Restricted until after publication
Manuscript submitted for publication
to: NZJ GEOL. & GEOPHYS.

DEPARTMENT OF MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD 1973/158

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ABSTRACT

Limestone beds forming the top of Mount Patriarch, 1687 m, are named the Summit Limestone and are described from the section exposed on the northern ridge of the mountain. Trilobites from the basal beds and conodont faunas from the lower and upper parts of the limestone indicate that the age ranges from latest Tremadocian to early Arenigian.

The development of carbonates in the Lower Ordovician is established for the first time and contrasts markedly with the only other known New Zealand rocks of this age - the graptolite-bearing slates and quartzites at Aorangi Mine and Preservation Inlet and turbidites of the Greenland Group - and suggests a pattern of Lower Ordovician sedimentation in belts of contrasting facies.

Twenty form species of conodonts, from six samples, are described. They are grouped into two faunal assemblages, one correlated with the Drepanodus? gracilis - Scolopodus sexplicatus Zone of Australia, of basal Arenigian age, and the other with an undescribed faunal assemblage from Australia representing a later horizon in the early Arenigian.

INTRODUCTION

The thick Lower Paleozoic limestones of West Nelson have generally been grouped into two main formations by previous workers, the Tasman Formation (Haupiri Group) and the Arthur Marble Formation (Mount Arthur Group; Grindley, 1961). Prior to 1968, age-diagnostic fossils were known from Arthur Marble only in Takaka Valley, where Benson et al. (1936) and Cooper (1965) had reported late Ordovician corals, and from Tasman Formation only in Cobb Valley where Benson (1965) had reported late Middle Cambrian trilobites. An indication that other horizons were represented by limestone was given by Wright (1968) who listed conodonts of late Middle Ordovician (Llanvirnian or Llandeilian = Darriwilian) age from a small limestone lens of uncertain lithostratigraphic position in Paturau Valley. Wright further indicated that the limestone on Mount Patriarch, here named the Summit Limestone, might be considerably older than the Arthur Marble, with which it had been equated (Grindley 1961).

The present work establishes an early Lower Ordovician age for the Summit Limestone, thus confirming Wright's suspicions, and indicates a third important horizon of limestone development in the Lower Paleozoic. Limestone bodies at Mount Baldy and Mount Sodom, along the same structural belt as that of Mount Patriarch, are equated with the Summit Limestone by Coleman (in press). The upper part of underlying Patriarch Formation (Grindley 1961) is here regarded as of Tremadocian age.

The conodonts described herein are the first to be described from the Lower Paleozoic of New Zealand. In addition to the Middle Ordovician fauna mentioned above, conodonts have also been reported or listed from the late Upper Ordovician (Arthur Marble) by Wright (1968) and from the Lower Devonian (Reefton Group) by Jenkins (1967).

Mount Patriarch, 1687 m, forms part of the main divide separating the Wangapeka River-Motueka River drainage system from the Crow River - Karamea River drainage system in West Nelson. The upper 400 m of the mountain protrudes above the bush-line and provides good rock exposures.

The stratigraphic section on which this report is based has been compiled from outcrops in the ridge extending northwards from the summit of Mount Patriarch (the central of the three peaks which form the top of the mountain) to the saddle at the junction with Kiwi Track (Fig. 1). Up to about the 1524 m (5000 ft) level the beds dip from 10° to 30° to the south. Several small faults, down-thrown to the north, interrupt the sequence, and although their inferred throw was allowed for in compiling the stratigraphic column

(Fig. 2), thicknesses given are only approximate. The upper part of the limestone, that forming the summit of the mountain (Fig. 3), is separated from the lower part by a flat-lying fault which outcrops at about the level of the 1524 m (5000 ft) contour. The nature of movement on the fault is unknown, but is likely to be related to the large west-facing overturned fold formed by beds of the upper plate. Structure of Mount Patriarch is discussed by Coleman (in press) in a description of the structure, stratigraphy and regional setting of the southern Mount Arthur Range.

Conodont samples were collected from the lower part of the limestone and from the upper part of the underlying Patriarch Formation at an average stratigraphic interval of 15 m. Several grab samples were collected from the upper part of the limestone but the stratigraphic relations of the sampled horizons with those in the lower part of the limestone are unknown.

In addition to conodonts, trilobites are present at several horizons near the base of the section and phosphatic (inarticulate) brachiopods were recovered from the insoluble residues at several horizons throughout the limestone. The upper part of the measured section also contains unidentified siliceous branching tubular fossils and small ovoid silicified algal? remains.

The New Zealand Ordovician sequence traditionally has been discussed in terms of the sequence of graptolite-based stages used in Victoria, the graptolite sequences of the two areas being closely comparable (Cooper & Waterhouse, in press). Unfortunately, fossils other than graptolites are extremely rare in the graptolitic beds of both Victoria and New Zealand and the conodont correlations discussed below are in terms of the British standard sequence. The British divisions are related to those of Victoria in Table 1.

Field work and stratigraphic discussion in the present paper are by Cooper, conodont descriptions and correlations are by Druce. Fossil locality numbers refer to the New Zealand Fossil Record File; conodonts are held by New Zealand Geological Survey.

STRATIGRAPHY

Two main lithostratigraphic units are represented in the sampled section: the Patriarch Formation of Grindley (1961), the uppermost beds of which form the lower part of the section, and the Summit Limestone (new) which forms the middle and upper parts of the section.

PATRIARCH FORMATION

Definition. The name Patriarch Formation, erected by Grindley (1961), is discussed and redefined by Coleman (in press). A standard section for the formation is proposed, and extends from the base of the Summit Limestone, on the northern ridge of Mount Patriarch, along the main divide for a distance of approximately 3 kms to the top of the underlying unit, equated by Coleman with the Anatoki Formation (Grindley 1961). The basal part of the measured section of this report thus includes the upper beds of the standard section for the formation.

Description. A full description of the unit is given by Coleman. Only the upper 50 m of the Formation, included in the measured section, is described here. The beds are comprised of graphitic and calcareous shale and phyllite with irregular bands and lenses of dark limestone ranging from 3 cm to 30 cm in thickness. Petrographically, the limestone is composed of dark grey micrite with rare bands of finely granular carbonate, and scattered secondary calcite crystals. Fine parallel discontinuous streaks of clay material represent cleavage.

Cleavage in the phyllite, and shearing, brecciation and quartz-veining in all rock types are prominent at some horizons in the lower part. One band of limestone has been offset by small (intra-formational) normal faults.

Fossils and age. Indeterminate trilobite fragments and inarticulate brachiopods were collected at several horizons but no age-diagnostic fossils were found. From further north along the main divide the trilobite *Dionide hectori* was described by Reed (1927). Generic assignment was later changed to *Taihungshania* by Kobayashi (1940) and most recently Wright (1968) suggested that the form more closely resembles *Pseudohysterolenus*, a Tremadocian genus described from Argentina (Harrington & Leanza, 1957). Ceratopygids, asaphids, and pliomerids, suggesting a Tremadocian age, have since been found by the writer. A Tremadocian age would be consistent with that indicated here for the overlying limestone and is adopted.

SUMMIT LIMESTONE

Definition and nomenclature. The thick limestone succession forming the upper few hundred metres of Mount Patriarch was mapped as Arthur Marble (Mount Arthur Marble) by Grindley (1961); in view of the much older age now established for it, the limestone is here regarded as a distinct lithostratigraphic unit. Unfortunately, the only suitable geographic name available, Mount Patriarch, is preoccupied and we prefer to avoid the risk of ambiguity by adopting the name of another locality, such as Mount Baldy, Mount Sodom, or Mount Mytton where equivalent rocks are thought to occur. The name Summit Limestone is therefore proposed. Type section is exposed in the ridge leading northwards from the summit towards the saddle at the junction with Kiwi Track. Base of the unit is taken at the incoming of calcareous sandstone with lensoidal bedding and limestone bands, about 100 m south of the junction with Kiwi Track. Top of the formation is not represented at Mount Patriarch and overlying beds are unknown.

Description. The limestone is generally thinly bedded, and contains bands and lenses of calcareous sandstone, shale and phyllite, giving it the overall composition of an impure limestone. Partial dolomitization, rarely exceeding about 20% of the rock, is particularly prominent in the upper beds, but affects beds throughout the unit; the Fe-rich variety (ankerite) is usually represented. Bedding is generally wavy or lensoidal in detail, rather than laminar, and gives way to a reticulate structure with the effects of shearing. The end product, particularly marked in the lower beds, is a reticulate network of limestone nodules separated by sheared siltstone. The limestone is most conveniently discussed in three units: a lower unit (Unit 1), the lower 145 m, a middle unit (Unit 2), approximately the next 250 m, and an upper unit (Unit 3) of approximately 200 m. The boundary between the lower two units which together comprise a relatively undisturbed stratigraphic sequence, is gradational, whereas that between the upper two is a bedding-plane fault.

Unit 1. The lower 145 m is composed of dark, flaggy limestone, calcilutite and calcarenite. Basal beds are calcareous, medium to fine sandstone with small, closely spaced, richly calcareous lenses and patches, 5 to 20 mm thick, which give the rock a mottled appearance. Thin micaceous sandstone and siltstone laminae are rare. The beds become more calcareous upwards and the lensoidal bedding structure gives way to a reticulate structure with the effects of shearing. Overlying beds are laminated limestone and calcilutite, nodular limestone, and calcareous shale with limestone lenses and bands several centimetres thick. The upper beds are sandy, and pure, dark flaggy limestone, and calcareous siltstone with lenses and bands of limestone (Fig. 4). Petrographically, the limestone bands and nodules are composed mainly of micritic ground mass with scattered fossil fragments and well rounded grains up to 0.7 mm in diameter, some of which probably represent recrystallized oolites. The rock is a fossiliferous micrite in the terminology of Folk (1968).

Dolomite rhombs, grown in the micritic matrix, form up to about 10% of the rock. A 0.5 m thick band of black shale in the middle part of the unit contains abundant phosphatic brachiopods and less common trilobite fragments.

Bedding Structure in Unit 1

In the laminated limestone and calcilutite beds, individual limestone laminae, 1 to 5 cm thick, are seldom more than 20 or 30 cm in length and many comprise layers of discrete lenses or nodules, each only a few centimetres long. The intercolated calcilutite laminae are generally more continuous. In extreme, but not uncommon, examples there are no continuous laminae and the rock is a nodular limestone. Surfaces parallel to bedding show that the nodules have a broadly disc-shaped outline. Weathered surfaces normal to bedding have a distinctive honeycombed texture.

Fossils in some of the nodules, in contrast to fossils from the enclosing calcilutite, are undistorted, which suggests that the nodules represent zones in the original sediment that were lithified, or cemented prior to compaction of the overall sequence, in a manner similar to that described by Grundel and Rosler (1963) for nodular limestones and shales (Knollenkalk, Kalkknollenschiefer) in the Upper Devonian of Thuringia.

The nodular or lensoidal structure of much of Unit 1 has undoubtedly been accentuated, or possibly, in some rocks, produced, by deformation of the overall sequence. Limestone laminae, in some outcrops, are intruded by tongues and veinlets of clastic material derived from the immediately overlying calcilutite or calcarenite lamina, and are sometimes disrupted and rotated as blocks within a calciclastic matrix (Fig. 5), suggesting that deformation took place after cementation of the limestone but before lithification of the calcilutite. The deformation can clearly be seen in some laminated limestone-calcilutite sequences, the laminae of which are deflected or offset along discrete but parallel bands or zones of "shearing" spaced about 3 to 10 cm apart (Figs 6, 7), resembling fracture cleavage, and giving the rock an apparently tectonic fabric. Individual limestone laminae and lenses are disrupted, generally being offset in a normal rather than reverse sense, whereas the more argillaceous laminae are deflected rather than disrupted. As the effect becomes more pronounced, the rock develops the texture of a "flaser limestone" with "boudinage" structure.

Unit 2. The unit, about 250 m thick, differs from the underlying unit in having fewer intercolated beds of sandstone and siltstone, the limestone being more massive, paler, and of purer overall composition. Limestone beds also contain medium to coarse sand impurity. Beds are generally 5 to 20 cm thick, bedding commonly being wavy or lensoidal as in Unit 1. Contact with Unit 1 is gradational, the boundary between the two being placed at the change from a dark to pale shade, in upward sequence.

The limestone, in thin section, ranges in composition from dominantly intraclasts in a matrix of sparry cement (intrasparite) to fossil fragments and indeterminate carbonate grains in micrite (biomicrite). The intraclasts range up to about 0.8 mm long and 0.3 mm thick and are composed mainly of micrite. Some intraclasts have calcite encrustations which probably represent algal secretions. Dolomite rhombs comprise up to about 5% of the rock.

Siliceous branching tube fossils and small spherical algal? fossils are common in the upper part.

Unit 3. In the uppermost 200 m of Mount Patriarch the limestone forms a huge overturned syncline whose axis strikes north-south and lies near the summit ridge, and whose axial plane dips to the east at a low angle. The Unit is separated from the underlying Unit 2 by a flat-lying fault, interpreted as a thrust fault by Coleman (in press). Unit 3 may thus be allochthonous and may also include beds of Units 1 and 2.

The unit is composed of pale, sandy to gritty, well bedded limestone, resembling that of the upper part of Unit 2, with beds of alternating limestone and calcareous sandstone, resembling those of the upper part of Unit 1.

The sandy limestone, in thin section, is mainly composed of carbonate grains including oolites up to 0.4 mm diameter, algal? encrusted elongate fragments, skeletal material including fragments of shell and fine tubes. Well-rounded quartz sand grains are common in bands. The matrix is mainly micritic with some sparry calcite cement. Dolomite forms up to about 15% of the rock.

Siliceous fossils, similar to those in the underlying unit are common in bands in the central (summit) and northern peaks.

Irregular bodies, a few metres across, of dark to medium grey-green hornblende porphyry are enclosed within the limestone at several localities; they are generally associated with chaotic bedding, faulting, and, in the southern-most peak, a cross-cutting band of breccia. Contact alteration of the limestone is not apparent and most bodies appear to have been tectonically emplaced. However, one inaccessible thin igneous band exposed in the south-western face of the southern peak was concordant with bedding over a distance of about 100 m and probably represents a sill, or interbedded volcanic band.

The breccia is composed mainly of angular fragments of limestone, up to one metre across, in a matrix of volcanic and siliceous grit. Small fragments of dark shale, grey laminated argillite and chert are also present.

Relation to Underlying Beds. The contact between the Summit Limestone and the underlying Patriarch Formation is most readily examined on the main ridge, immediately south of the junction with Kiwi Track. The transition from calcareous shale and phyllite of the Patriarch Formation into the basal calcareous sandstone and siltstone of the Summit Limestone takes place over an unexposed interval of about 4 metres. However, the overall change in lithology, passing from the upper part of the Patriarch Formation to the lower part of the Summit Limestone, is a gradual, rather than sudden, one. Although bands of shearing and brecciation are present in both formations, there is no significant change in attitude of bedding across the boundary and the two are thought to be essentially conformable.

Fossils and Age. Fossils have been found at several horizons. In Unit 1 phosphatic brachiopods were recovered from the insoluble residues of several samples but few are well preserved. Trilobite fragments are present in several of the shale bands near the base of the unit; Ceratopygidae (including *Onychopyge*), Olenidae, Richardsonellinae (cf. *Kainella*) and Asaphidae are represented and suggest a late Tremadocian age. Poorly preserved silicified trilobites have also been recovered from limestone at two horizons. Conodonts were recovered from 5 of the 15 samples collected; two samples (S19/641, 671), from a loose block derived from the lower part of the Unit, contained moderately rich faunas. A single faunal assemblage is represented, equivalent to that of the lower part of the *Drepanodus? gracilis* - *Scolopodus sexplicatus* assemblage zone of Western and Central Australia (Jones, 1971), of basal Arenigian age.

From Unit 2 no age diagnostic fossils have been collected.

Unit 3 was sampled at six horizons for conodonts; one moderately rich fauna was obtained (S19/664). The fauna represents a horizon in the lower Arenigian later than the *Drepanodus? gracilis - Scolopodus sexplicatus* Zone.

Age of the Summit limestone is thus taken as extending from latest Tremadocian to at least lower Arenigian.

Correlation. The limestone forming the caps of Mount Baldy (approximately 1463 m) and Mount Sodom (approximately 1555 m), 6 and 9 km to the north-east of Mount Patriarch respectively, and previously mapped as Arthur Limestone (Grindley, 1961), is equated with the Summit Limestone by Coleman (in press). Limestone forming Mount Mytton in Cobb Valley is also likely to represent the Summit Limestone.

The only other rocks in New Zealand known to be of similar age are the Aorangi Mine formation at Aorangi Mine, its equivalent in Fiordland - the Preservation Formation, and the Greenland Group at Reefton (Cooper in press a; Table 1). Direct correlation is not possible because of the lack of common fossil groups, but by correlation of both the trilobite-conodont faunas and the graptolitic faunas with the mixed shelly-graptolitic sequences of Britain, Scandinavia, and North America it is probable that the Summit Limestone is of equivalent age to the lower part of the Aorangi Mine Formation, that is of Lancefieldian (La 2) to Bendigonian (about Be 2) age. The underlying Patriarch Formation, on this correlation, would be, at least in part, of equivalent age to the Webb Formation (Bishop 1968), and the Greenland Group at Reefton (Table 1).

ORDOVICIAN FACIES BELTS

The Aorangi Mine Formation forms part of a continuous, noncalcareous, graptolite-bearing sequence in the Western Sedimentary Belt extending from basal Ordovician (Webb and Sandhills Creek Formations) to Upper Ordovician (Golden Bay Group). The lower part of the Aorangi Mine Formation (La 2-Be 2) is comprised of a condensed sequence of graphitic, pyritic slate and chert and contrasts markedly in lithofacies, biofacies, and depositional environment with the Summit Limestone in the Central Sedimentary (Haupiri) Belt. The Central Belt facies suggests a relatively shallow, off-shore, carbonate rise, whereas the Western Belt facies, at Aorangi Mine, suggests a quiet-water reducing environment such as in a starved basin. Similarly, the calcareous siltstone and sandstone with shelly fossils, of the Patriarch Formation, contrast with the barren, thick, uniform quartz-rich sandstone-siltstone sequence of the Webb Formation, and the thick monotonous turbidite sequence of the Greenland Group (Laird and Shelley in press).

The pattern of sedimentation represented by the sediments of the west Nelson region during early Ordovician time was thus likely to be one of elongate belts of contrasting facies, rather than one of uniform deposition of widespread formations; a shallow, carbonate facies in the region of the Central Sedimentary Belt and a deeper water graptolite-turbidite facies in the region of the Western Sedimentary Belt.

Interpretation of the spacial relations between the facies belts depends on interpretation of regional structure. According to the allochthonous Central Belt hypothesis of Grindley (1961, 1971, in press) the Central (Haupiri) Belt, within which lie the Patriarch Formation and Summit Limestone (Cooper in press b) is composed of a series of exotic thrust slices, or nappes, Eastern Sedimentary Belt. The Lower Ordovician shallow water carbonate belt would thus have lain considerably to the south and east of its present position. On the other hand, the in situ Central Belt hypothesis (Cooper in press b) proposes that the Central Belt, and Lower Ordovician carbonates, are basically in situ with respect to the Eastern and Western Sedimentary Belts.

In our opinion, interpretation of regional structure is the major problems to be solved in unravelling the early Paleozoic geological history of West Nelson, and requires further work for resolution, in particular detailed analysis of intra- and inter-Belt structure (e.g. Coleman in press) and study of facies distributions and sedimentary basin analysis.

THE CONODONT FAUNA

A total of 78 specimens identifiable at specific level were recovered from 6 samples: S19/f641, f662, f664, f665, f671, f693; the fauna from S19/f664 is the most abundant (42 specimens). All the conodonts are black, and many are warped, cracked, and recrystallized; most specimens are covered with extremely fine quartz grains. Because of the poor preservation the nature of the basal cavity is indeterminable in all specimens and identifications are tentative; 20 form-species are recognized (Table 2).

The faunas represent two distinct faunal assemblages, indicating two horizons; earliest Arenigian (samples from S19/f641, f671), and a slightly younger

Arenigian horizon (samples from S19/f664 and possibly S19/f665). A list of species is given in Table 2; except for ?Oepikodus sp A, Oistodus cf O. forceps, and Scolopodus gracilis, all are figured (Figs 8, 9).

Faunal comparison (Table 3)

The older assemblage is closely comparable with latest Tremadocian and earliest Arenigian faunas from Central and Western Australia (Druce & Jones 1971; Jones 1971). Of the ten form-species present in the New Zealand fauna, seven forms, or closely comparable forms, are present, in Australia: Chosonodina herfurthi Müller, Cordylodus angulatus Pander, Drepanodus suberectus (Branson & Mehl), Oistodus cf. O. lanceolatus Pander, Scolopodus cf. S. filosus Ethington & Clark, Scolopodus cf. S. quadraplicatus Branson & Mehl, and Scolopodus sexplicatus Jones.

Younger Australian faunas have not yet been described. However, of the ten species present in the New Zealand younger assemblage, at least nine occur in the Georgina Basin in formations overlying the Tremadocian Ninaroo Formation, at present under study by Druce.

Conodont faunas described from the Columbia Ice Fields section of Alberta (Ethington & Clark 1964), the El Paso Formation (unit B1) of Texas (Ethington & Clark 1965), and the Arbuckle Group of Oklahoma (Mound 1968) are closely comparable with the New Zealand faunas. Both the older and younger New Zealand faunas are represented in all three sections. Faunas from Newfoundland (Barnes & Tuke 1970; Fahraeus 1970) also contain many common species and both New Zealand faunas are represented.

European faunas, especially from the Baltic region, show strong affinities, especially the oistodids; however the scolopodids are poorly represented in Baltic faunas.

Faunas from Siberia (Moskalenko 1967; Abaimova 1972) and the Far East (Malaya, Igo & Koike 1967; Korea, Muller 1964) show the least affinity. This is probably due to several factors; the Korean fauna, with only Chosonodina herfurthi Müller in common with New Zealand, and the Malayan faunas are from relatively small samples. The Siberian faunas still lack monographic treatment and, except for several forms illustrated by Moskalenko (1967), comparison is mainly by means of faunal lists. There appear to be differences among workers in nomenclatorial procedure, especially within the scolopodid group. Further work will probably show that differences between Australasian and Siberian faunas are more apparent than real.

Summarising, the New Zealand faunas show strongest affinity with faunas of Australia; other affinities are with, in decreasing degree, Western North America, especially in the scolopodid group, and the Baltic, mainly within the oistodid group.

Age (Table 4)

The older assemblage (S19/f641, f671) can be correlated with the lower part of the Drepanodus? gracilis - Scolopodus sexplicatus Assemblage Zone of Australia (Jones 1971); this zone is earliest Arenigian.

Of the ten species present in the older assemblage, seven are known from the Chosonodina herfurthi - Loxodus bransoni Assemblage Zone of the Arbuckle Mountains, Oklahoma (Mound 1968). Jones (1971, Fig. 13) and Jones et al. (1971, chart 2) correlate this zone with the Australian Chosonodina herfurthi - Acodus Assemblage Zone, which underlies the Drepanodus? gracilis - Scolopodus sexplicatus Assemblage Zone.

The presence of Chosonodina herfurthi Müller and Scolopodus sexplicatus Jones in the same New Zealand sample suggests that C. herfurthi Müller may range into the base of the Drepanodus? gracilis - Scolopodus sexplicatus Assemblage Zone. The older New Zealand assemblage would thus be of very earliest Arenigian age and the Chosonodina herfurthi - Loxodus bransoni Assemblage Zone would straddle the Tremadocian-Arenigian boundary.

Two species from New Zealand, Acodus deltatus Lindström and Cordylodus angulatus Pander, are common in the Baltic region; A. deltatus is early Arenigian, C. angulatus ranges from late Tremadocian to early Arenigian. The older New Zealand assemblage is thus probably early Arenigian (early Latorpian, Hunnebergian) in terms of the Baltic sequence. The two species also suggest correlation with Fauna C (Ethington & Clark 1971) from North America.

The presence of Acodus deltatus Lindström in the younger New Zealand assemblage (S19/f664) indicates an early Arenigian age. The assemblage probably correlates with part of Bed 15 of the El Paso Formation and Samples 41 - 50 of the Columbia Ice Fields Section (Ethington & Clark 1964, 1965). The scolopodids compare closely with the scolopodid faunas from the Scolopodus quadraplicatus quadraplicatus

Assemblage Zone of Oklahoma (Mound 1968), suggesting that the Zone is slightly younger than postulated by Jones et al. (1971) and Jones (1971). The assemblage correlates with either Fauna D or E of North America (Ethington & Clark 1971); the absence of gothodids and oepikodids suggests Fauna D rather than Fauna E.

SYSTEMATIC DESCRIPTIONS

Genus Acodus Pander, 1856

TYPE SPECIES: Acodus erectus Pander, 1856

Acodus deltatus Lindstrom

Fig. 8 nos. 1-3

1955 Acodus deltatus Lindström, Geologiska Föreningen Stockholm Förhandlingar (1954) 76: 544, pl. 3, fig. 30.

1955 Acodus deltatus n.sp. var. altior nov. Lindström, ibid., pl. 3, figs. 27-29.

?1958 Acodus sp. Sando, Geological Society of America Bulletin 69, pl. 2, fig. 4.

1965 Acodus deltatus Lindström, Ethington & Clark, Brigham Young University Studies 12: 187, pl. 1, fig. 3.

?1969 Acodus combsi Bradshaw, Journal of Paleontology 43, pl. 132, figs 11, 12.

MATERIAL, HORIZON: Twelve specimens, from S19/f664 (one of which is figured), S19/f671 (two of which are figured) and S19/f641.

DESCRIPTION: The cusp is proclined to erect and subcircular in cross-section with anterior and posterior knife-edges. The base is triangular and the oral margin and antero-basal angle are knife-edged. A strong costa is present on the base, extending on to the cusp and to the aboral margin.

Because of the poor preservation the nature of the basal cavity is not known.

REMARKS: Lindström (1971 pp. 42, 54) considers that A. deltatus is the prioniodiform element of both the multi-element Gothodus costulatus Lindström and multi-element

Drepanoistodus forceps (Lindström). Of the other elements postulated for G. costulatus only Oistodus linguatus Lindström is present. In the case of Drepanoistodus forceps the oistodiform element is missing but one of the drepanodiform elements (D. suberectus) is present. This may be due to several causes: lack of preservation; a statistically too small sample; or perhaps the presence of an ancestral form of these elements in which the gothodid and oepikodid elements had not developed extra processes and denticulation. Some specimens are close to Oistodus triangularis of Lindström but the concave posterior margin of the cusp distinguishes them.

OCCURRENCE: Apart from the type locality in south-central Sweden the species has also been reported from the southern Baltic (Viira 1968; Viira et al., 1970). Ethington & Clark (1965) have reported it from Alberta, Canada and forms illustrated by Sando (1958) and Bradshaw (1969) are close to A. deltatus. Abaimova (1972) has illustrated specimens from Siberia.

AGE: The type species comes from low in the Lower Planilimbata Limestone which comprises the Hunneberg substage of the Latorpian. Viira (1968) gives the range as Arenigian B_1a - B_1b and in a later paper with Kivimagi & Loog (1970) restricts this to Arenigian B a - lower B b. In Siberia it is present in the Tschun stage (Lower Ordovician; Moskalenko 1967; Abaimova 1972) and in Canada it is present in rocks considered to be of early Ordovician age (Ethington & Clark 1965).

Genus Chosonodina Müller, 1964

TYPE SPECIES: Chosonodina herfurthi Müller, 1964

Chosonodina herfurthi Müller, 1964

Fig. 8 no. 4

1964 Chosonodina herfurthi Müller, Neues Jahrbuch fur Geologie und Paläontology, Abhandlungen 119: 99, pl. 13, figs 3a-c.

1968 Chosonodina herfuthi Müller (sic); Mound, Micropaleontology 14: 408, pl. 2, figs 1-3.

1971 Chosonodina herfurthi Müller; Druce & Jones, Bureau Mineral Resources Australia Bulletin 110: 59, pl. 4, figs 1a-6c, 9a, b; text fig. 21b, c.

?1971 ?*Chosonodina herfurthi* Müller; Jones, *ibid.* *117*: 44, pl. 7, figs 2a-c.

1971 *Chosonodina herfurthi* Müller, Clark & Ethington, *Geological Society of America Memoir 127*: 72, pl. 1, fig. 10.

MATERIAL, HORIZON: Six specimens, from S19/f671 (one specimen figured), and S19/f641.

DESCRIPTION: A palmate unit with four cusps. The two lateral cusps are broken. Each cusp has a rounded costa on its concave face and pointed oral terminations. A groove is present along the curved aboral margin and extends up along the lateral faces of the unit.

REMARKS: The genus *Chosonodina* is represented in the literature by four species. Druce & Jones (1971) erected a new species *C. fisheri* with fewer and rounded denticles, which they consider to be ancestral to *C. herfurthi*. Harris & Harris (1965) questionably refer a new species, *lunata*, to the genus; Uyeno & Barnes (1970) have left in open nomenclature a species of *Chosonodina* characterized by a massive main denticle with two minor lateral denticles.

C. fisheri and *C. herfurthi* are both late Tremadocian in age; *C.*? *lunata* is Arenigian, and *C.* n.sp. 1 is late Arenigian or early Llanvirnian.

OCCURRENCE: *C. herfurthi* was initially described from the Lower Ordovician of the Kangwon Province, South Korea. Subsequently it has been reported from the Ninmaroo Formation of western Queensland (Druce & Jones 1971) and the Jinduckin Formation of the Northern Territory (Jones 1971). The only other known occurrences are in the McKenzie Hill Formation of Oklahoma (Mound 1968) and the Manitou Formation, Colorado (Ethington & Clark 1971), in the USA.

AGE: Druce & Jones (1971) give the range as being confined to the Tremadocian *Chosonodina herfurthi* - *Acodus* Assemblage Zone of Western Queensland. Jones (1971) found a solitary broken specimen in a fauna considered by him to belong to this zone in the Daly River Basin of the Northern Territory. Mound's specimens came from his *Chosonodina herfurthi* - *Loxodus bransoni* Assemblage Zone of Lower Ordovician age. The present specimens extend the range into the base of the Arenigian.

Genus Cordylodus Pander, 1856

TYPE SPECIES: Cordylodus angulatus Pander, 1856

Cordylodus angulatus Pander, 1856

Fig. 8, nos 5, 7

1856 Cordylodus angulatus Pander, Monog. foss. Fische sil. Syst. russ. balt. Gouvts 33, pl. 2, figs 28-31, 34; pl. 3, fig. 10.

1971 Cordylodus angulatus Pander; Druce & Jones, Bureau Mineral Resources Australia Bulletin 110: 66, pl. 3, figs 4a-7b, text-figs 23a, b (complete synonymy to 1971).

1971 Cordylodus angulatus Pander; Jones, ibid 117: 45, pl. 8, figs 3a-c.

1971 Cordylodus angulatus Pander; Ethington and Clark, Geological Society of America Bulletin 127: 68, pl. 1, figs 15, 16, 20.

MATERIAL, HORIZON: Three specimens from S19/f671 (2 specimens figured) and S19/f641.

REMARKS: The present specimens are black and are coated with quartz grains; the cavity is not visible. They lack the anterior opening cavity of C. rotundatus Pander and so we have assigned them to C. angulatus.

OCCURRENCE: The species was first described from the Baltic region (Pander 1856); subsequently it has been reported from the same region by Lindström (1954, 1960, 1964), Viira (1968, 1970) and Viira et al. (1970). In North America the specimen referred to Belodus sp. A by Sando may belong to C. angulatus and Ethington & Clark (1965) record it from Alberta, and (1971) from Utah. In Australia it has been illustrated by Druce & Jones (1971) from Queensland and by Jones (1971) from the Northern Territory.

AGE: Viira (1970) gives the range as Tremadocian A_2 up to the Arenigian B_1 with questionable extension into the Arenigian B_1 zone (Viira et al. 1970). In Australia Druce & Jones (1971) give the range as late Tremadocian (Cordylodus rotundatus - C. angulatus Assemblage Zone to Chosonodina herfurthi - Acodus Assemblage Zone). Jones (1971) extends the range into the base of his Drepanodus? gracilis - Scolopodus sexplicatus Assemblage Zone of earliest Arenigian age.

Genus Drepanodus Pander, 1856

TYPE SPECIES: Drepanodus arcuatus Pander, 1856.

Drepanodus suberectus Branson & Mehl, 1933

Fig. 8, no. 11

1933 Oistodus suberectus Branson & Mehl, University of Missouri Studies 8: 111, pl. 9, fig. 7.

1971 Drepanodus suberectus (Branson & Mehl); Jones, Bureau Mineral Resources Australia Bulletin 117: 53, pl. 8, figs 6a-7c (synonymy complete to 1971).

MATERIAL, HORIZON: Eight specimens, from S19/f664 (one specimen figured), S19/f641, and S19/f671.

REMARKS: Jones (1971, p. 54) reviewed D. suberectus noting the nomenclature problems with D. incurvus (Pander) and the fact that the form-species had been included in a multi-element species together with the form species D. homoarcuatus Lindström and Oistodus inclinatus Branson & Mehl. The present faunas lack these form-species but D. suberectus is rare and their absence could be a result of insufficient sampling.

OCCURRENCE AND AGE: Jones (1971, p. 54) points out that D. suberectus is a relatively long-ranging cosmopolitan species.

Drepanodus cf. D. toomeyi Ethington & Clark, 1964

Fig. 8 nos 6, 8, 9

cf. 1964 Drepanodus toomeyi Ethington & Clark, Journal of Paleontology 38: 690, pl. 113, fig. 17; pl. 114, fig. 22; text-fig. 2, H.

MATERIAL, HORIZON: Thirteen specimens, from S19/f671 (2 specimens figured), S19/f644 (one specimen figured) and S19/f641.

REMARKS: The present forms are poorly preserved but are close to D. toomeyi Ethington & Clark. They differ in being slightly more reclined rather than proclined and in the nature of the aboral margin. One specimen (Pl 1, fig. 6) has an aboral outline similar to D. toomeyi but in the others both the oral-aboral angle and the antero-basal angle are elongated. The anterobasal process can become elongate and reclined, giving a sigmoidal outline to the anterior edge.

OCCURRENCE, RANGE: D. toomeyi s.s. was first described from the El Paso Formation Bed 15 (Ethington & Clark, 1964) which Jones (1971, p. 41, fig. 13) considers to be Arenigian, possibly slightly younger than the Drepanodus ?gracilis - Scolopodus sexplicatus Assemblage Zone of Australia. The only other record is from the St George Formation, Newfoundland which is considered by Barnes & Tuke (1970, p. 82-83) to be lower Arenigian and equivalent to the Jefferson City of Missouri and Zone G of the Utah Lower Ordovician reference section. It has also been recorded from the Nora Formation of western Queensland (Hill, Playford & Woods, 1969).

Genus Oistodus Pander, 1856

TYPE SPECIES: Oistodus lanceolatus Pander, 1856

Oistodus angulatus Bradshaw, 1969

Fig. 8, nos 12, 13

1965 ?Oistodus sp A Ethington & Clark, Brigham Young University Geological Studies 12: 196, pl. 2, fig. 18.

1969 Oistodus angulatus Bradshaw, Journal of Paleontology 43: 1156, pl. 134, figs 8, 9.

MATERIAL, HORIZON: Three specimens, S19/f664.

DESCRIPTION: An oistodid with a sharply reclined cusp and extremely short oral margin. The cusp is strongly laterally compressed with anterior and posterior knife edges and some thickening in the medial part of the lateral faces. The base is low and short; the anterobasal angle is acute to rounded; the posterior process is extremely short. The aboral margin is flared on the inner side and a depression occurs in the central part of the flare in some specimens.

The cavity appears to be shallow extending over the whole of the aboral margin.

REMARKS: The present forms agree closely with the illustrations and description given by Bradshaw although it is impossible to determine the nature of the basal cavity because of the preservation.

OCCURRENCE: The type species is from the Fort Peña Formation of the Marathon Basin, Texas (Bradshaw 1969). It is also present in the Columbia Ice Fields section of Alberta, Canada (Ethington & Clark 1965).

AGE: The Canadian specimen came from Sample 48A of the Columbia Ice Fields section which is Arenigian and probably equivalent to B_1b or B_1c (Jones 1971). Only two specimens were recorded in the Fort Peña Formation, one in the lower and one in the middle part of the unit. Bradshaw considered the Fort Pena to be of Middle Ordovician age but it would appear that the lower part at least is Arenigian.

Oistodus sp. aff. O. forceps Lindstrom, 1955 (sensu Ethington & Clark 1964)

Fig. 8, no. 10

1934 ?Oistodus vulgaris Branson & Mehl, University of Missouri Studies 8: 60, pl. 4, fig. 5.

1964 Oistodus sp. aff. O. forceps Lindström; Ethington & Clark, Journal of Paleontology 38: 694, pl. 113, fig. 19; ?pl. 114, fig. 9.

MATERIAL, HORIZON: One specimen, S19/f644.

DESCRIPTION: An oistodid with an erect cusp and a short base. The cusp is laterally compressed with well developed knife edges and a tumid medial portion. The anterior edge is gently convex, meeting the basal margin at an angle of about 45°. The posterior edge is sigmoidal; it meets the convex oral margin at an acute angle. There is slight flaring of the cavity lip on the inner side.

REMARKS: This specimen agrees closely with the specimen illustrated by Ethington & Clark (1964, pl. 113, fig. 19). It differs from O. forceps Lindström in having a more erect cusp, and lacking the marked extension of the postero-aboral edge.

OCCURRENCE, RANGE: The specimen illustrated by Ethington & Clark (1965) is from Bed 15 of the El Paso Formation considered by Jones (1971) to be Arenigian.

Oistodus cf. O. lanceolatus Pander, 1856

Fig. 9, no. 1

1856 Oistodus lanceolatus Pander, Mon. foss. Fische Sil. Sys. russ-balt. Gouvts., 27, pl. 2, fig. 37.

cf. 1955 Oistodus lanceolatus Pander; Lindström, Geologiska Föreningen Stockholm Förhandlingar 76: 577, pl. 3, fig. 58-60.

MATERIAL, HORIZON: Two specimens, S19/f671.

REMARKS: This specimen differs from O. lanceolatus sensu Lindström in having a straight anterior margin and a shorter posterior process. Forms figured by Druce & Jones (1971) from the Tremadocian of western Queensland also have a short posterior process but have a convex anterior margin. This specimen has a strongly concave aboral margin.

OCCURRENCE, AGE: Forms referred to O. lanceolatus have been recorded from the Tremadocian (Cordylodus rotundatus - C. angulatus Assemblage Zone of Australia; Druce & Jones 1971) as high as the latest Arenigian of the Baltic region (Lindström 1955; Viira 1966). Viira (1970) erects an Oistodus lanceolatus Zone which corresponds to the upper two-thirds of the B_1 stage.

Oistodus linguatus extenuatus Lindström, 1955

Fig. 9, no. 2

1955 Oistodus linguatus extenuatus Lindström, Geologiska Föreningen Stockholm Förhandlingar, 76: 578, pl. 3, fig. 42.

MATERIAL, HORIZON: One specimen, S19/f664.

REMARKS: Lindström (1954, p. 577-579) recognized three subspecies of O. linguatus, one of which, O. linguatus complanatus, was later elevated to specific rank (Lindström 1960). Ethington & Clark (1965, p. 195) consider that O. linguatus extenuatus probably falls within the range of variability of the nominate species.

This specimen agrees closely with Lindstrom's original description and illustration and it is referred to the subspecies rather than the species.

OCCURRENCE, RANGE: The subspecies was originally described from the Limbata Limestone of Sweden (early Volkhovian), or middle Arenigian in British terms. Ethington & Clark (1965) report some specimens referable to the subspecies from the Columbia Ice Fields section of Alberta, Canada from samples equivalent to Arenigian B_1a and B_1b. The nominate species is known from the Leningrad region (Sergeeva 1962) and from the Joins Formation of Oklahoma (Mound 1965).

Oistodus longiramis Lindström, 1955

Fig. 9, no. 6

1955 Oistodus longiramis Lindström, Geologiska Föreningen Stockholm Förhandlingar, 76: 579, pl. 4, figs 35-37.

1964 Oistodus longiramis Lindström; Ethington & Clark, Journal of Paleontology 38: 693, pl. 114, figs 2, 7.

1965 Oistodus longiramis Lindström; Ethington & Clark, Brigham Young University Geological Studies 12: 195, pl. 1, fig. 5.

1965 Oistodus longiramis Lindström; Mound, Tulane Studies in Geology 4: 28, pl. 3, fig. 32.

1971 Oistodiform element of Prioniodus evae Lindström; Lindström, Geological Society of America Memoir 127: 52, fig. 13.

1971 Oistodus longiramis Lindström; Ethington & Clark, ibid: 77, pl. 2, fig. 15.

MATERIAL, HORIZON: One specimen from S19/f664.

REMARKS: O. longiramis is easily identified by its elongate undeticulate posterior process. Lindström (1971, p. 52) considers it to be the oistodiform element of a multi-element species, Prioniodus evae; none of the other elements appear to be present in the fauna.

OCCURRENCE, RANGE: The type species is from the basal part of the Upper Planilimbata Limestone of Sweden (Arenigian; Billingian substage; Lindstrom 1955, p. 579). It has also been recorded from the Leningrad region (Sergeeva 1962), Scotland (Lamont & Lindström 1957), the USA (Ethington & Clark 1964, 1971; Mound 1965) and Canada (Ethington & Clark 1965).

Genus Scolopodus

TYPE SPECIES: Scolopodus sublaevis Pander, 1856.

Scolopodus cf. S. cornutiformis Branson & Mehl, 1933

Fig. 9, no. 11

cf. 1933 Scolopodus cornutiformis Branson & Mehl, University of Missouri Studies 8: 62, pl. 4, fig. 23.

MATERIAL, HORIZON: Six specimens from S19/f664 (one figured), S19/f665, and S19/f664.

DESCRIPTION: An oistodid with a recurved cusp and small base. The cusp is strongly costate, the costae being directed to the posterior.

REMARKS: The specimen is much slimmer and more recurved than S. cornutiformis; the costae are also much more strongly developed.

OCCURRENCE, AGE: S. cornutiformis was originally described from the 'Jefferson City' Dolomite of Missouri. The 'Jefferson City' fauna is probably lower Arenigian (Jones 1971).

Scolopodus cf. S. filosus Ethington & Clark, 1964

Fig. 9, no. 10

cf. 1965 Scolopodus filosus Ethington & Clark, Journal of Paleontology 38: 699, pl. 114, figs 12, 17-19, text-fig. 2E.

MATERIAL, HORIZON: One specimen, S19/f664

DESCRIPTION: A massive recurved unit, slightly laterally compressed, with a small base. The cusp bears very fine striations especially towards its oral termination. No details of the basal cavity can be seen.

REMARKS: The unit is more laterally compressed than the type specimen and the striations are not as prominent.

OCCURRENCE, AGE: The type specimen of S. filosus is from the El Paso Formation, bed 15, of Texas (Ethington & Clark 1964) which is probably of early Arenigian age (Jones 1971).

Scolopodus aff. S. iowensis (Furnish 1938)

Fig. 9, no. 9

aff. 1938 Scontiodus iowensis Furnish, Journal of Paleontology 12: 325, pl. 42, figs 16, 17.

aff. 1971 Scolopodus iowensis (Furnish); Druce & Jones, Bureau of Mineral Resources Australia Bulletin 110: 93, pl. 16, figs 1a-7e, text-fig. 30d, e.

MATERIAL, HORIZON: One specimen, S19/f671.

DESCRIPTION: An erect unit with a convex anterior margin and a costate posterior margin. The posterior costa is knife-edged and lacks a medial grove; the lateral costae are also knife-edged and extend posteriorly, giving a hooded appearance to the cusp. The base is short with, presumably, a shallow cavity; at the inter-section of the posterior costa and the oral surface of the base a prominent "boss" is developed. The junction of the lateral costae and the base is marked by a sharp angle, the base tending to be narrower at its aboral margin.

REMARKS: Druce & Jones (1971, fig. 15) show the interrelationships of scolopids during the latest Tremadocian. They restricted S. staufferi to forms with a trough along the posterior costa, erecting a new species S. warendensis for forms lacking the trough. S. warendensis is a slender elongate form; squatter forms with the development of hood-like lateral costae are referred to S. iowensis. The form illustrated here is closest to S. iowensis but is distinguished by the prominent boss on the posterior basal margin and the development of a shoulder at the junction of the base and the cusp.

OCCURRENCE, AGE: No forms similar to this specimen have been illustrated. Scolopodus iowensis ranges from the Cordylodus rotundatus - C. angulatus Assemblage Zone into the Chosonodina herfurthi - Acodus Assemblage Zone in Western Queensland (Druce & Jones 1971). Jones (1971) records the species from the base of the overlying Drepanodus? gracilis - Scolopodus sexplicatus Assemblage Zone, which he considers to be early Arenigian.

Scolopodus cf. S. quadraplicatus Branson & Mehl, 1933

Fig. 9, no. 3

cf. 1933 Scolopodus quadraplicatus Branson & Mehl, University of Missouri Studies 8: 63, pl. 4, figs 14, 15.

MATERIAL, HORIZON: Four specimens from S19/f644, one figured.

REMARKS: The present specimens differ from S. quadraplicatus in having a slightly offset posterior groove. In S. quadraplicatus the groove is situated posteriorly (see Ethington & Clark 1964, p. 699) whereas in these specimens it is in a postero-lateral position. They are also laterally compressed with an elliptical, rather than a quadrate, outline. In some respects it more closely resembles S. triplicatus Ethington & Clark but it has an extra lateral costa.

OCCURRENCE, AGE: They type specimens are from the Jefferson City Formation, Oklahoma, of early Arenigian age.

Scolopodus sexplicatus Jones, 1971

Fig. 9, no. 7

1971 _Scolopodus sexplicatus_ Jones, _Bureau of Mineral Resources, Australia Bull. 117_: 65, pl. 5, figs 4a-5c, 7a-8c; pl. 9, figs 4a-c, text-figs 16a-c.

MATERIAL, HORIZON: Two specimens from S19/f641 (one figured), and S19/f671.

REMARKS: The specimen agrees closely with Jones' figured and topo-type material. It differs in having an additional costa on one lateral face. In Jones' plates, one caption is incorrect: _Scolopodus sexplicatus_ sp.nov. should be substituted for _Scolopodus_ sp. cf. _S. iowensis_ (Furnish 1938) in the description of plate 5.

OCCURRENCE, AGE: Jones (1971, p. 67) records it from the Pander Greensand, Bonaparte Gulf Basin, Western Australia, and the Jinduckin Formation, Daly River Basin, Northern Territory. The species is an index form for the _Drepanodus? gracilis_ - _Scolopodus sexplicatus_ Assemblage Zone (Jones, p. 15) which is early Arenigian.

Gen. nov. A

Fig. 9, nos 12, 13

MATERIAL, HORIZON: Five specimens from S19/f644, two figured.

DIAGNOSIS: A cup-like unit with a denticulate rim and no obvious basal cavity.

DESCRIPTION: The unit consists of a laterally compressed cup with a denticulate rim. In one specimen (Pl. 2, fig. 13) one side is higher than the other and one end appears to be open. In the other specimen (Pl. 2, fig. 12) the unit is the same height around the oral edge and it is closed at both ends. The oral edge (rim) bears a series of low node-like denticles. The long axis of the unit varies from straight to curved. No basal cavity is apparent.

REMARKS: The poor state of preservation makes this form difficult to interpret. However, no similar form has been described or illustrated.

Gen. nov. B

Fig. 9, no. 8

MATERIAL, HORIZON: Three specimens from S19/f664, one figured.

DIAGNOSIS: A scolopodid-like unit with the lateral costae strongly developed and produced aborally as alate projections.

DESCRIPTION: A proclined unit with a convex anterior margin and two lateral costae. The posterior face is generally concave with a strong posterior costa which bears a median groove. The lateral costae are strongly developed and are produced aborally as alate ante-cusps giving a deltoid outline. The basal cavity is situated between the alate ante-cusps and beneath the posterior costa.

REMARKS: The development of alate lateral costae is seen in the genus Stolodus Lindström; however the posterior costa is also developed in that genus to give a hibbardellid pattern whereas the present specimen has a trichonodellid pattern. One of us (E.C.D.) has obtained specimens of the genus from Arenigian rocks in the Toko Syncline, Georgina Basin, on the border of the Northern Territory and Queensland.

Indeterminable specimens

Fig. 9, nos 4, 5

One specimen (Pl. 2, fig. 5) from sample S19/f664 is a drepanodid. It possesses strong knife edges on the cusp and is similar to drepanodids which are probably ancestral to acanthodids in the Tremadocian.

The other specimen, from the same locality, is an oistodid-like element with a strongly striated cusp. The inner aboral edge of the base is strongly flared.

ACKNOWLEDGEMENTS

The conodonts, many of them extremely fragile, were extracted by J.E. Simes who, together with A. Coleman, also assisted with field work. We have benefited from discussions with our colleagues on various aspects of carbonate sedimentation, a much neglected field in New Zealand, but in particular wish to thank B.W. Riddolls, P.B. Andrews, M.G. Laird, and D. Lewis.

The opportunity for the authors to co-operate on this project was made possible by a study travel award to one of us (R.A.C.), supported by a grant from the Department of Scientific and Industrial Research, New Zealand, and an Honorary Fellowship at the Geology Department, Australian National University during 1972/3.

The contribution by Druce is published with the permission of the Director, Bureau of Mineral Resources, Canberra.

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Table I

<table>
<tr><th colspan="2" rowspan="2">BRITAIN</th><th colspan="2" rowspan="2">VICTORIA</th><th colspan="2">WESTERN BELT</th><th colspan="2">CENTRAL BELT</th></tr>
<tr><th>GREENLAND GROUP, REEFTON</th><th>AORANGI MINE</th><th colspan="2">MOUNT PATRIARCH</th></tr>
<tr><td rowspan="11">LOWER ORDOVICIAN</td><td rowspan="8">Arenigian (part)</td><td>Yapeenian</td><td>1,2</td><td rowspan="11">?
Undifferentiated Greenland Group
?</td><td rowspan="10">Aorangi Mine Formation</td><td colspan="2" rowspan="4"></td></tr>
<tr><td>Castlemainian</td><td>1,2,3</td></tr>
<tr><td>Chewtonian</td><td>1,2</td></tr>
<tr><td rowspan="4">Bendigonian</td><td>Be 4</td></tr>
<tr><td>Be 3</td><td rowspan="6">Summit Limestone</td><td rowspan="4">Middle & Upper Units</td></tr>
<tr><td>Be 2</td></tr>
<tr><td>Be 1</td></tr>
<tr><td rowspan="3">Lancefieldian</td><td>La 3</td></tr>
<tr><td rowspan="3">Tremadocian</td><td>La 2</td><td rowspan="2">Lower Unit</td></tr>
<tr><td>La 1</td></tr>
<tr><td colspan="2">pre-Lancefieldian</td><td>Webb Formation (incl. Sandhills Creek Fmn)</td><td colspan="2">?
Patriarch Formation</td></tr>
<tr><td>U.CAMBRIAN</td><td></td><td colspan="2">Upper Cambrian</td><td></td><td></td><td colspan="2">?
Haupiri Group (part)</td></tr>
</table>

TABLE 2 - Faunal list and distribution of conodonts, Summit Limestone.

Species	Age	S19/ f641	S19/ f671	S19/ f693	S19/ f662	S19/ f665	S19/ f664
Acodus deltatus Lindstrom 1,2	Earliest Arenigian	3	4	.	.	.	5
Chosonodina herfurthi Muller 1,2	Latest Tremadocian	5	1	.	.	.	.
Cordylodus angulatus Pander 1,2	Latest Tremadocian-Earliest Arenigian	1	2	1	.	.	.
Drepanodus suberectus Branson & Mehl 1,2	Early Ordovician	3	2	.	.	.	3
cf. Drepanodus tooneyi Ethington & Clark 1,2	Early Arenigian	2	1	.	.	.	10
? Oepikodus sp. A Barnes & Tuke 1	Early Arenigian	2	.	.	.	.	.
Oistodus angulatus Bradshaw 2	? Llanvirnian	.	.	.	.	.	3
Oistodus cf. forceps Lindstrom 1	? Early Arenigian	.	1	.	.	.	.
Oistodus aff. forceps Lindstrom 2	? Early Arenigian	.	1	.	.	.	1
Oistodus cf. lanceolatus Pander 1	? Early Arenigian	.	2	.	1	.	.
Oistodus linguatus extenuatus Lindstrom 2	Early-mid Arenigian	.	.	.	.	.	1
Oistodus longiramis Lindstrom 2	Early-mid Arenigian	.	.	.	.	.	1
Scolopodus cf. cornutiformis B. & M. 2	? Early Ordovician	.	.	.	.	1	5
Scolopodus cf. filosus Ethington & Clark 2	? Early Arenigian	.	.	.	.	.	1
Scolopodus gracilis Ethington & Clark 1	Arenigian	1	.	.	.	.	.
Scolopodus aff. iowensis (Furnish) 1	? Earliest Arenigian	.	1	.	.	.	.
Scolopodus cf. quadraplicatus B. & M. 2	? Arenigian	.	.	.	.	.	4
Scolopodus sexplicatus Jones 1	Earliest Arenigian	1	1	.	.	.	.
Gen. nov. A 2	?	.	.	.	.	.	5
Gen. nov. B 2	?	.	.	.	.	.	3

NOTE : Names of species in the older faunal assemblage (those from Unit 1 - localities S19/f641, f671, f693, f662) are followed by "1", those of species in the younger faunal assemblage, (from Unit 3 - localities S19/f665, f664), by "2".

TABLE 3 - Distribution of New Zealand species in faunas from Australia ("Austr".), Malaya, Korea, North America, Baltic, Scotland, and U.S.S.R. showing faunal affinities.

Species.	AUSTR.				NORTH AMERICA									BALTIC				USSR		
	Qld Tremadocian Druce & Jones 1971	W.A. & N.T., Arenigian Jones 1971	Malaya, Setul Lst. Igo & Koike 1967	Korea Muller 1964	Alberta Ethington & Clark 1964	Texas - Arizona El Paso Fmn. E. & C. 1965	Oklahoma Arbuckle, Mound 1968	Oklahoma, Joins Fmn. Mound 1965, Harris & Harris 1965	Missouri, Jefferson City Fmn Branson & Mehl 1933	Texas Bradshaw 1969	U. Mississippi Valley Furnish, 1938	Pennsylvania, Beekmanton Group, Sando 1958	New Foundland, Barnes & Tuke 1970, Fahraeus 1970	Sweden Lindström 1955	Poland, Wolska 1961, Mehring, 1972	East Baltic, Viira 1968-70	Leningrad, Sergeeva 1962	Scotland Lamont & Lindström 1957	Sibera, Tschun, Moskalenko 1967	Siberia, Abaimova 1971-2
Acodus deltatus	•	•	•	•	×	•	×	•	•	•	•	•	•	×	•	×	•	•	×	×
Chosonodina herfurthi	×	?	•	×	•	•	×	•	•	•	•	•	•	•	•	•	•	•	•	•
Cordylodus angulatus	×	×	•	•	×	•	×	•	•	•	•	×	•	×	•	×	•	•	•	?
Drepanodus suberectus	×	×	×	•	×	•	×	×	•	×	•	•	×	×	×	×	×	•	•	×
cf. Drepanodus toomeyi	•	•	•	•	•	×	•	•	•	•	•	•	×	•	•	•	•	•	•	•
? Oopikodus sp. A	•	•	•	•	•	•	•	•	•	•	•	•	×	•	•	•	•	•	•	•
Oistodus angulatus	•	•	•	•	•	•	•	•	•	×	•	•	•	•	•	•	•	•	•	•
Oistodus cf. forceps	•	•	•	•	×	•	×	×	•	•	•	•	×	×	×	×	×	×	×	•
Oistodus aff. forceps	•	•	•	•	•	×	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Oistodus cf. lanceolatus	×	•	×	•	•	×	×	•	•	×	•	•	•	×	•	×	×	×	•	•
Oistodus linguatus extenuatus	•	•	•	•	•	•	•	×	•	•	•	•	•	×	•	•	×	×	•	•
Oistodus longiramus	•	•	•	•	×	×	•	×	•	•	•	•	•	×	•	•	×	×	•	•
Scolopodus cf. cornutiformis	•	•	×	•	×	×	×	•	×	•	•	•	×	•	•	•	•	•	•	•
Scolopodus cf. filosus	•	×	•	•	×	×	×	×	•	•	•	•	×	•	•	•	•	•	•	•
Scolopodus gracilis	•	•	•	•	×	×	×	•	•	•	•	•	×	•	•	•	•	•	•	•
Scolopodus aff. iowensis	×	×	•	•	•	×	×	•	•	•	×	•	×	•	•	•	?	•	•	•
Scolopodus cf. quadraplicatus	×	×	•	•	×	×	×	×	×	×	×	×	×	•	•	•	•	•	×	×
Scolopodus sexplicatus	•	×	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

Table 4

NEW ZEALAND	AUSTRALIA: CONODONT ZONE	AUSTRALIA: STAGE	CONOD. ZONE	EUROPE: STAGE		ESTONIA	BRITAIN	NORTH AMERICA: OKLAHOMA			TEXAS		ALBERTA		NEWF'D'LAND	
S19/665, S19/664	not erected	not erected	III	LATORPIAN	BILLINGEN	B_1b	ARENIGIAN	COOL CREEK	ARBUCKLE GROUP	*Scolopodus quadraplicatus*	EL PASO FORMATION (part)	Unit Bl, Bed 15	Columbia Ice Fields section	50, 41	ST GEORGE FORMATION	SAMPLE B
S19/662, S19/693	*Drepanodus ? gracilis – Scolopodus sexplicatus*	not erected	II	LATORPIAN	HUNNEBERG	B_1a	ARENIGIAN ?	COOL CREEK	ARBUCKLE GROUP	*Scolopodus quadraplicatus* / *Chos. herfurthi Lox. bransoni*	?	?	Columbia Ice Fields section	33	ST GEORGE FORMATION ?	SAMPLE A ?
S19/671, S19/641	*Chosonodina herfurthi – Acodus*	WARENDIAN (part)	I			?	TREMADOCIAN	McKENZIE HILL	ARBUCKLE GROUP	*Chos. herfurthi Lox. bransoni*			Columbia Ice Fields section	30, 25?		
	Cordylodus rotundatus – C.angulatus	WARENDIAN (part)	I				TREMADOCIAN	McKENZIE HILL	ARBUCKLE GROUP				Columbia Ice Fields section	17		

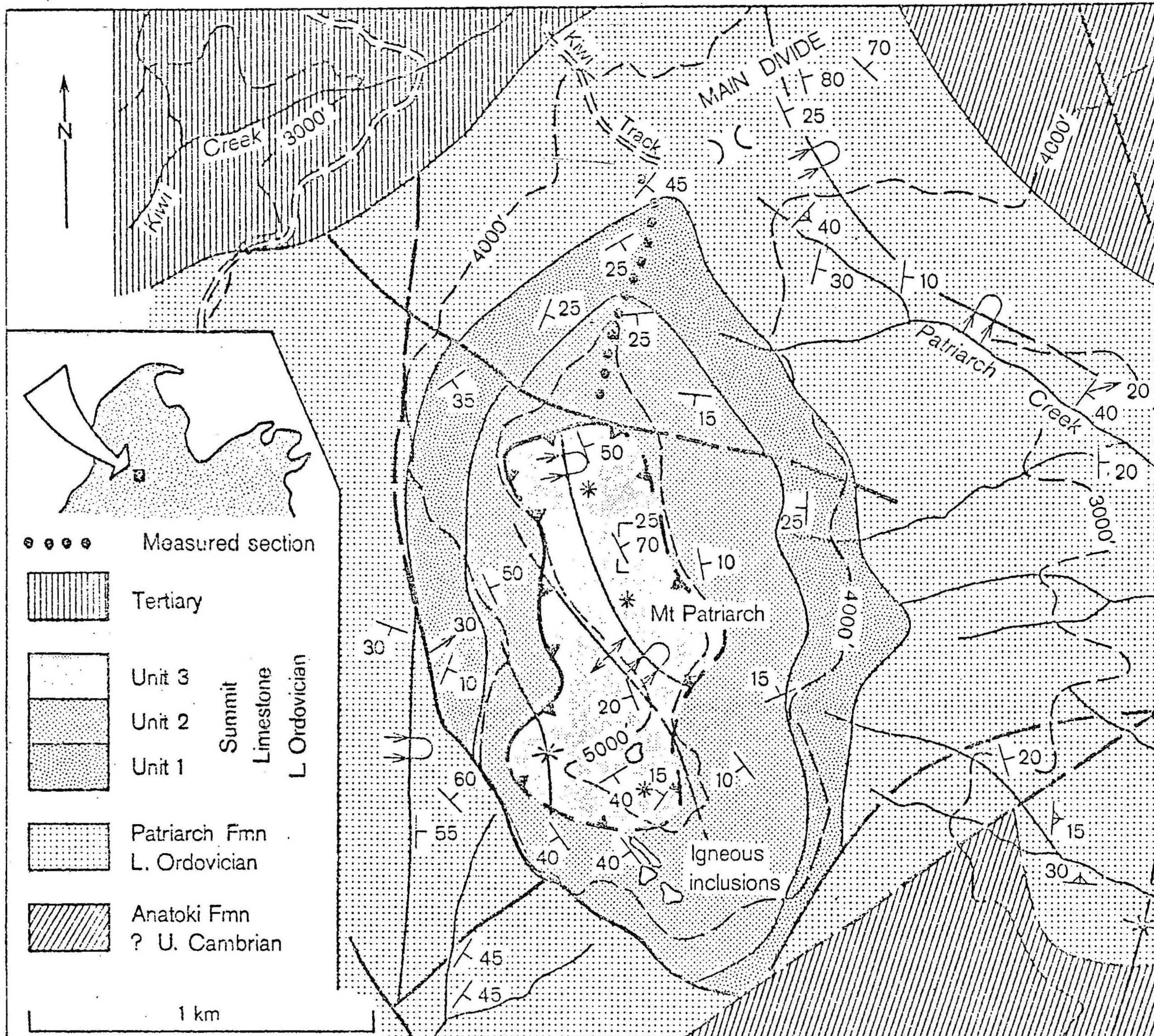
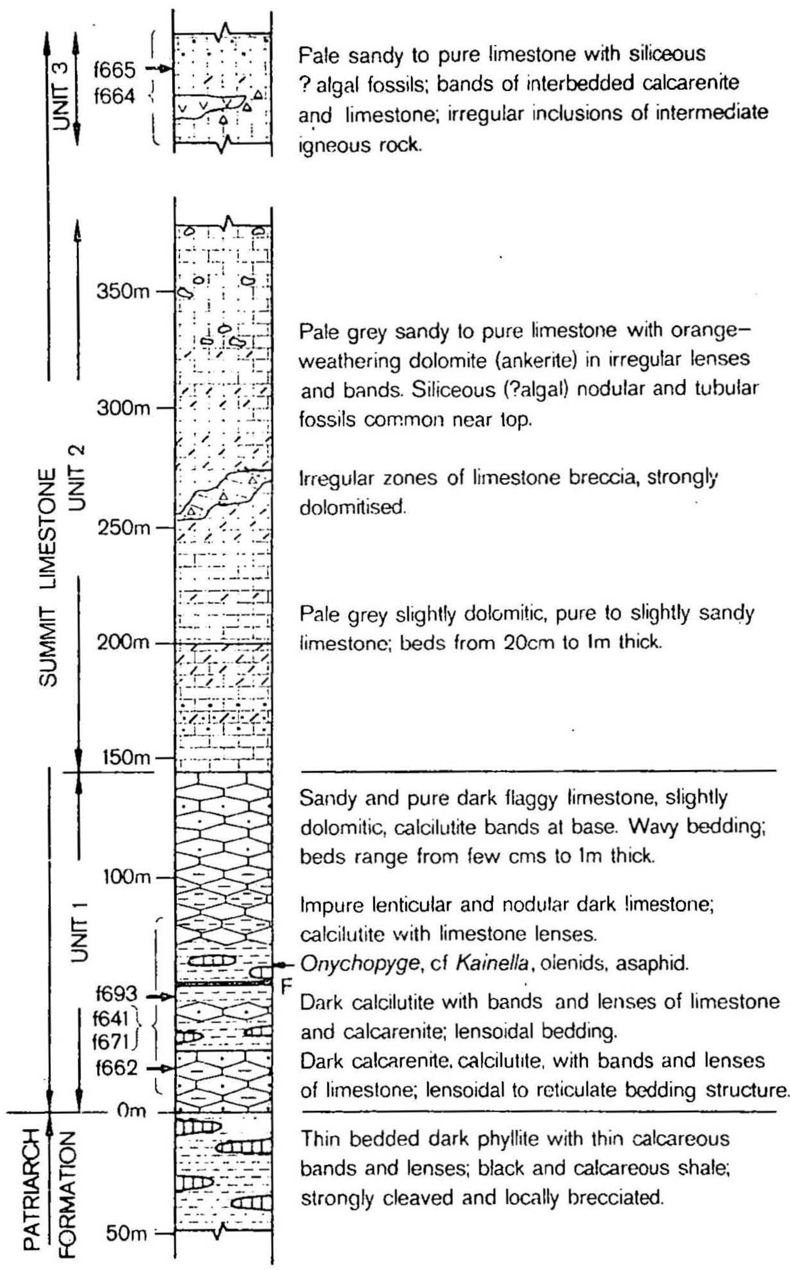


Figure I Locality Map



UNIT 3
f665
f664
Pale sandy to pure limestone with siliceous ? algal fossils; bands of interbedded calcarenite and limestone; irregular inclusions of intermediate igneous rock.
350m
300m
250m
200m
150m
100m
0m
50m
SUMMIT LIMESTONE
UNIT 2
Pale grey sandy to pure limestone with orange-weathering dolomite (ankerite) in irregular lenses and bands. Siliceous (?algal) nodular and tubular fossils common near top.
Irregular zones of limestone breccia, strongly dolomitised.
Pale grey slightly dolomitic, pure to slightly sandy limestone; beds from 20cm to 1m thick.
UNIT 1
Sandy and pure dark flaggy limestone, slightly dolomitic, calcilutite bands at base. Wavy bedding; beds range from few cms to 1m thick.
Impure lenticular and nodular dark limestone; calcilutite with limestone lenses.
Onychopyge, cf *Kainella*, olenids, asaphid.
F
f693
f641
f671
f662
Dark calcilutite with bands and lenses of limestone and calcarenite; lensoidal bedding.
Dark calcarenite, calcilutite, with bands and lenses of limestone; lensoidal to reticulate bedding structure.
PATRIARCH FORMATION
Thin bedded dark phyllite with thin calcareous bands and lenses; black and calcareous shale; strongly cleaved and locally brecciated.

Figure 2

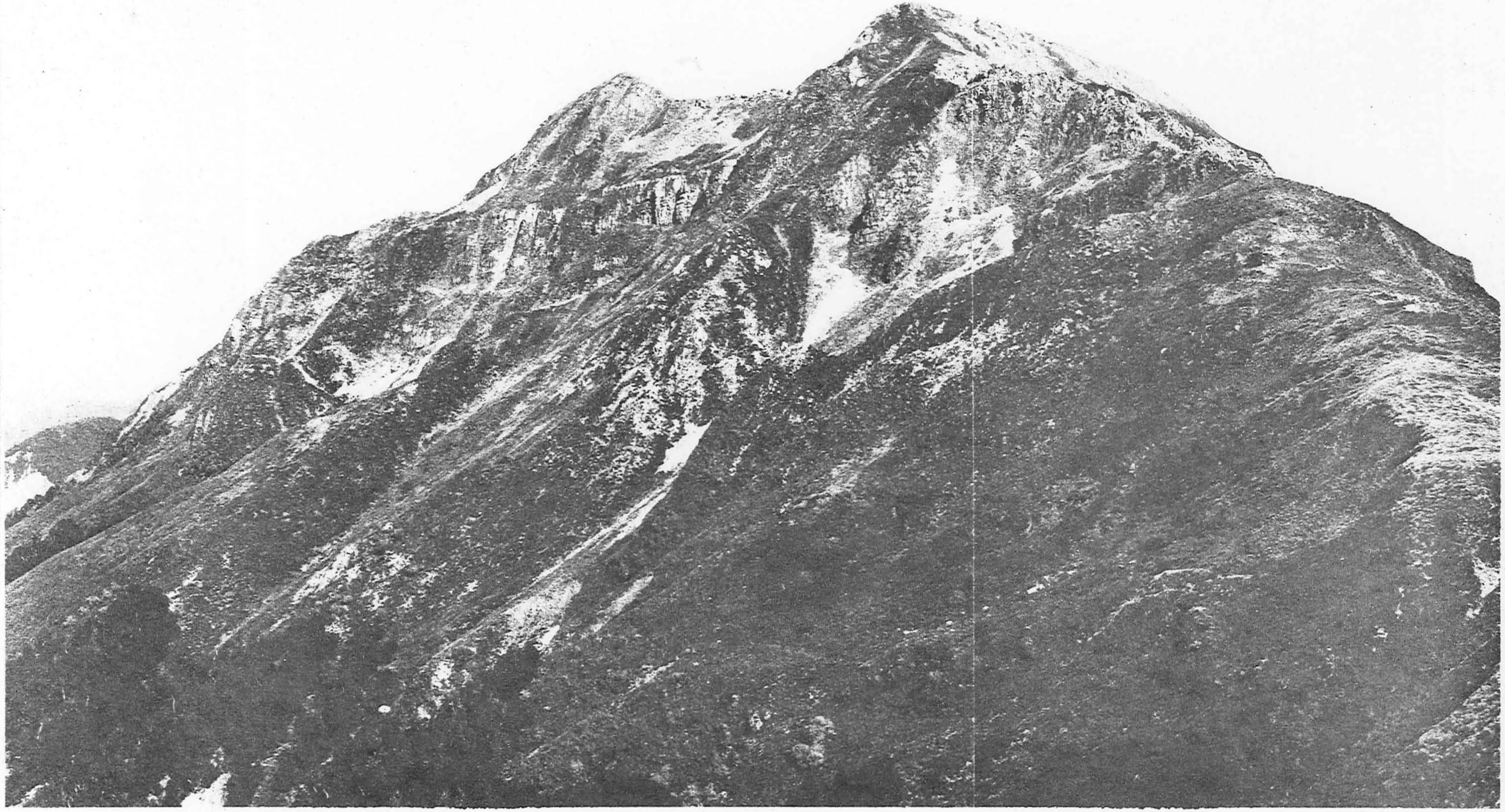


Fig. 3. View of Mt Patriarch showing horizontally bedded Ordovician rocks.

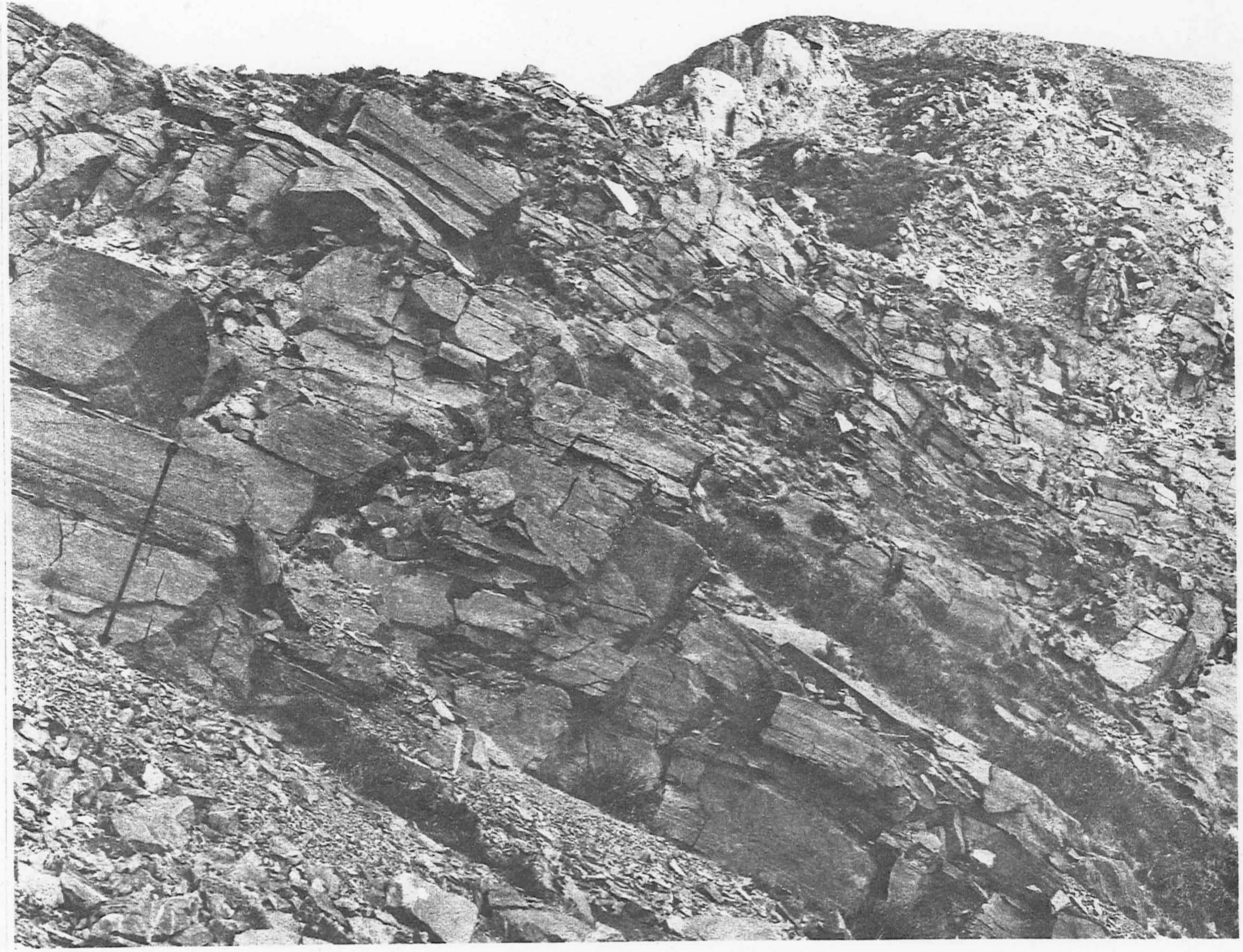


Fig. 4. Flaggy limestone and calcareous siltstone of Unit 1.

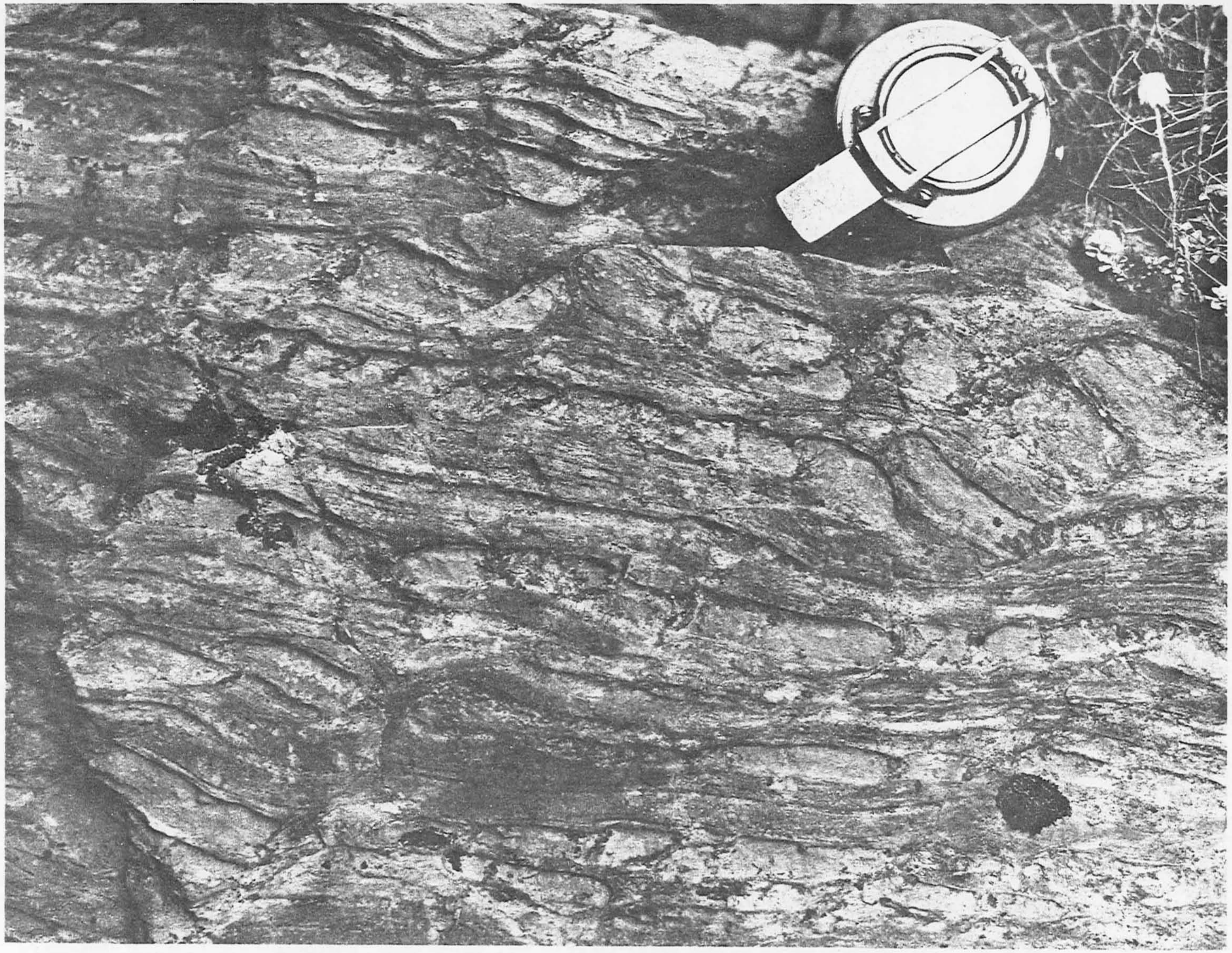


Fig. 5. Limestone blocks within a matrix of calciclastic material, Unit 1.

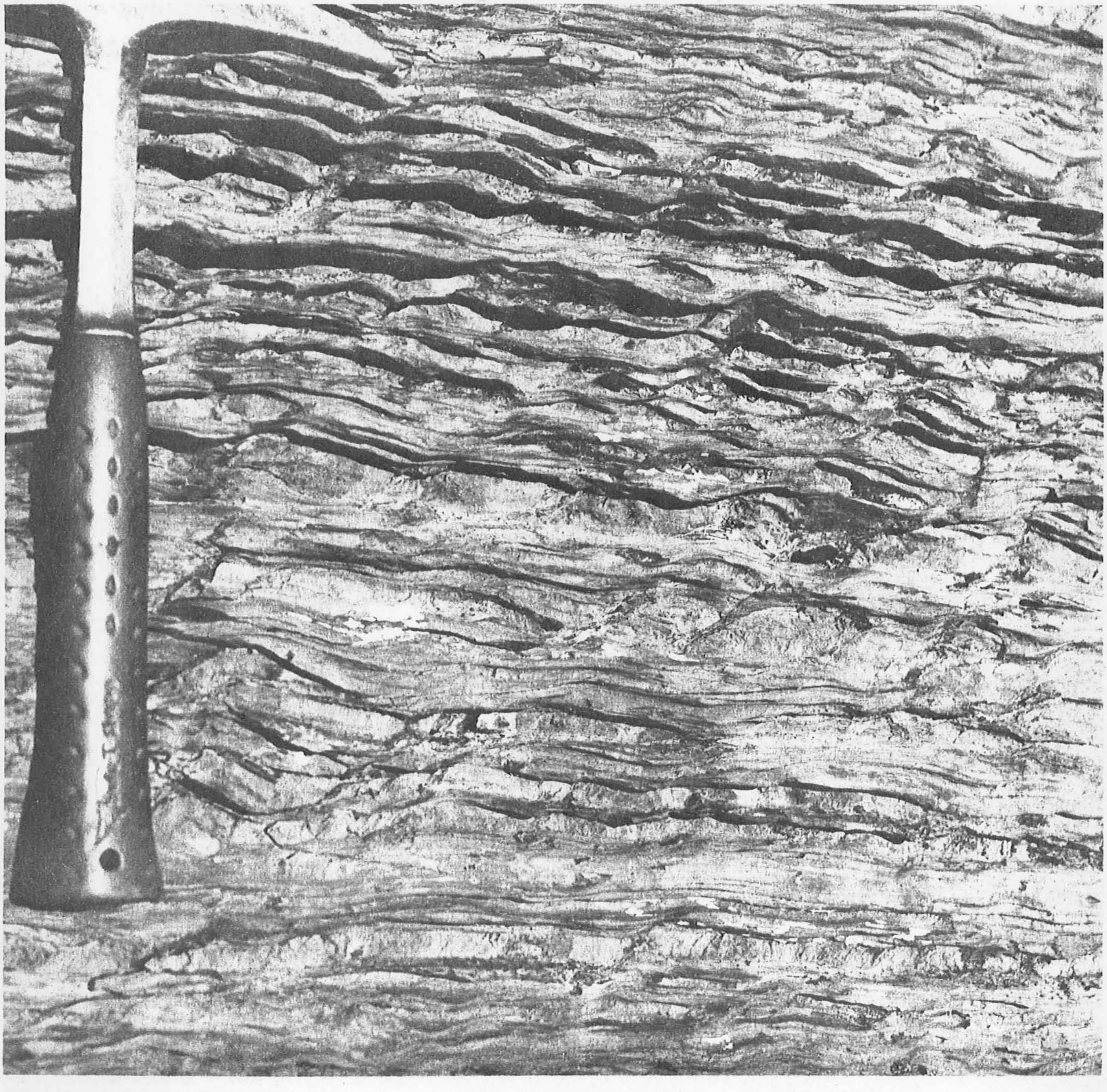


Fig. 6. Zones of "shearing" in Unit 1.

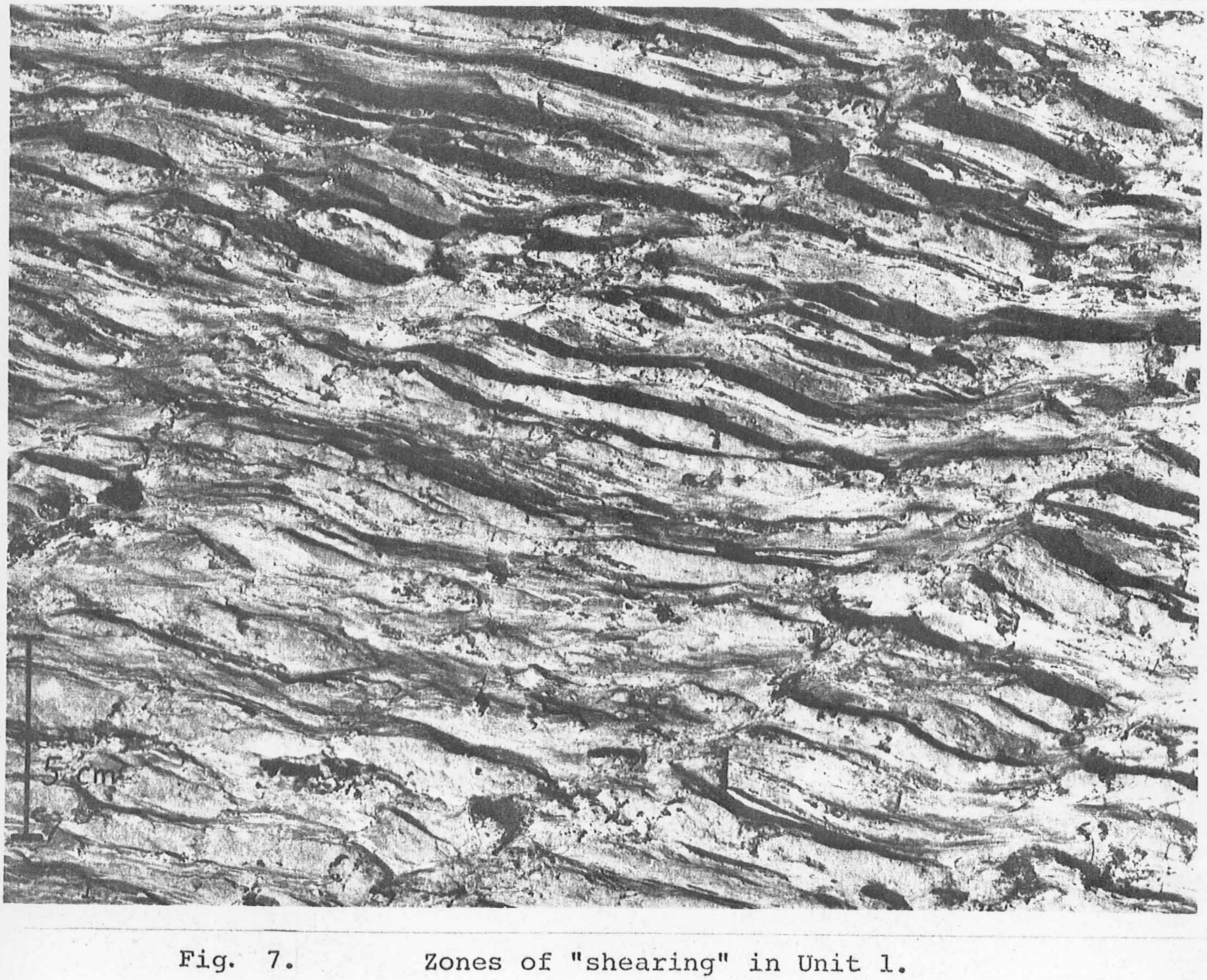


Fig. 7. Zones of "shearing" in Unit 1.

Acodus deltatus Lindstrom, 1955

Fig. 1 Lateral view of specimen CNP 1026 from sample C88.

Fig. 2 Lateral view of specimen CNP 1024 from sample C85

Fig. 3 Lateral view of specimen CNP 1028 from sample C85

Chosonodina herfurthi Muller, 1964

Fig. 4 Posterior view of specimen CNP 1029 from sample C85

Cordylodus angulatus Pander, 1856

Fig. 5 Lateral view of specimen CNP 1030 from sample C85

Fig. 7 Lateral view of specimen CNP 1031 from sample C85

Drepanodus cf. D. toomeyi Ethington & Clark, 1964

Fig. 6 Lateral view of specimen CNP 1032 from sample C85

Fig. 8 Lateral view of specimen CNP 1033 from sample C88

Fig. 9 Lateral view of specimen CNP 1034 from sample C85 showing elongate ante-cusp

Oistodus cp. aff. O. forceps Lindstrom (sensu Ethington & Clark, 1964)

Fig. 10 Lateral view of specimen CNP 1035 from sample C88

Dreponodus suberectus Branson & Mehl, 1933

Fig. 11 Lateral view of specimen CNP 1036 from sample C88

Oistodus angulatus Bradshaw, 1969

Fig. 12 Lateral view of specimen CNP 1037 from sample C88

Fig. 13 Lateral view of specimen CNP 1038 from sample C88

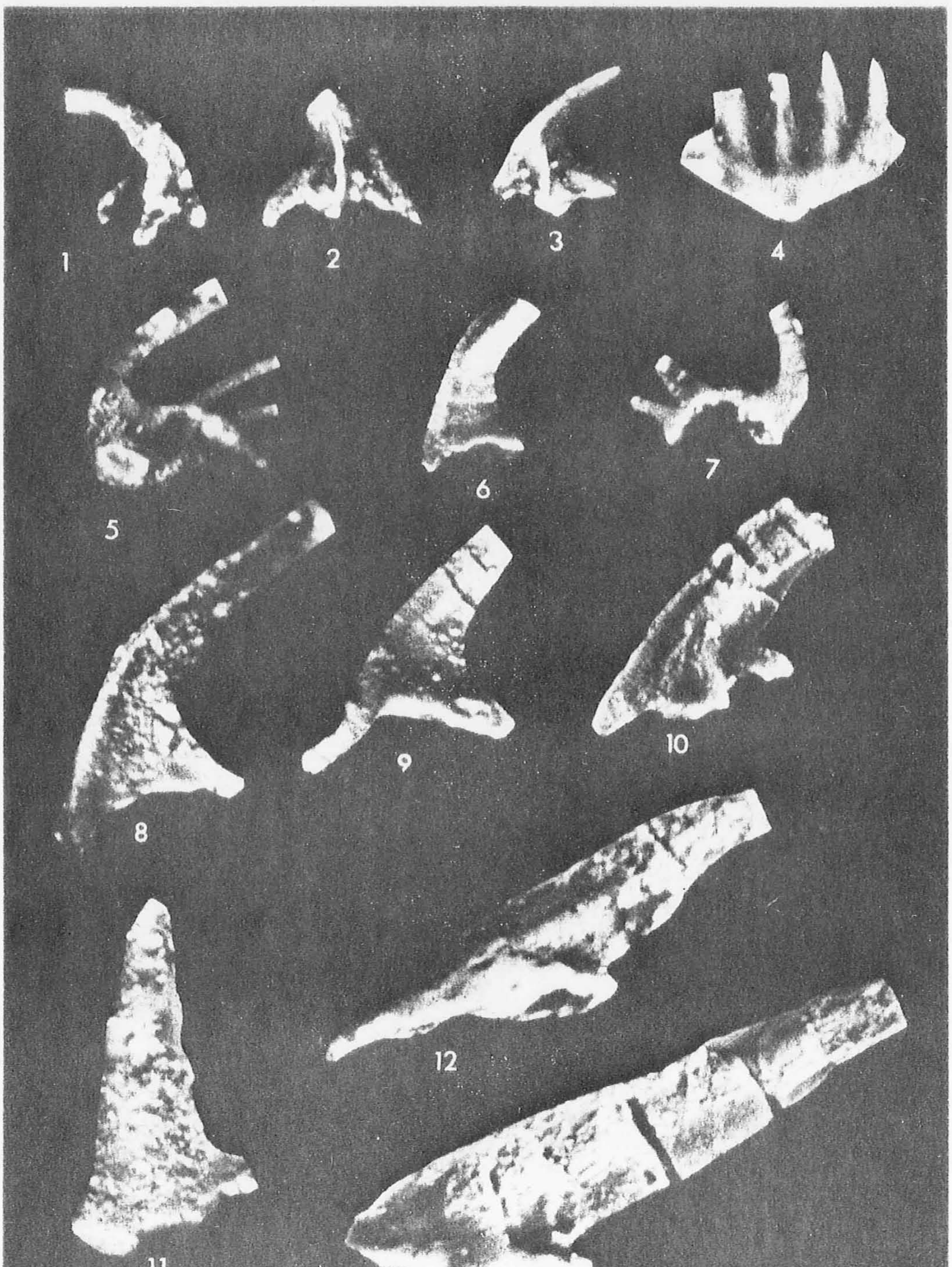


Figure 8

Oistodus cf. O. lanceolatus Pander, 1856

Fig. 1 Lateral view of specimen CNP 1039 from sample C85

Oistodus linguatus extenuatus Lindstrom, 1955

Fig. 2 Lateral view of specimen CNP 1040 from sample C88, cusp broken

Scolopodus cf. S. quadraplicatus Branson & Mehl, 1933

Fig. 3 Lateral view of specimen CNP 1041 from sample C88

Indeterminate species

Fig. 4 Lateral view of specimen CNP 1042 from sample C88

Fig. 5 Lateral view of specimen CNP 1043 from sample C88

Oistodus longiramis Lindstrom, 1955

Fig. 6 Lateral view of specimen CNP 1044 from sample C88

Scolopodus sexplicatus Jones, 1971

Fig. 7 Lateral view of specimen CNP 1045 from sample C16

gen. nov. B

Fig. 8 Posterior view of specimen CNP 1046 from sample C88

Scolopodus aff. S. iowensis (Furnish, 1938)

Fig. 9 Posterior view of specimen CNP 1047 from sample C85

Scolopodus cf. S. filosus Ethington & Clark, 1964

Fig. 10 Lateral view of specimen CNP 1048 from sample C88

Scolopodus cf. S. cornutiformis Branson & Mehl, 1933

Fig. 11 Lateral view of specimen CNP 1049 from sample C88 gen nov. A

Fig. 12 Oral view of specimen CNP 1050 from sample C88

Fig. 13 Latero-oral view of specimen CNP 1051 from sample C88

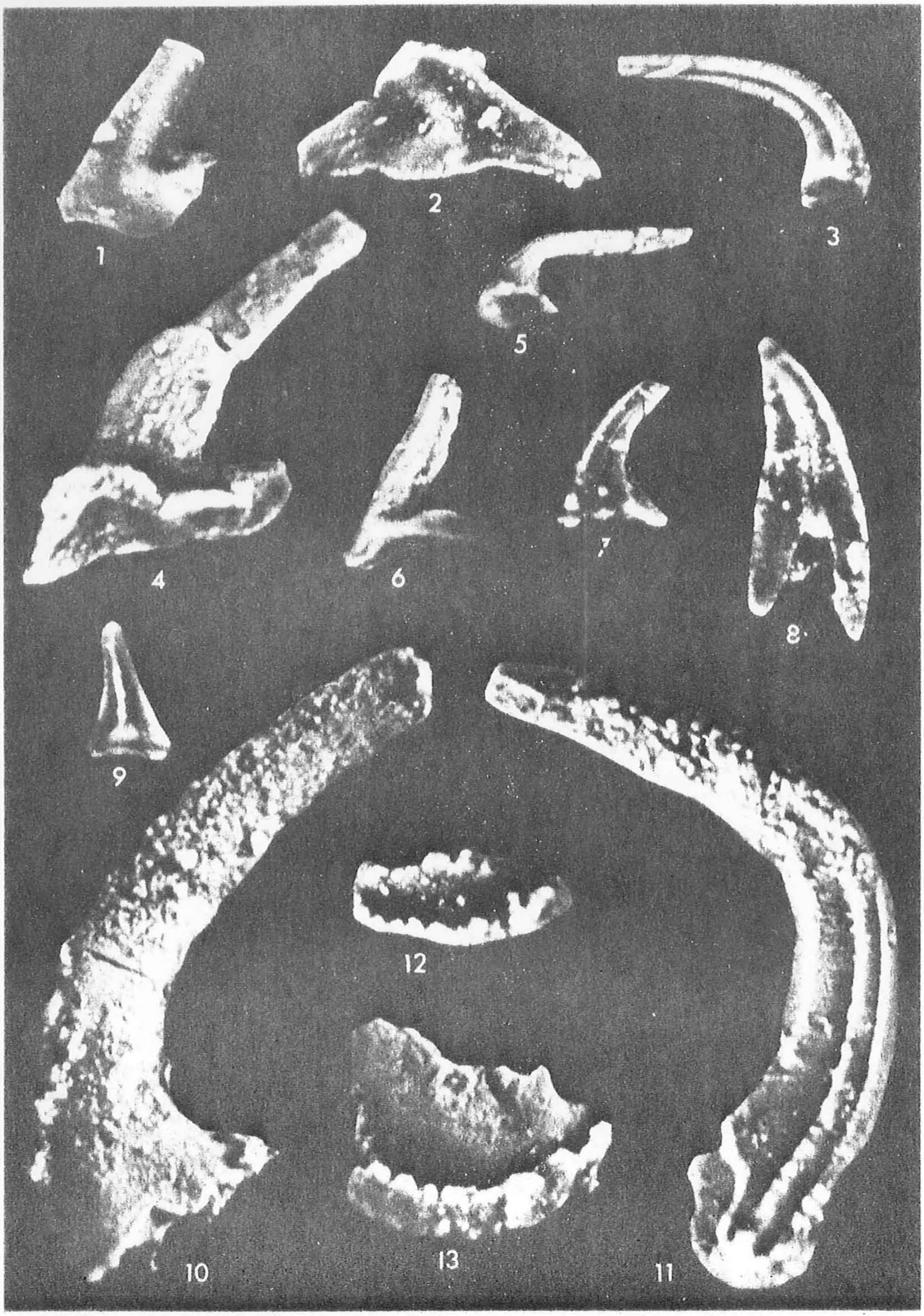


Figure 9