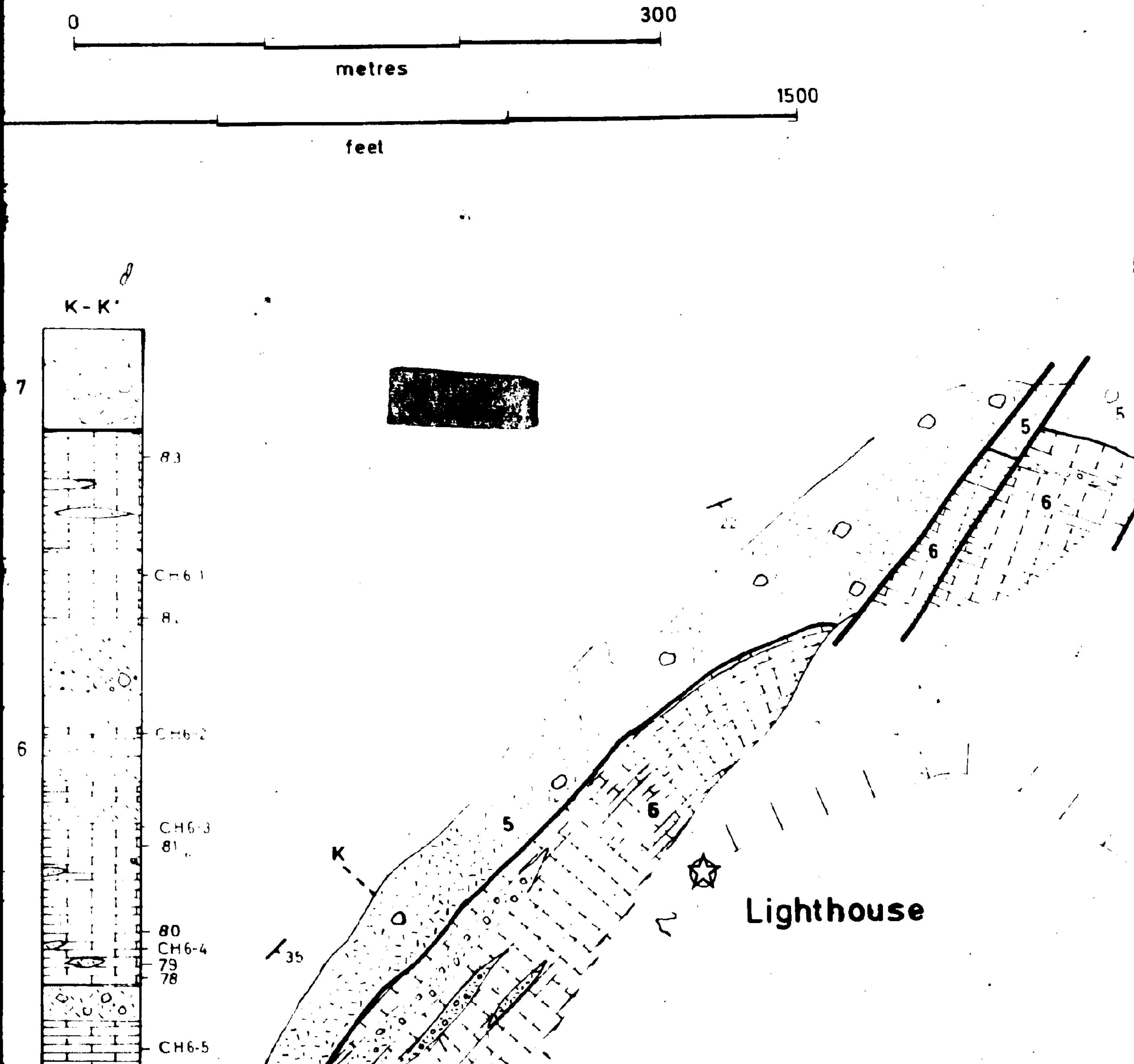
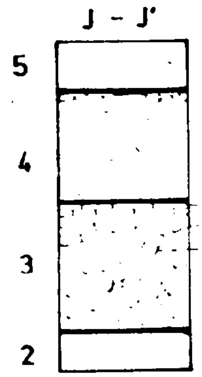


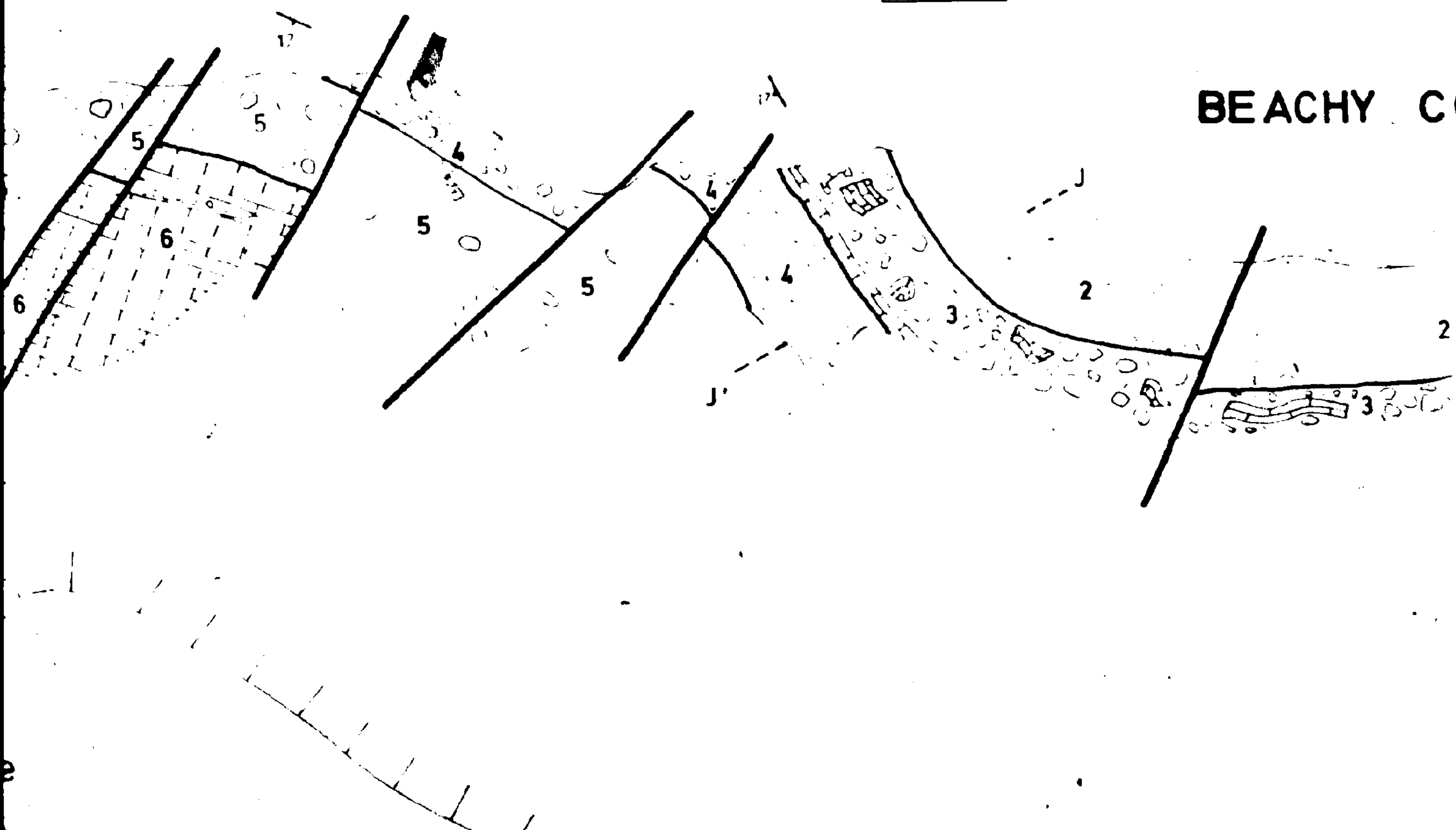
FIG. 3

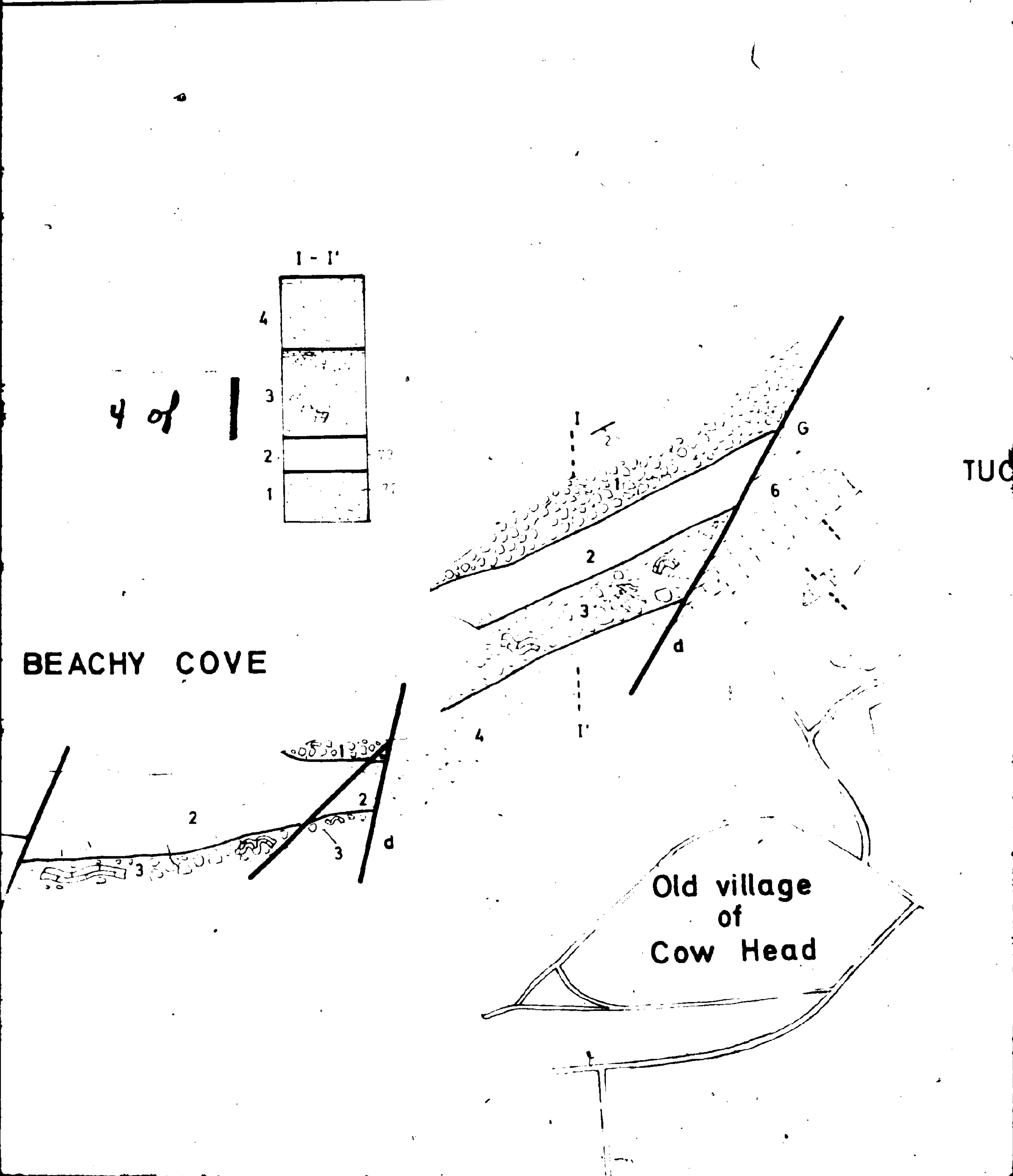
WFOUNDLAND

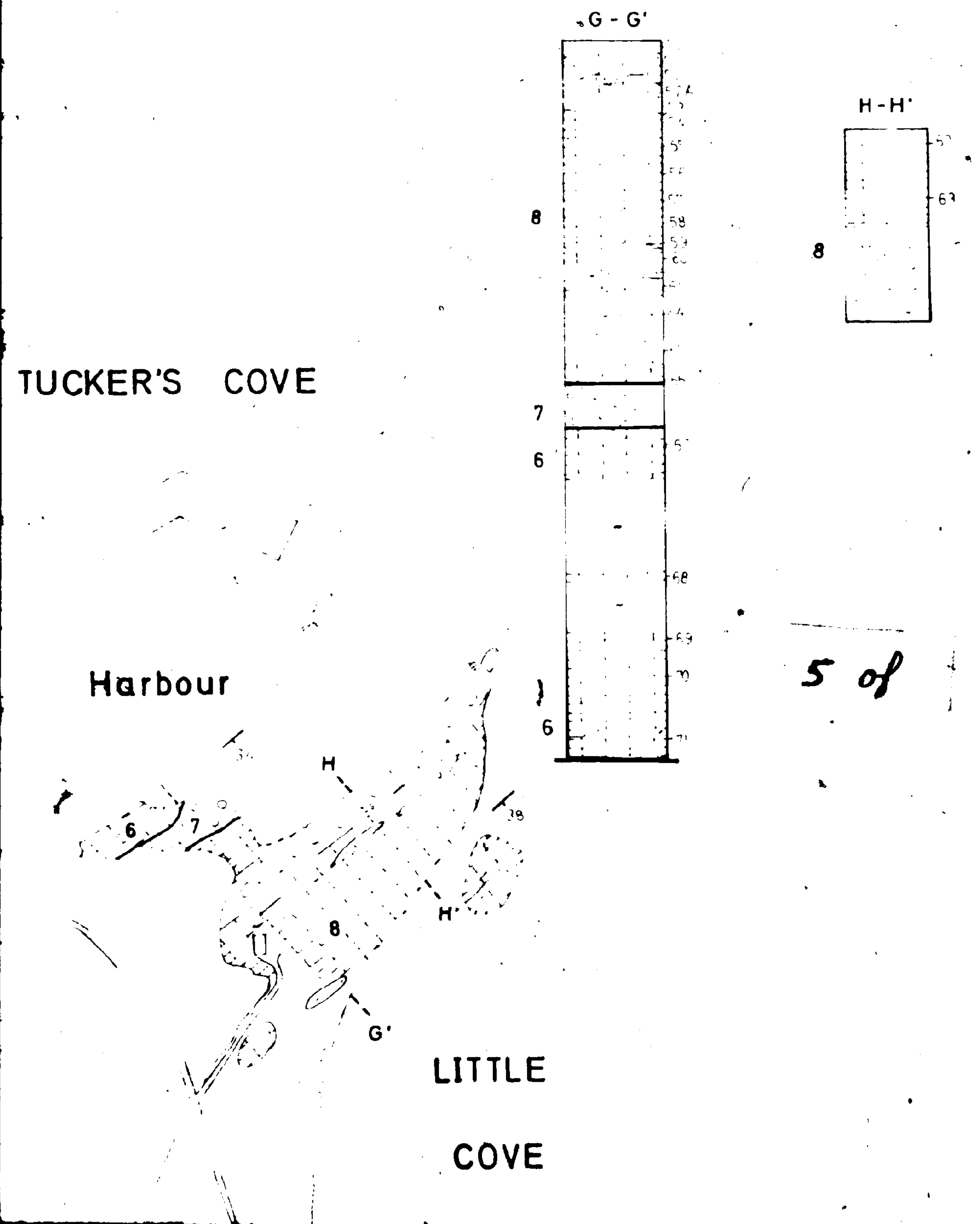
ATIONS ~

3 of



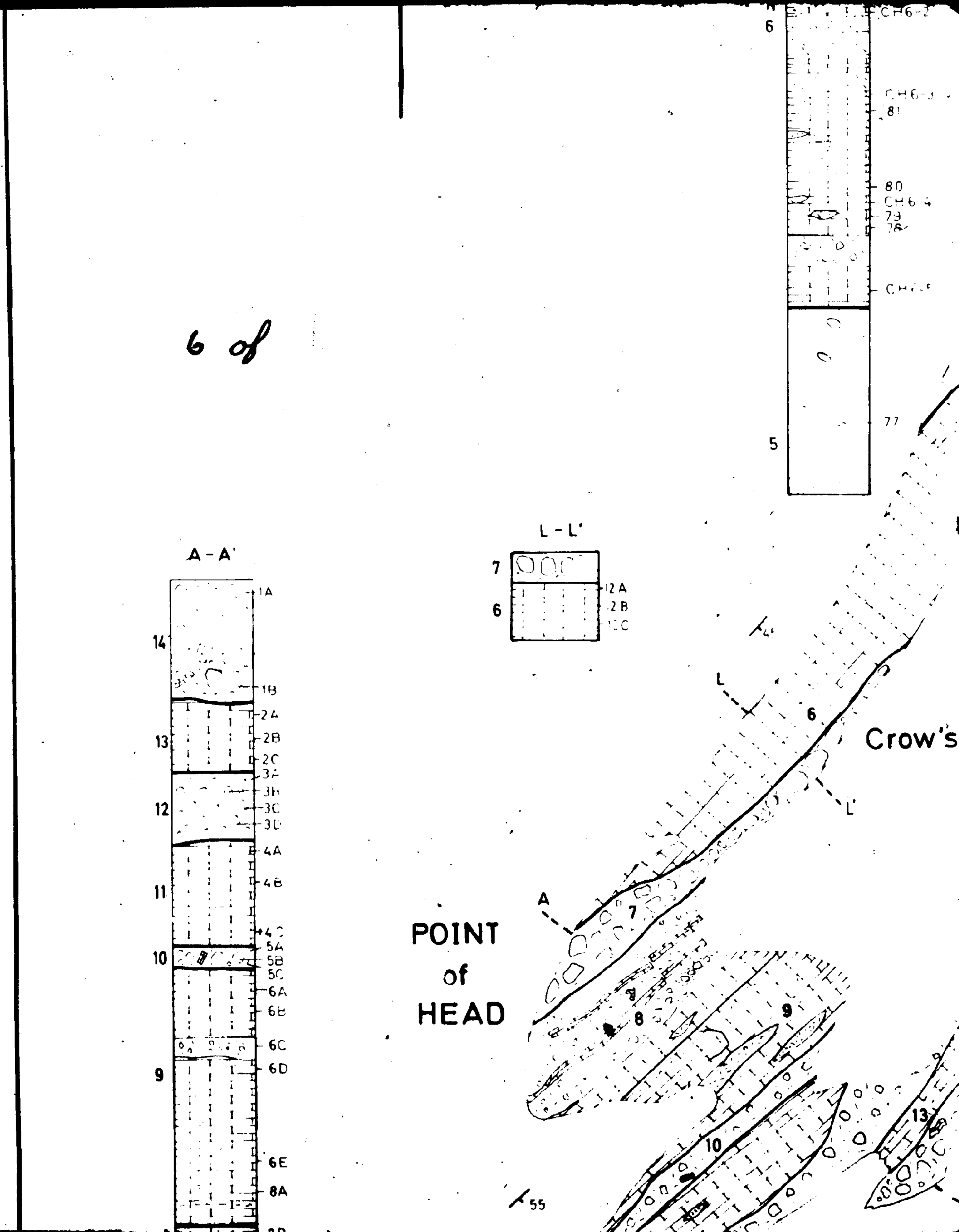



I - I'
4
3
2
1
BEACHY COVE
TUC
G
6
d
Old village
of
Cow Head

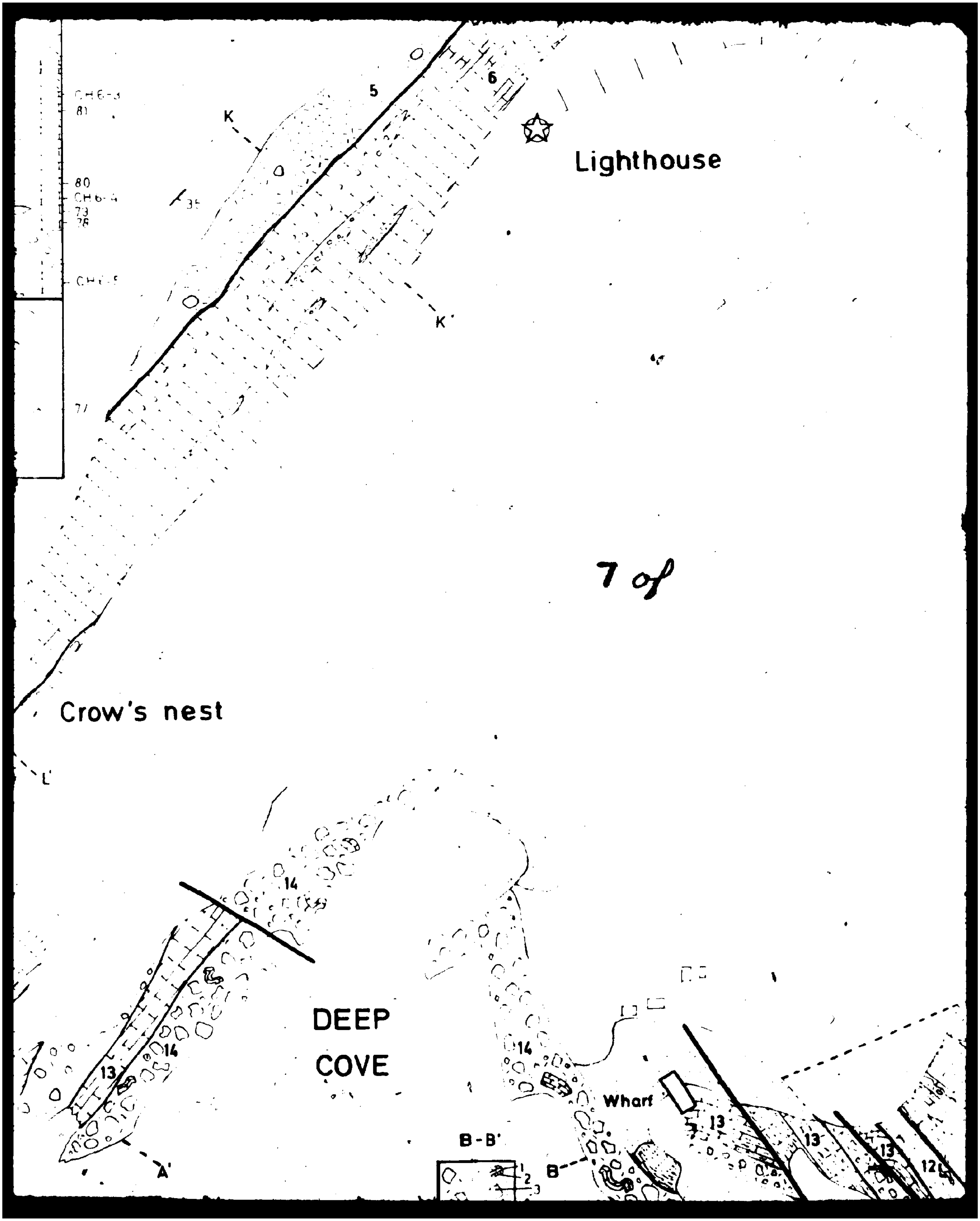


5 of

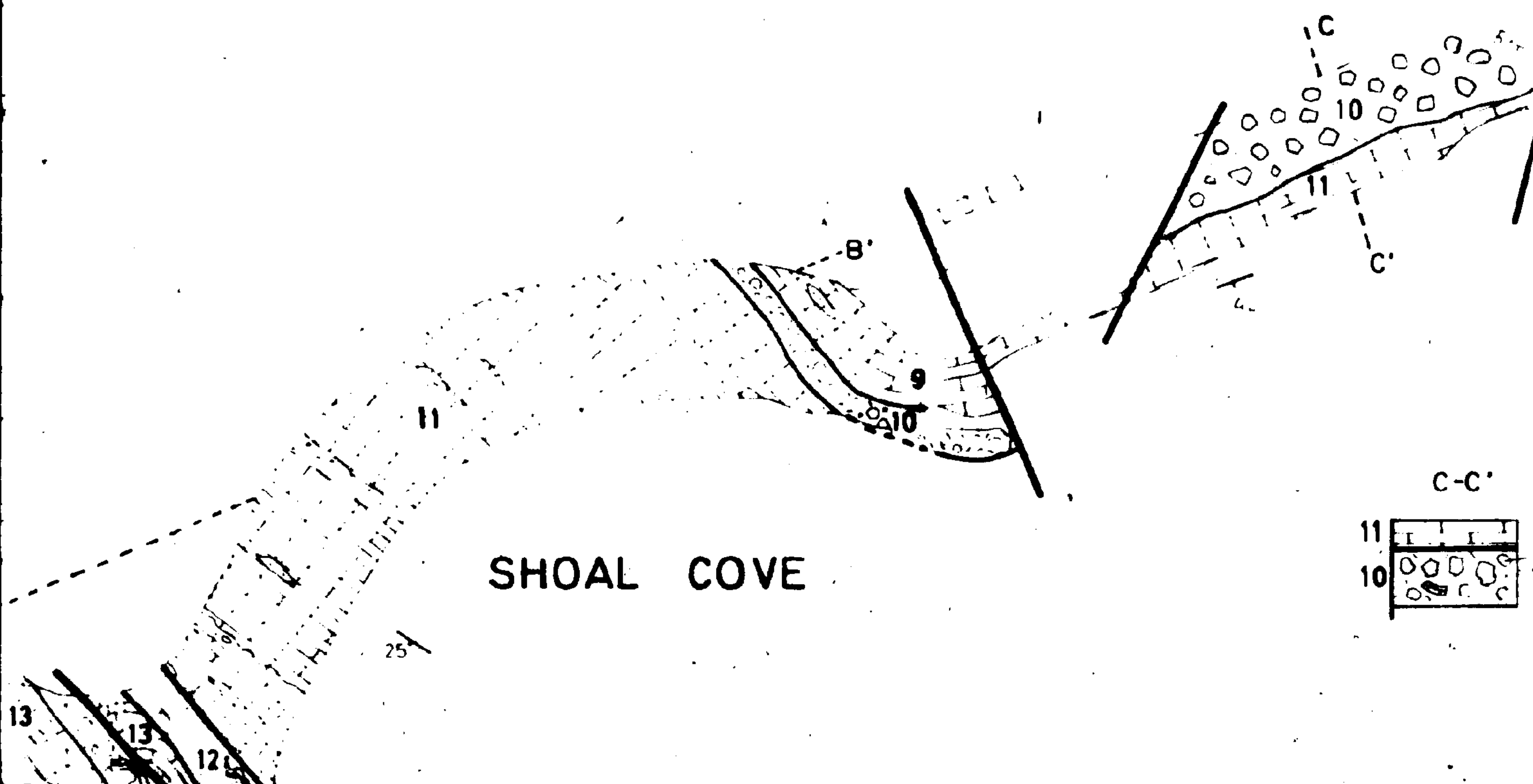
6 of

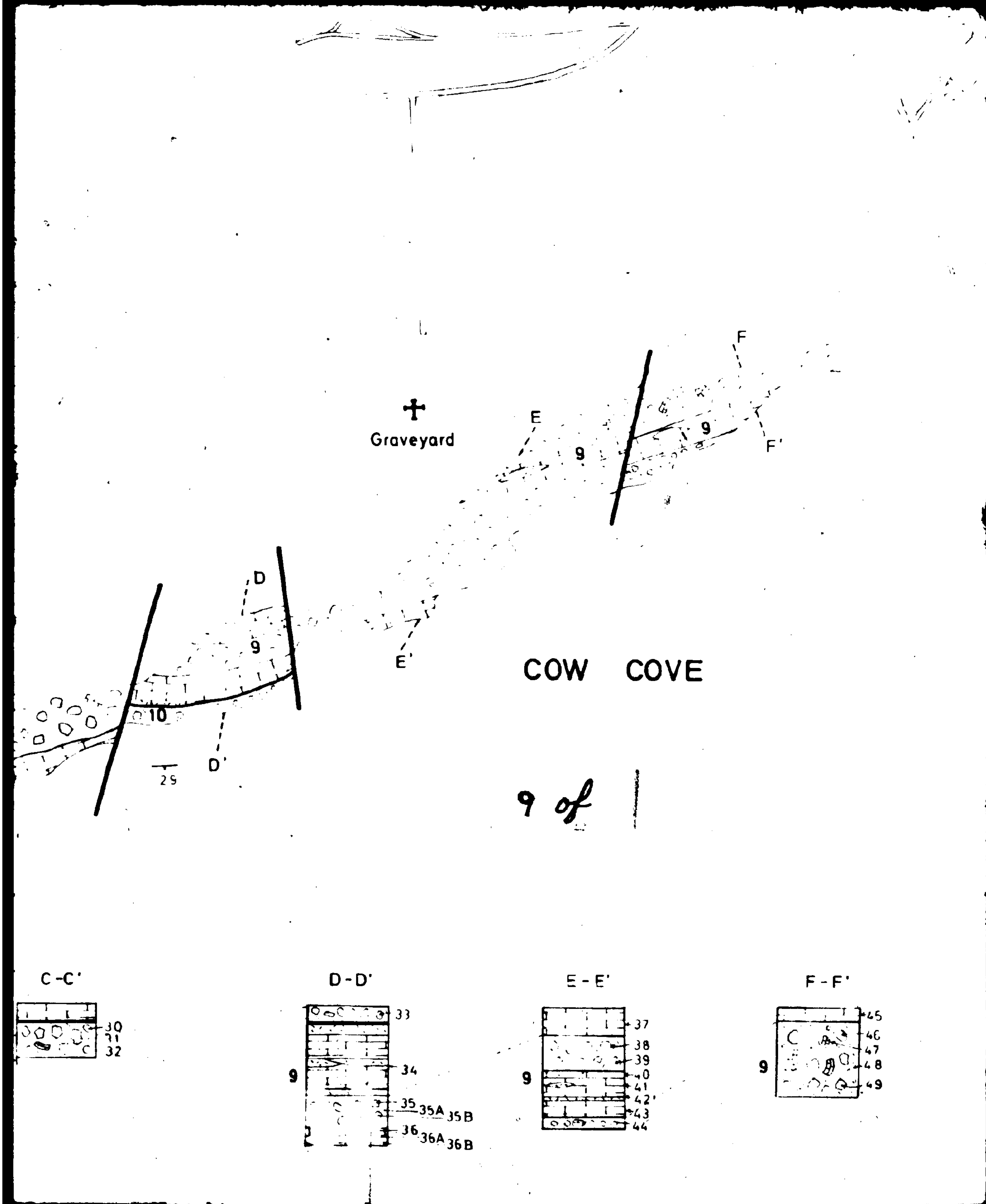


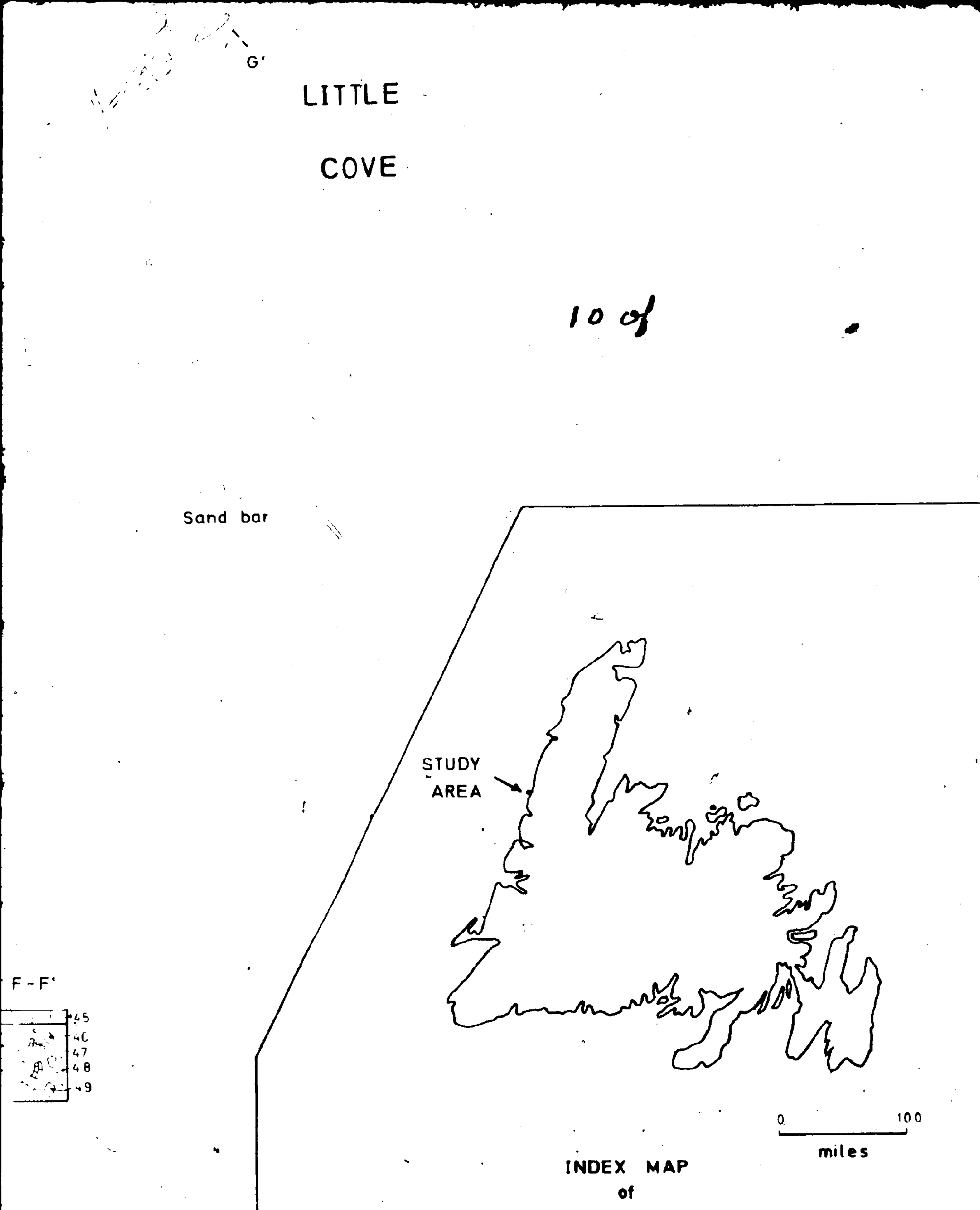
CH6-2
CH6-3
81
80
CH6-4
79
78
77
6
5
A - A'
1A
1B
2A
2B
2C
3A
3B
3C
3D
4A
4B
5A
5B
5C
6A
6B
6C
6D
6E
8A
14
13
12
11
10
9
L - L'
7
6
12A
12B
A
L
L'
POINT
of
HEAD
Crow's
55

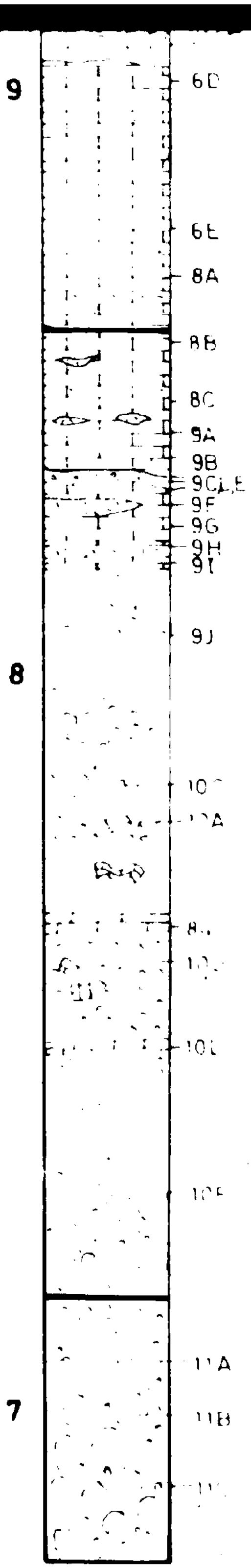

Lighthouse
Crow's nest
DEEP
COVE
Wharf
B - B'
K
K'
L'
A'
B
5
6
13
14
12
7 of

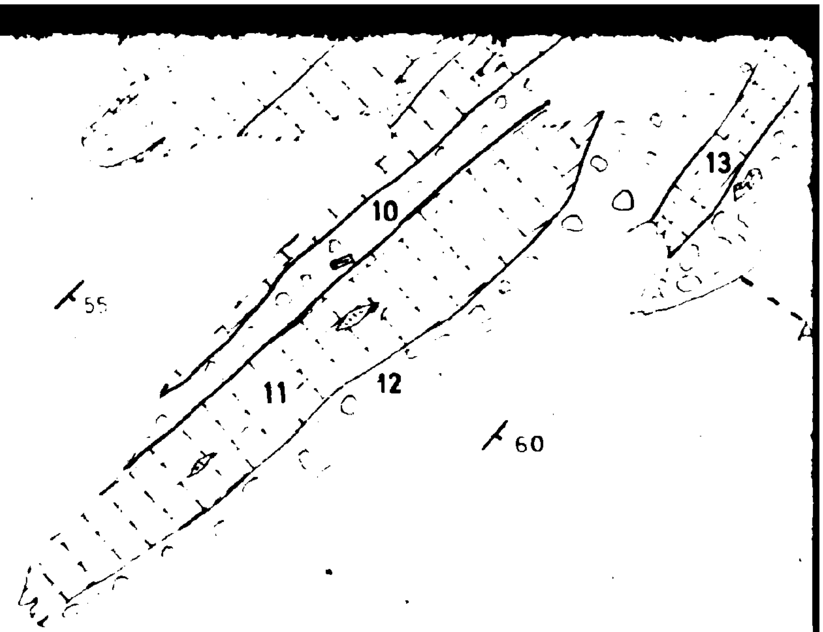
8 of 1




Graveyard
E
E'
F
F'
D
D'
9
10
25
COW COVE
9 of
C - C'
30
31
32
D - D'
33
34
35
35A
35B
36
36A
36B
E - E'
37
38
39
40
41
42
43
44
F - F'
45
46
47
48
49


G'
LITTLE
COVE
10 of
Sand bar
STUDY
AREA
F - F'
45
47
48
0
100
miles
INDEX MAP
of

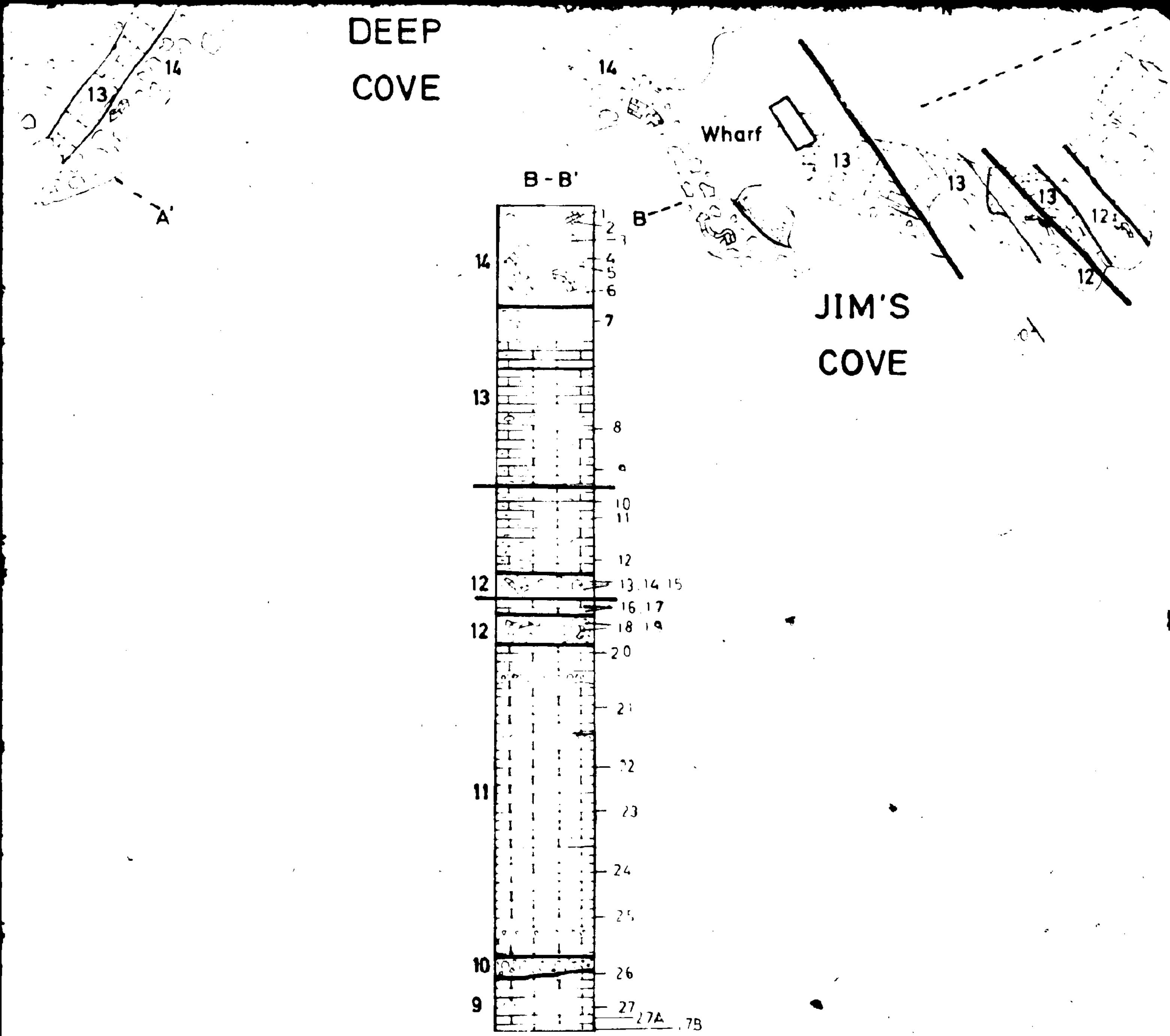




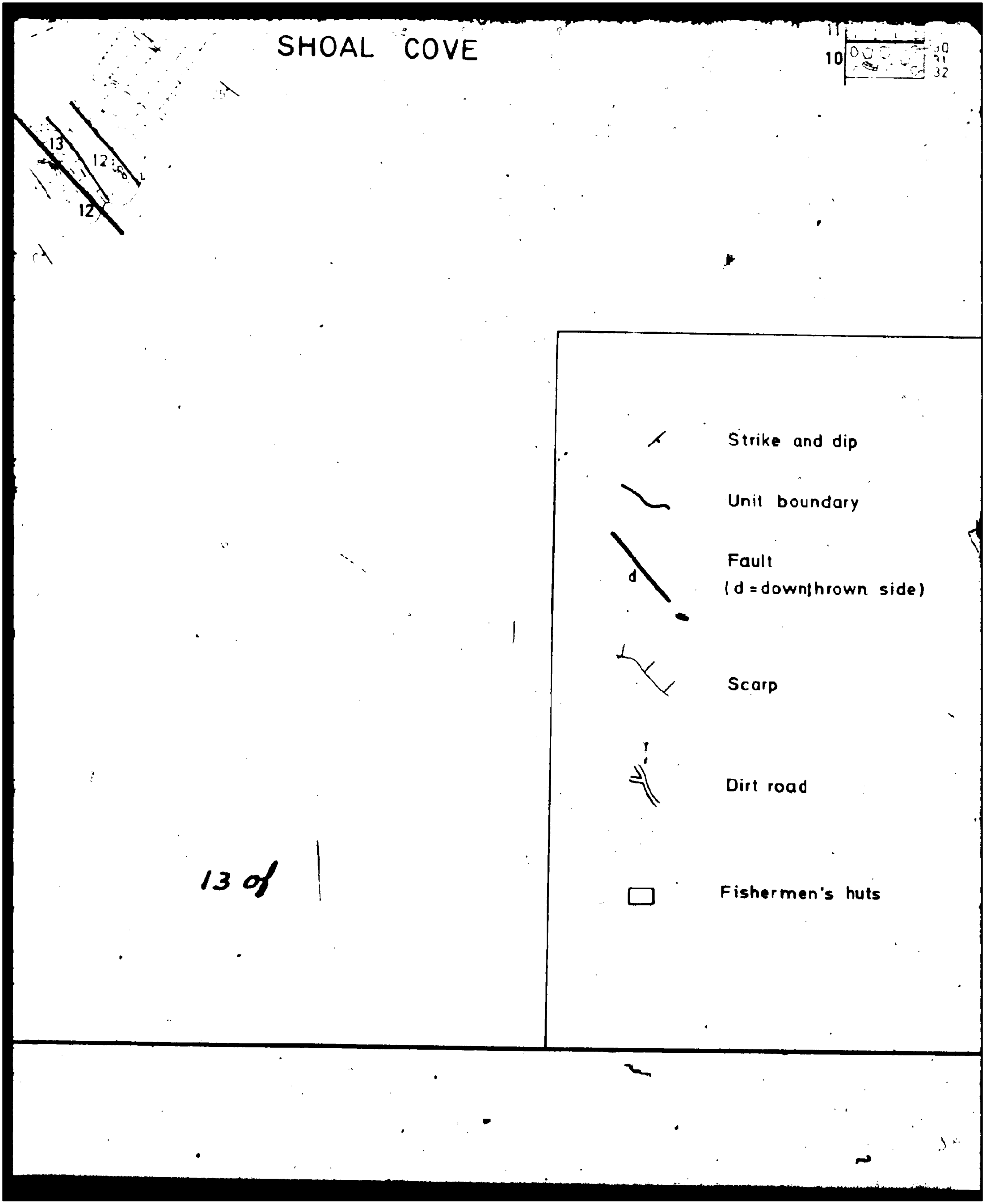
THE LEDGE

11 of

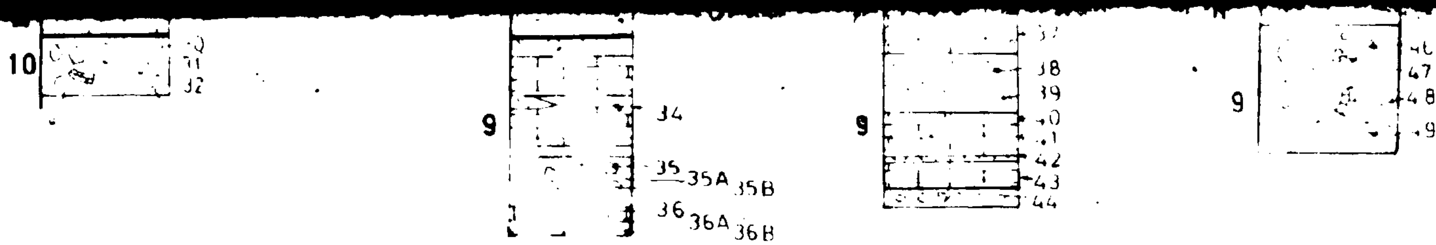
G.S.Nowlan, M.Sc. thesis, M.U.N. 1973.


DEEP
COVE
14
13
A'
14
Wharf
B
B - B'
13
13
13
12
12
JIM'S
COVE
14
13
12
12
11
10
9
1
2
3
4
5
6
7
8
9
10
11
12
13 14 15
16 17
18 19
20
21
22
23
24
25
26
27
27A
27B

12 of 1



SHOAL COVE
11
10
30
31
32
13
12
12
Strike and dip
Unit boundary
Fault
d
(d = downthrown side)
Scarp
Dirt road
Fishermen's huts
13 of



LEGEND

nd dip

undary

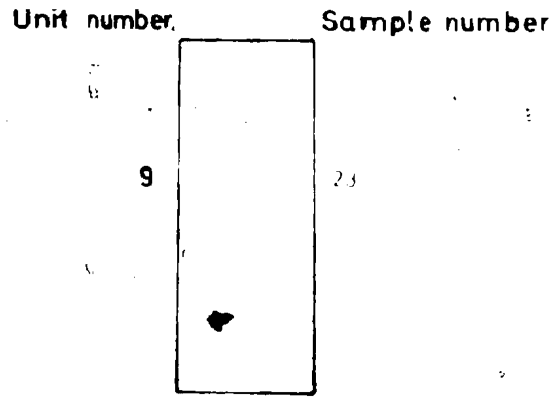
nthrown side)

d

en's huts

14 of

Columnar log



Vertical scale:

1cm. = 10m.

Line of log section

0 100

miles

INDEX MAP
of
NEWFOUNDLAND

Limestone and shale

Limestone and thick shale

Shale

Quartz sandstone

Subangular - subrounded boulders

Folded blocks of limestone

Types of boulders

Flat pebbles and boulders

Lenses of breccia