

Life Sciences Contributions 126  
Royal Ontario Museum

Upper Cambrian to  
Lower Ordovician Conodont  
Biostratigraphy and Biofacies,  
Rabbitkettle Formation,  
District of Mackenzie

Ed Landing  
Rolf Ludvigsen  
Peter H. von Bitter



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LIFE SCIENCES CONTRIBUTIONS  
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NUMBER 126

ED LANDING  
ROLF LUDVIGSEN  
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# Upper Cambrian to Lower Ordovician Conodont Biostratigraphy and Biofacies, Rabbitkettle Formation, District of Mackenzie

## Abstract

Conodonts have been recovered from two sections through the Cambrian-Ordovician boundary beds of the upper Rabbitkettle Formation, near the headwaters of the Broken Skull River, western Mackenzie Mountains. The two sections are separated by a thrust fault. The sequence of trilobite faunas from the low-energy outer shelf facies of the Rabbitkettle is equivalent to the *Saukiella junia* through *Symphysurina brevispicata* subzones from the inner carbonate platform in Oklahoma and Texas. Significant differences in trilobite faunas between the Mackenzie Mountains and United States sequences represent contrasting biofacies developments. Similarly, the sparse and low diversity conodont faunas of the Rabbitkettle resemble coeval Appalachian continental slope and outer shelf faunas rather than those reported from the inner carbonate platform in Texas and Utah. The *Proconodontus* and *Cordylodus oklahomensis* (new name) zones can be recognized in the Rabbitkettle but cannot be divided into the subzones established in Utah. These data suggest that lithofacies associations and biofacies developments in conodont distribution may prohibit detailed conodont-based correlations of Cambrian-Ordovician boundary beds.

## Introduction

Uppermost Cambrian and lowest Ordovician conodonts are known from sections in the western United States (Miller, 1969, 1970, 1975, 1977, 1978; Kurtz, 1976), Alberta (Derby et al., 1972), Iran (Müller, 1973), and Australia (Druce and Jones, 1971). The similarities of conodont faunal sequences in these widely separated areas have been interpreted to reflect a lack of or weak development of conodont biofacies or provincialism in Cambrian-Ordovician boundary beds (Barnes et al., 1973). Land-

ing et al. (1978) suggested that conodont faunas bridge the biofacies differences shown by trilobites. Consequently, conodonts have received considerable discussion in intercontinental correlation of Cambrian-Ordovician boundary beds (Jones et al., 1971; Miller, 1977, 1978; Landing et al., 1978).

Available lithologic information indicates that the North American, Iranian, and Australian conodont successions listed above were derived from intertidal or very shallow sublittoral, inner carbonate platform sequences. Similarities of the faunal successions may reflect the appearance of comparable conodont assemblages ("communities") in similar but geographically separated environments.

Based on studies of continental slope deposits in the northern Appalachians, Landing (1978, 1979) proposed that major conodont biofacies differences existed during the uppermost Cambrian and lowest Ordovician. Faunas from inner carbonate platform sequences appear to differ from those in sequences deposited in environments with unrestricted access to the open ocean.

The upper Rabbitkettle Formation in the western Mackenzie Mountains (Fig. 1) has lithologic and faunal features representative of an open shelf facies. The trilobite

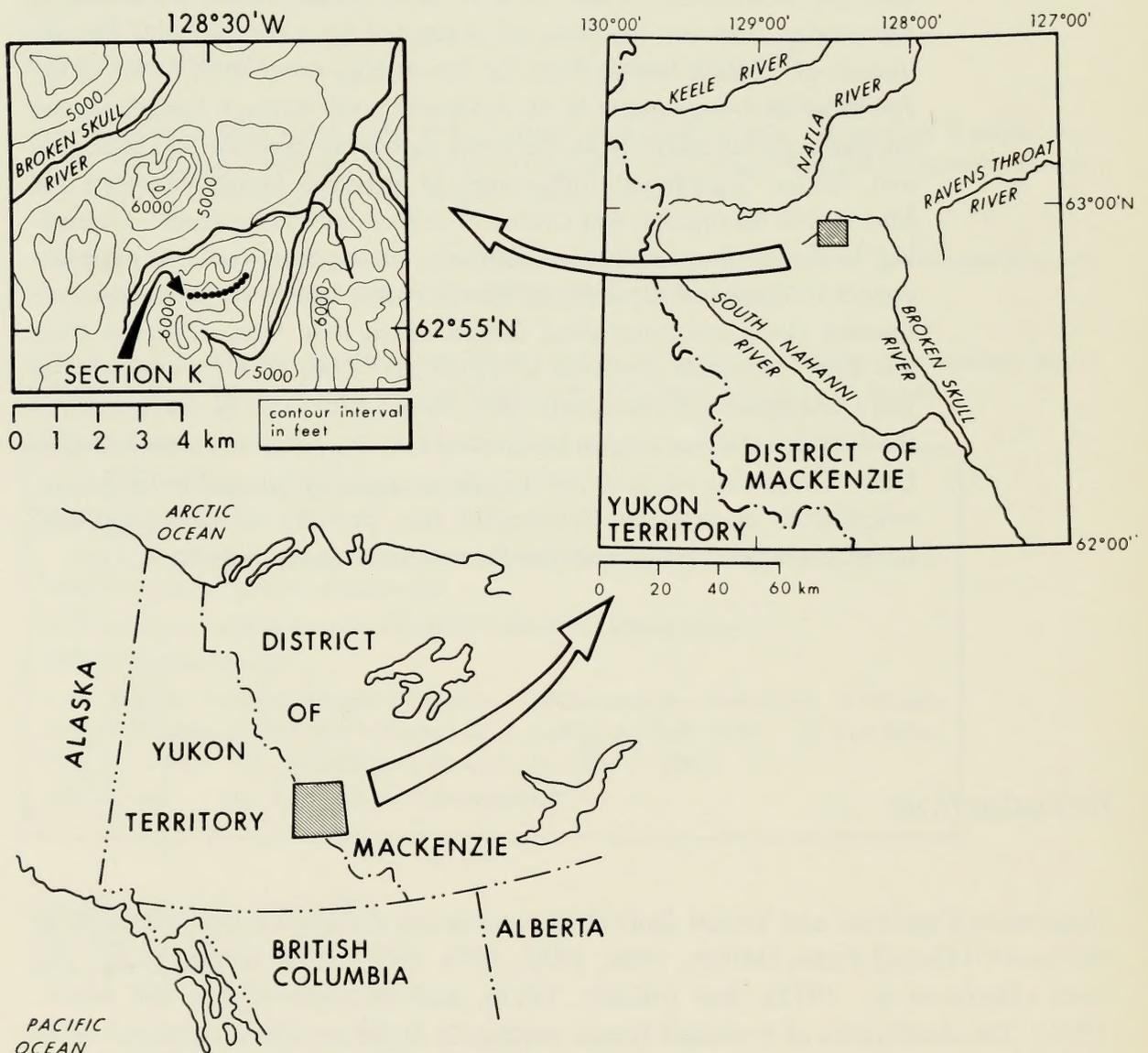


Fig. 1 Locality maps showing Section K.

sequence from this interval, briefly summarized in this report, can be correlated with those from the uppermost Cambrian to lowest Ordovician successions of Texas (Winston and Nicholls, 1967; Longacre, 1970) and Oklahoma (Stitt, 1971, 1977) although significant differences in faunal composition are present. These differences are attributed to the more open marine biofacies represented by the Rabbitkettle trilobites. Conodonts were examined to determine whether the sequences and composition of open shelf faunas from the Rabbitkettle have closer affinity to Miller's (1969, 1970, 1975, 1978) diverse carbonate platform conodont faunas or to Landing's (1978, 1979) coeval low diversity conodont faunas with restricted biostratigraphic utility from slope sequences.

This report contributes towards a biofacies evaluation of Cambrian-Ordovician boundary bed conodonts and illustrates the probable limitations on a highly resolved conodont-based correlation of this interval between strongly contrasting lithofacies.

## *Geologic Setting and Stratigraphy*

Three formations of Late Cambrian and Early Ordovician age are exposed on the Mackenzie Platform, a stable tectonic element which received dominantly shallow-water sediments from the Helikian to the Late Devonian (Gabielse, 1967): the Franklin Mountain Formation in the Mackenzie Valley (Norford and Macqueen, 1975), the Broken Skull Formation in the eastern and central Mackenzie Mountains (Gabielse et al., 1973; Ludvigsen, 1975), and the Rabbitkettle Formation in the western Mackenzie Mountains and the Selwyn Mountains (Gabielse et al., 1973).

These formations are poorly dated. Scattered fossil collections suggest that each spans the interval of, at least, Franconian to Canadian (Norford and Macqueen, 1975; Gabielse et al., 1973; Ludvigsen, 1975; Tipnis et al., 1979).

The Rabbitkettle Formation comprises a thick sequence of grey weathering and banded silty limestones and calcareous siltstones near the border between the District of Mackenzie and Yukon Territory. Complete stratigraphic sections have not been located, but Gabielse et al. (1973) suggested a minimum thickness of 1200 m for the Rabbitkettle in the Selwyn Mountains. Towards the east, the Rabbitkettle is replaced by silty and sandy, locally cross-bedded and pisolitic limestones and dolostones of the Broken Skull Formation which are, in turn, replaced by stromatolitic dolostones of the Franklin Mountain Formation further to the east.

Detailed biostratigraphic work on the upper Rabbitkettle Formation dates from 1972 when Ludvigsen measured a 750 m section of Upper Cambrian and Ordovician rocks near the headwaters of the Broken Skull River (Fig. 1). This section, designated Section K (Fig. 2), includes the upper Rabbitkettle Formation and the lower Road River Formation. A prominent black dolostone member overlying the Rabbitkettle was initially assigned to the lower Sunblood Formation and a significant hiatus was presumed to separate these units (Ludvigsen, 1975: fig. 7). However, Tipnis et al. (1979) demonstrated that Early Arenigian conodonts occur above the black dolostone member and that the hiatus, if indeed present, must be minor. This dolostone unit is herein considered to be a basal member of the Road River Formation.

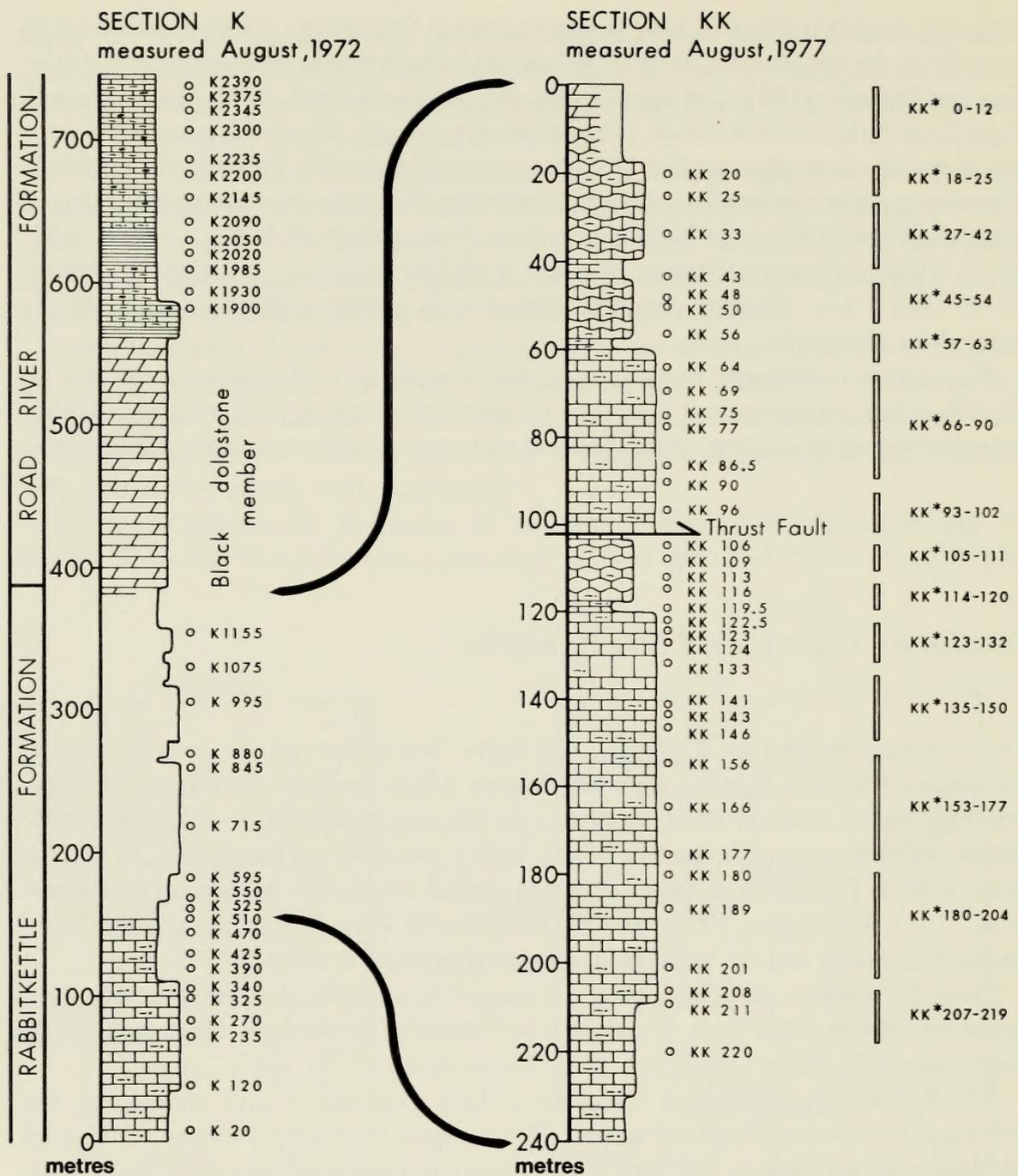


Fig. 2 Diagram of Section K showing the samples (K prefix) that yielded the conodonts discussed by Tipnis et al. (1979). When Section K was measured, it was considered to represent a continuous and structurally uncomplicated stratigraphic section. Detailed sampling of the upper 240 m of the Rabbitkettle Formation (Section KK) provided evidence of a thrust fault located 102 m below the top of the formation. Thus, the interval 44–102 m of the hanging wall corresponds to the interval 102–160 m of the foot wall. The position of samples dissolved in the search for conodonts is indicated (KK prefix). Also shown are the intervals represented by composite samples (KK\* prefix).

The recovery of silicified trilobites at a number of levels below the black dolostone in Section K prompted a reinvestigation of this part of the section, and the upper 240 m of the Rabbitkettle was sampled in detail by Ludvigsen in 1977. This new section was designated Section KK (Fig. 2). Thirty-five bulk limestone samples, ranging in weight from 2 to more than 20 kg, were collected through the section. One and

Table 1 Conodont abundance in samples from the foot wall of Section KK (see Fig. 2)

	KK 211	KK 189	KK 180	KK 177	KK 166	KK 156	KK 146	KK 141	KK 133	KK 124	KK 123	KK 122.5	KK 119.5	KK 116	KK 113	KK 109	KK 106
<i>Cordylodus oklahomensis</i>										18					7		7
cordylodiform element										10							2
cyrtioniodiform element											1						
<i>Fryxellodontus?</i> sp. nov.																	
<i>serratus</i> element							1										
" <i>Proconodontus</i> " <i>carinatus</i>																	
drepanodiform element			1		1			1					1				1
scandodiform element			1		1												1
" <i>Prooneotodus</i> " <i>tenuis</i>																	
isolated element																	1
<i>Phosphannulus universalis</i>			1				1			1	1						



**Table 3** Conodont abundance in productive composite samples from the foot and hanging walls of Section KK (see Fig. 2)

	KK* 135-150	KK* 45-54	KK* 27-42	KK* 0-12
<i>Cordylodus oklahomensis</i>				
cordylodiform element		1	2	
cyrtioniodiform element		1	3	
" <i>Oneotodus</i> " <i>nakamurai</i>	1			
" <i>Proconodontus</i> " <i>carinatus</i>				
drepanodiform element				
scandodiform element				1
<i>Proconodontus serratus s.f.</i>	1			
Protoconodont sp. indet. <i>s.f.</i>	2			
<i>Phosphannulus universalis</i>	1			

one-half to 2 kg of each sample were dissolved in acetic acid to recover conodonts; the remainder was dissolved in hydrochloric acid in the search for silicified trilobites. The samples are identified by a letter/number combination (e.g., KK 50) indicating the distance in metres below top of the Rabbitkettle Formation. In addition, a suite of hand samples, identified in the form of KK\* 0-12 to indicate the stratigraphic interval represented by these composite samples, was processed to recover conodonts.

Examination of the sequence of silicified trilobites in Section KK led to the recognition that a 58 m interval in the upper Rabbitkettle Formation is repeated by a thrust fault which is located 102 m below the top of the formation (Fig. 2). The interval KK 44 to KK 102 of the hanging wall corresponds to the interval KK 102 to KK 160 of the foot wall of the thrust. The repeated interval includes the Cambrian-Ordovician boundary. The resulting composite Section KK (Fig. 3) shows the true stratigraphic thickness of the interval from KK 220 to the top of the Rabbitkettle to be about 160 m. In this paper, levels within the upper Rabbitkettle are cited as distances in metres below the top of the formation in the composite section.

## Previous Investigations

Tipnis et al. (1979) outlined a conodont succession for Section K (Fig. 2). Biostratigraphically nondiagnostic Upper Cambrian conodonts were recovered from samples K 270 and K 390 (249 m and 213 m below the top of the Rabbitkettle Formation). *Proconodontus muelleri* Miller *s.f.* (= *sensu formo*) in K 525 (172 m below top of Rabbitkettle) represents some portion of Miller's (1975, 1977) *Proconodontus* Zone and suggests a possible early or middle Trempealeauan age. Similarly, their report of "*Oneotodus*" *nakamurai* Nogami, "*O. cf. O. datsonensis*" Druce and Jones and "*O. simplex*" (Furnish) (here regarded as "*O.*" *nakamurai*), *Oistodus cf. cambricus*

# COMPOSITE SECTION KK BIOSTRATIGRAPHY

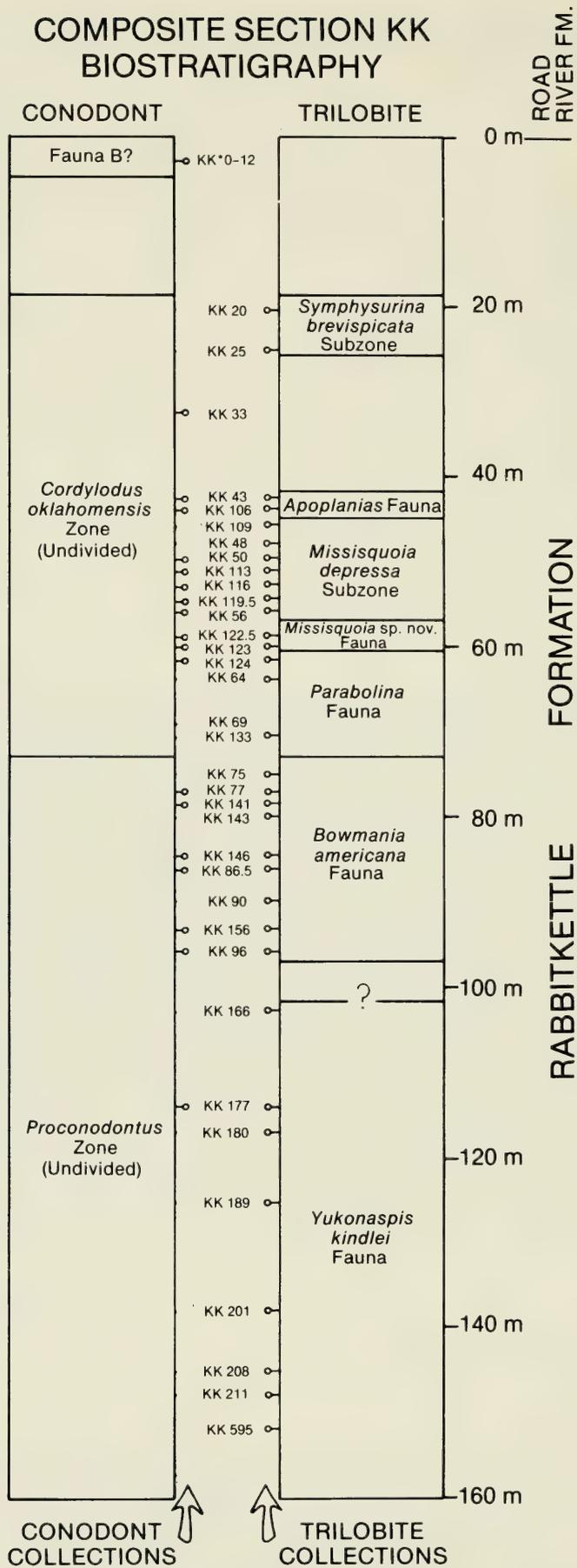


Fig. 3 Composite Section KK showing restored stratigraphic position of samples from the foot and hanging walls of the thrust fault. Productive conodont and trilobite samples are indicated, as are the stratal limits for the conodont and trilobite biostratigraphic units that are discussed in the text.

Miller *s.f.* and *Proconodontus* spp. *s.f.* in K 715 (112 m below top of Rabbitkettle) represents Miller's (1975, 1978) *Proconodontus notchpeakensis* or *Oistodus minutus* subzones of the *Proconodontus* Zone. This fauna indicates an equivalency with the upper *Saukiella junia* or *S. serotina* subzones of the *Saukia* Zone in Utah (Miller, 1978). *Cordylodus* spp. *s.f.* in association with *Missisquoia* Zone trilobites from K 880 (57 m below top of Rabbitkettle) represents the lowest Ordovician portion of Miller's (1975) *Cordylodus proavus* Zone.

An illustrated drepanodiform element, *Drepanodus* cf. *D. simplex* Furnish *s.f.*, with 'Oneotodus' spp. from K 995 and unfigured platform elements from K 1150 (60 m and 25 m below top of Rabbitkettle) were respectively referred to Ethington and Clark's (1971) Fauna B (K 995) and the middle or upper Tremadocian (K 1150). The occurrence of North Atlantic lower Arenigian (K 1900), middle Arenigian (K 2020–K 2145), and upper Arenigian or Llanvirnian (K 2375) conodonts from the Road River Formation suggests that no significant unconformity is present above the Rabbitkettle Formation (Tipnis et al., 1979).

## Trilobite Sequence

The lower 76 m of the composite section (KK 166 to KK 211 and K 510 to K 595 in the foot wall) is assigned to the *Yukonaspis kindlei* Fauna and is considered correlative to the *Saukiella junia* Subzone of Texas and Oklahoma. This correlation is based on the presence of *Euptychaspis typicalis* Ulrich, *Triarthropsis limbata* Rasetti, *Heterocaryon tuberculatum* Rasetti, *Rhaptagnostus clarki* (Kobayashi), and *Calvinella* cf. *prethoparia* Longacre as well as stratigraphic position below the superjacent biostratigraphic unit. This interval also includes species of *Richardsonella* (?), *Eurekia*, *Tatonaspis*, and a sauikiid, as well as *Yukonaspis kindlei*.

The next 22 m in the composite section (KK 141 to KK 156 in the foot wall and KK 75 to KK 156 in the hanging wall) is assigned to the *Bowmania americana* Fauna. *Yukonaspis*, *Richardsonella* (?), *Idiomesus*, *Eurekia*, *Heterocaryon*, *Liostracinoidea*, *Bowmania americana* (Walcott), and two new genera also occur in this fauna.

Overlying the *Bowmania americana* Fauna in the composite section is a 9 m interval assigned to the *Parabolina* Fauna (KK 124 to KK 133 in the foot wall and KK 64 in the hanging wall). This fauna includes *Parabolina* sp. nov., *Richardsonella* (?) cf. *quadrspinosa* Palmer, *Bienvillia* cf. *corax* (Billings), and 'Leobienvillia' *leonensis* Winston and Nicholls, in addition to species of *Yukonaspis*, *Geragnostus*, *Idiomesus*, *Eurekia*, and *Plethometopus*. A single specimen of *Missisquoia* occurs in KK 133. This fauna is correlated with the *Corbinia apopsis* Subzone of Texas and Oklahoma.

A narrow stratigraphic interval above the *Parabolina* Fauna in the foot wall (KK 122.5 and KK 123) contains a low diversity assemblage of *Missisquoia* sp. nov., *Parabolinella*, *Geragnostus*, and *Plethometopus*. This is named the *Missisquoia* sp. nov. Fauna. It is not certain whether this represents an older level than the base of the *Missisquoia* Zone in Oklahoma.

The next 12 m of the composite section (KK 109 to KK 119.5 in the foot wall and

KK 48 to KK 56 in the hanging wall) is confidently assigned to the *Missisquoia depressa* Subzone. This interval is very fossiliferous and contains *Parabolinella* sp. nov., *Parabolinella hecuba* (Walcott), *Missisquoia depressa* Stitt, *Ptychopleurites brevifrons* (Kobayashi), *Geragnostus*, *Levisaspis glabrus* (Shaw), and *Plethome-topus*.

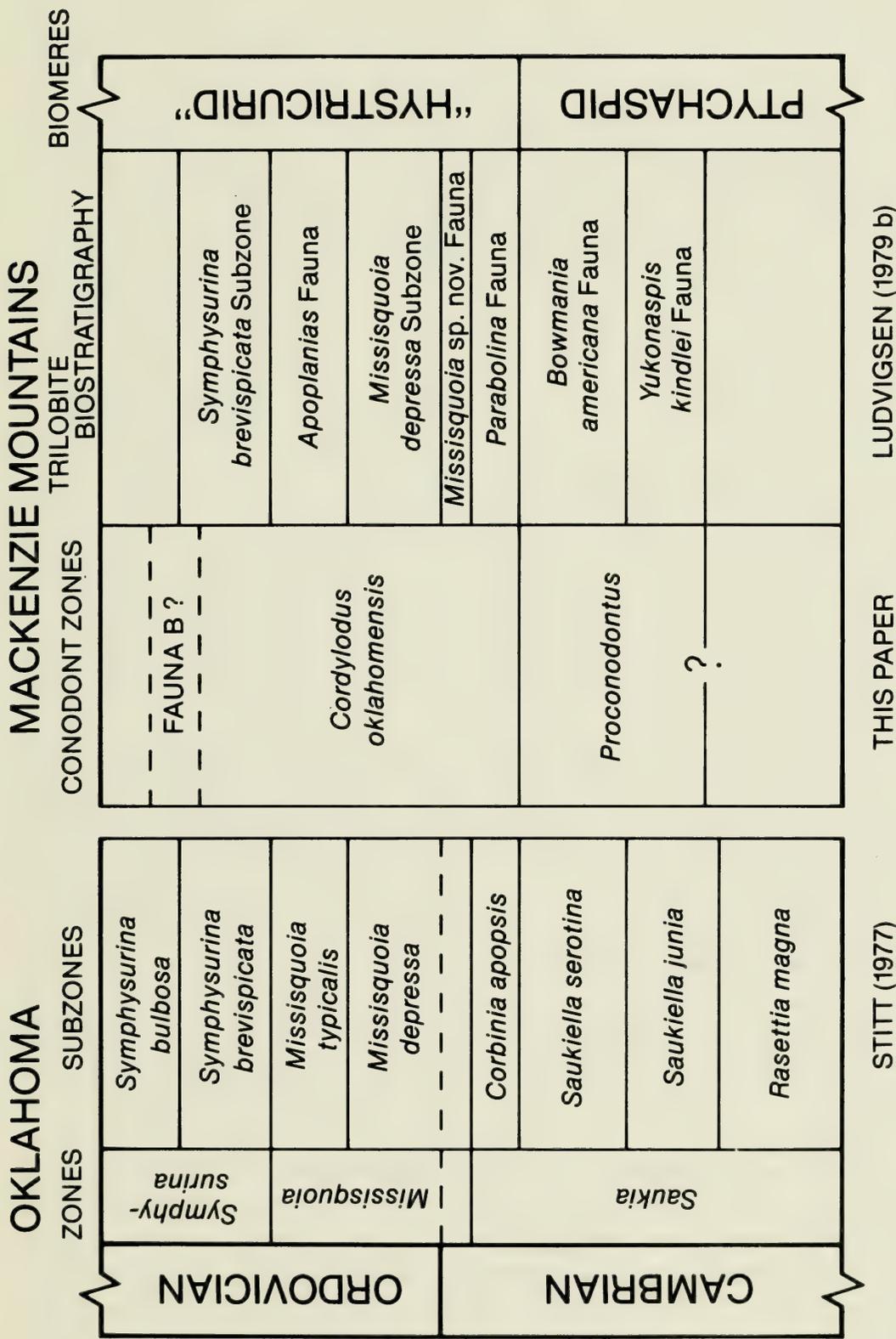
Overlying the *Missisquoia depressa* Subzone in the composite section is an interval (KK 106 in the foot wall and KK 43 in the hanging wall) dominated by *Parabolinella*, *Apoplanias*, and *Geragnostus*. This is named the *Apoplanias* Fauna and is tentatively correlated with the *Missisquoia typicalis* Subzone of Oklahoma.

The highest trilobite-bearing interval in the Rabbitkettle Formation is a narrow interval (KK 20 and KK 25 in the hanging wall) with *Apoplanias*, *Symphysurina* cf. *brevispicata* Hintze, and *Geragnostus*. These collections are correlated with the *S. brevispicata* Subzone of the *Symphysurina* Zone in Oklahoma.

Considerable problems are encountered in correlating the trilobite succession in the upper Rabbitkettle Formation at Section KK with coeval successions in central Texas (Winston and Nicholls, 1967; Longacre, 1970) and the Arbuckle and Wichita Mountains of Oklahoma (Stitt, 1971, 1977). Saukiid trilobites, the prime biostratigraphic indices of the Trempealeuan zonation established in Texas by Winston and Nicholls (1976) and Longacre (1970), are uncommon in the Rabbitkettle Formation. *Calvinella* is the only well-represented member of this family in Section KK and it only occurs in a single collection. Other important genera of the latest Cambrian zonation in Texas and Oklahoma, such as *Acheliops*, *Bayfieldia*, *Rasettia*, *Stenopilus*, *Theodenisia*, *Briscoia*, *Keithiella*, *Bynumina*, *Bynumiella*, and *Corbinia* have not been recovered from the Rabbitkettle Formation.

One of the few firm correlation tie-points between the Northwest Territories and Oklahoma (Fig. 4) is the 12 m thick *Missisquoia depressa* Subzone in the Rabbitkettle which undoubtedly is correlative with the 6 m thick *M. depressa* Subzone in the Signal Mountain Limestone in Oklahoma (Stitt, 1977). The substantial difference in generic composition within this subzone suggests the influence of environmental factors. The *M. depressa* Subzone in Oklahoma is strongly dominated by *Plethopeltis* (about 85% of 260 specimens). This genus does not occur in Section KK where the subzone is dominated by *Parabolinella* (about 65% of 760 specimens). *Geragnostus* is also much more abundant in the *M. depressa* Subzone in Section KK than in Oklahoma.

Each of the 14 trilobite collections from the base of the *Missisquoia* sp. nov. Fauna to the *Symphysurina* Zone at Section KK is dominated by olenid and agnostid trilobites. In addition, two olenids and one agnostid occur in the *Parabolina* Fauna. Thus, the upper part of Section KK is numerically dominated by trilobites characteristic of slope and outer shelf facies in the Lower Palaeozoic (Lochman-Balk and Wilson, 1958; Fortey, 1975; Taylor, 1977; Ludvigsen, 1979a). The evidence for the lower part of Section KK is less clear, but it is not inconsistent with a similar outer shelf position (Taylor, 1977:table 3). Section KK, therefore, records a sequence of trilobite faunas which, in comparison with coeval inner shelf sequences in Texas and Oklahoma, appears to represent an unrestricted open marine sequence deposited in an outer shelf setting.



STITT (1977)      THIS PAPER      LUDVIGSEN (1979 b)

Fig. 4 Correlation of conodont zones and trilobite biostratigraphic units in the Cambrian-Ordovician boundary beds of the upper Rabbitkettle formation at Section KK with sequence of trilobite zones and subzones in Oklahoma.

## *Depositional Setting*

Dark grey, thinly bedded, more-or-less silty lime mudstone and fossiliferous lime wackestone that regularly alternate with finely laminated, thinner calcareous siltstones dominate the section. Thin oolitic and granule intraclastic lime wackestones and packstones appear in the *Yukonaspis kindlei* Fauna and the *Bowmania americana* Fauna. Bedding surfaces are typically planar with sedimentary boundinage appearing with the *Parabolina* Fauna and through higher strata. Bioturbation and light grey lime wackestones and mudstones are present only in the *Bowmania americana* Fauna interval. Trilobite remains observed on bedding surfaces and in etched residues are typically disarticulated but are neither abraded nor severely broken.

The regular alternations of fine-grained silty, dark limestones and thinner calcareous siltstones with occasional well-sorted and winnowed allochem limestones suggest episodic deposition generally below effective wave base. The absence of features such as penecontemporaneously contorted and folded beds, slumps, mass movement deposits occupying channels, and carbonate flyschoid beds with erosional bases precludes deposition on or at the foot of a steep submarine slope. Such features appear in coeval fine-grained clastics of the Road River Formation in the Selwyn Basin to the northwest of Section K (Cecile, 1978).

Similarly, a restricted marine, very shallow or intertidal, inner shelf depositional environment is not indicated because of the absence of fenestral fabric, flat pebbles, channels and scour and fill structures, early dolomitized lime mudstone, prominent bioturbation, algalaminates and stromatolites, wave or tidally produced sedimentary structures, evaporites, and light coloration (Roehl, 1967; Shinn, 1968; Wilson, 1970, 1974; Cook, 1972).

The upper Rabbitkettle Formation of Section KK contains few lithologic features which can be assigned to a unique depositional environment. However, it is probable that these beds were deposited under low energy open shelf or very low angle muddy slope conditions. It is questionable whether Wilson's (1969) association of the type of sedimentary boudinage present within the Lower Ordovician of Section KK with shallow subtidal shelf deposition below effective wave base is appropriate. The presence of intercalated oolitic, intraclastic, and fossiliferous (trilobite and "pelmatozoan") grainstones and packstones low in the sequence suggests that lime mud and silt deposition was punctuated by the transport of allochthonous carbonate debris by nonturbid bottom traction currents or nonturbid sand sheet flows. The source of this debris quite likely lay to the east in the area of platform deposition of the Broken Skull Formation.

A two-fold division is apparent in the rocks of Section KK: 1) a lower sequence of planar bedded, medium to light grey and silty lime mudstones, wackestones, and grainstones, which locally are bioturbed, and 2) an upper sequence of wavy bedded, dark grey and silty lime mudstones which lack bioturbation. This lithologic division also coincides with a pronounced faunal division. The lower sequence (*Yukonaspis kindlei* Fauna and *Bowmania americana* Fauna) contains typical *Saukia* Zone trilobites and the upper sequence (*Parabolina* Fauna to *Symphysurina brevispicata* Subzone) is dominated by olenids, agnostids, and trilobites of probable extra-North American origin. The base of the *Parabolina* Fauna thus coincides with a significant environmental change and this level was interpreted by Ludvigsen (1979b) as a biomere boundary.

## Conodont Sequence

### General

Ten multi-element and form species are represented among the 202 specimens recovered from 23 of 45 samples. Conodont elements have a thermal colour alteration index of 4.5 to 5 (Epstein et al., 1977) and slightly corroded surfaces. The sparse, low diversity conodont faunas from Section KK can be compared with Miller's (1975, 1977, 1978) conodont zonation of the western USA.

### *Proconodontus* Zone

Conodonts from the upper *Yukonaspis kindlei* Fauna and *Bowmania americana* Fauna intervals of Section KK include multi-element "*Proconodontus*" *carinatus* Miller (= *Proconodontus carinatus s.f.* and *P. notchpeakensis* Miller *s.f.*), *P. serratus* Miller *s.f.*, "*Oneotodus*" *nakamurai* Nogami, "*Prooneotodus*" *tenuis* (Müller), and *Furnishina asymmetrica* Müller.

Miller (1978) has equated the upper *Saukiella junia* Subzone and lowest *S. serotina* Subzone with the *Proconodontus notchpeakensis* Subzone of the *Proconodontus* Zone. The first appearance of *Oistodus minutus* Miller *s.f.* in the lower *S. serotina* Subzone and its persistence to the top of that trilobite subzone defines the *Oistodus minutus* Subzone of the upper *Proconodontus* Zone.

*Oistodus minutus s.f.* was not recovered in this study. Consequently, the faunally similar *Proconodontus notchpeakensis* and *O. minutus* subzones cannot be differentiated in Section KK.

"*Oneotodus*" *nakamurai* appears in the *Bowmania americana* Fauna in Section KK. The species has its lowest occurrence in the *Corbinia apopsis* Subzone in the western United States where it regularly appears along with the first *Cordylodus* form species (Miller, 1975, 1977, 1978; Kurtz, 1976). However, "*O.*" *nakamurai* occurs in rocks older than those bearing *Cordylodus* in the People's Republic of China (Nogami, 1967), Alberta (Derby et al., 1972), Appalachian North America (Landing, 1977, 1979), Korea (Lee, 1975), and Australia (Druce and Jones, 1971).

A single element representing *Fryxellodontus?* sp. nov. from the *Bowmania americana* Fauna is a possible Upper Cambrian representative of the genus. *Fryxellodontus lineatus* Miller and *F. inornatus* Miller first appear at the base of the Lower Ordovician *Missisquoia typicalis* Subzone in the western United States (Miller, 1977, 1978).

Tipnis et al. (1979) report an anomalous occurrence of *Clavohamulus* cf. *C. bulbosus* (Miller) from K 390 (213 m below the top of the Rabbitkettle). The species is known from the upper *Missisquoia typicalis* Subzone and lower *Symphysurina* Zone in the western USA (Miller, 1978). The occurrence of the species below the lowest studied trilobites in Section KK (*Yukonaspis kindlei* Fauna) suggests that the *Clavohamulus* lineage originated considerably before the Lower Ordovician.

## *Cordylodus oklahomensis* Zone

The disappearance of several conodont species and the appearance of *Cordylodus proavus* Müller *s.f.*, *C. oklahomensis* Müller *s.f.*, “*Oneotodus*” *nakamurai*, and *Hirsutodontus* at the base of the *Corbinia apopsis* Subzone define the base of Miller’s (1975, 1977, 1978) *Cordylodus proavus* Zone. Miller (1975, 1977, 1978) has divided the latest Cambrian through lowest Ordovician *Cordylodus proavus* Zone (= *Corbinia apopsis* Subzone– lower *Symphysurina* Zone) into five subzones.

*Cordylodus proavus s.f.* is part of multi-element *C. oklahomensis* (see Systematic Palaeontology) and the designation “*Cordylodus oklahomensis* Zone” is here substituted for “*C. proavus* Zone”.

*Cordylodus oklahomensis* Zone faunas from Section KK are sparse and of low diversity. The eponymous species first appears in uppermost Cambrian strata equivalent to the *Corbinia apopsis* Subzone although the species was not recovered in this study from the base of the *Parabolina* Fauna. However, the *Proconodontus* and *C. oklahomensis* Zone faunas are not as strongly differentiated as they are in Texas, Utah, and Wyoming (Miller, 1975, 1977, 1978; Kurtz, 1976). As noted above, “*Oneotodus*” *nakamurai* first appears in the *Proconodontus* Zone in the Rabbitkettle. In addition, Tipnis et al. (1979) note the co-occurrence of *Proconodontus muelleri* Miller *s.f.* with *Cordylodus proavus s.f.* and *Missisquoia* in K 880 (57 m below top of Rabbitkettle Formation). The persistence of *P. muelleri* into the Lower Ordovician contrasts with the species’ disappearance just below the *Corbinia apopsis* Subzone in the western USA (Miller, 1975, 1977, 1978; Kurtz, 1976). *Proconodontus* Zone species also persist into the local range zone of *Cordylodus oklahomensis* in Vermont (Landing, 1979).

Miller’s subzonal sequence of the *Cordylodus oklahomensis* Zone is based on the range zones of species of *Hirsutodontus*, *Clavohamulus*, and *Fryxellodontus*. The absence of these forms precludes division of the zone in Section KK. A single element of *Fryxellodontus inornatus* from KK 43 supports the tentative correlation of the *Apoplanias* Fauna with the *Missisquoia typicalis* Subzone. Miller (1978) documents the occurrence of *F. inornatus* through the *Fryxellodontus inornatus* and lower *Clavohamulus* subzones (middle *Cordylodus oklahomensis* Zone) and equates these with the *Missisquoia typicalis* Subzone.

The youngest conodont collection (KK\* 0–12) consists of one element of “*Proconodontus*” *carinatus*. This composite sample was collected above the highest trilobite collection (KK 20) and could represent either the upper *Cordylodus oklahomensis* Zone or Ethington and Clark’s (1971) Fauna B. This uncertain correlation is due to the absence of associated *Cordylodus* form species. Fauna B is recognized by the appearance of advanced form species of *Cordylodus*, including *Cordylodus lindstromi* Druce and Jones, 1971, and *C. intermedius* Furnish, 1938 (Miller, 1975). However, 1) the recovery of *C. intermedius* from the *Cordylodus oklahomensis* Zone (Miller, 1978; Landing, 1979; this report), 2) the probability that “*C. lindstromi*” is an ontogenetic variant with supernumerary basal tips that appears in all *Cordylodus* elements (Landing, 1979), and 3) the persistence of upper *Cordylodus oklahomensis* Zone species into Fauna B (Miller, 1970; Landing, 1979) make the differentiation of Fauna B unclear at present.

## Conodont Biofacies

Although conodonts are sparsely represented in samples from Section KK, the faunal sequence has closer similarities with continental slope sequences from the Appalachians (Landing, 1979) than with inner carbonate platform successions in the western USA (Miller, 1969, 1970, 1975, 1977, 1978; Kurtz, 1976). These differences are most obvious in the generic composition of the euconodont components (Bengtson, 1976) of *Cordylodus oklahomensis* Zone faunas.

Multi-element "*Proconodontus*" *carinatus* and *Cordylodus oklahomensis* and mono-elemental "*Oneotodus*" *nakamurai* are dominant species both in continental slope and inner carbonate platform sequences. These three species are represented by 83 per cent of the elements from Miller's (1978) Lava Dam Five section in the upper Notch Peak Limestone and lower House Limestone, western Utah. Species of *Clavohamulus*, *Fryxellodontus*, and *Hirsutodontus*, which are used for the subzonation of the *Cordylodus oklahomensis* Zone (Miller, 1975), are represented by 7 per cent of the elements at the Lava Dam Five section. Although elements of *Clavohamulus*, *Fryxellodontus*, and *Hirsutodontus* are relatively minor components of *Cordylodus oklahomensis* Zone faunas in shallow-water sequences, these components are absent or very sparingly represented in continental slope deposits in the Appalachians. Landing (1979) recovered only one element of *Fryxellodontus lineatus* from the Highgate and Gorge formations, northwestern Vermont. Similarly, representatives of the three genera have not been encountered in *Cordylodus oklahomensis* Zone faunas from the Green Point Group, western Newfoundland (E. Landing, unpublished data). Similar *Cordylodus oklahomensis* Zone faunas are present in the lower Grove Formation, at Lime Kiln, central Maryland (E. Landing, unpublished data) where the transition from the upper Frederick Limestone to the lower Grove Formation represents a progradation of shallow shelf carbonates over fine-grained carbonates (Reinhardt, 1974). The lower Grove Formation at Lime Kiln consists of festoon bedded, oolite bar deposits. This shelf margin sequence has yielded low diversity conodont faunas comprised of *Cordylodus*, "*Proconodontus*", and "*Oneotodus*".

The reasons for the absence or near absence of *Clavohamulus*, *Fryxellodontus*, and *Hirsutodontus* from the outermost shelf or slope environments listed above and from the Rabbitkettle Formation are unknown. Water depth and energy of the environment do not seem to be common factors which would limit their distribution. It is possible that representatives of the three genera were adapted to variable and/or elevated salinities and temperatures of the restricted marine conditions of the inner shelf and were environmentally stenotopic. *Cordylodus* species and the ancestral "*Proconodontus*" *carinatus* and "*Oneotodus*" *nakamurai* are geographically widespread in terms of lithofacies associations and were presumably eurytopic.

Biofacies developments in euconodont distributions in *Proconodontus* Zone faunas are obscure at present. Landing (1979) did not encounter *Oistodus minutus* Miller *s.f.* in upper *Proconodontus* Zone faunas in slope deposits in northwestern Vermont. The form was recovered in turbiditic limestones in the Taconic allochthon (Landing, 1977, 1979) although it is absent in the uppermost Cambrian in the Green Point Group, western Newfoundland (E. Landing, unpublished data). Similarly, deep shelf lithotopes of the uppermost Frederick Limestone, central Maryland, have not yielded the species. It is possible that *O. minutus* may be found to be more regularly associated with restricted, marine inner shelf deposits.

## Discussion

Reinvestigation of the lithologic and faunal sequences of Section KK demonstrates the stratigraphic repetition of the section by a thrust fault located 102 m below the top of the Rabbitkettle Formation. Tipnis et al. (1979) recovered lowest Ordovician conodonts and trilobites at K 880 (Fig. 2). Conodonts from their sample K 995 higher in the section do not represent Ethington and Clark's (1971) Fauna B and are referable to the preuppermost Cambrian *Proconodontus* Zone (*Saukiella serotina* Subzone equivalent). Similarly, the report of middle or upper Tremadocian "platform elements" from K 1150 (30.4 m below top of Rabbitkettle) (Tipnis et al. 1979) cannot be evaluated because the specimens were not illustrated. However, conodonts recovered in this study from KK 33 and KK\* 0-12 seem to represent the upper *Cordylodus oklahomensis* Zone or, possibly, Fauna B, and are of Lower Tremadocian aspect.

As discussed above, the Rabbitkettle Formation at Section KK has no lithologic features indicating shallow, inner carbonate platform deposition. The deep, outer shelf or low angle slope depositional environment suggested above is supported by the composition of uppermost Cambrian and lowest Ordovician trilobite faunas.

The absence of *Clavohamulus* and *Hirsutodontus* and poor representation of *Fryxellodontus* in *Cordylodus oklahomensis* Zone faunas from the Rabbitkettle Formation at Section KK are considered to be related to unrestricted marine conditions of deposition and have parallels in Appalachian outermost shelf and continental slope faunas. Although it is less clear, the absence of *Oistodus minutus* s.f. in the upper *Proconodontus* Zone may also be related to the palaeogeographic setting of Section KK.

Miller's (1975, 1977, 1978) conodont-based subzonation of the uppermost Cambrian through lowest Ordovician (*Saukiella junia* Subzone through lower *Symphysurina* Zone) provides a biostratigraphic resolution comparable to that provided by trilobite faunas. However, the absence of key conodont species in Cambrian-Ordovician boundary beds in outer shelf and slope deposits results in recognition only of the *Proconodontus* and *Cordylodus oklahomensis* zones and not faunas referable to conodont subzones. This biofacies control of conodonts has probable implications for conodont-based correlations of Cambrian-Ordovician (Olenidian-Tremadocian series) boundary beds of the classic Acado-Baltic biofacies of the Cambrian and Ordovician systems. The deposition of the carbonate-poor Acado-Baltic sequences of this age in palaeogeographic settings that had unrestricted access to the open ocean (Ross, 1975) suggests that conodont species required for subzonation of the *Proconodontus* and *Cordylodus oklahomensis* zones may not be encountered here with enough regularity for precise correlations. Landing et al. (1978) recovered only *Proconodontus carinatus* s.f. and *Cordylodus proavus* s.f. in the uppermost Cambrian in the Acado-Baltic sequence on Navy Island, New Brunswick, and did not encounter the *Hirsutodontus* species which appear in the lowest *Cordylodus oklahomensis* Zone in the western USA (see also Miller, 1977, 1978).

# *Systematic Palaeontology*

## **Remarks**

Conodont taxa are listed alphabetically. A suprageneric classification is not applied although the informal designations "protoconodont", "paraconodont", and "euconodont" (Bengtson, 1976) are used to summarize the growth modes of conodont elements. Conodont form species are designated in *sensu formo* (*s.f.*) when the composition of the apparatus is unknown. The presumed hyolithelminthoid *Phosphannulus* is listed at the end of the section.

## **Repository**

Royal Ontario Museum, Toronto (ROM). Figured specimens are stored under ROM numbers 38361 to 38375. Topotype collections from the upper Rabbitkettle Formation are repositied under ROM numbers 38401 to 38444.

### **Phylum uncertain**

### **Class uncertain**

### **Order Conodontophorida Eichenberg, 1930**

### **Genus *Cordylodus* Pander, 1856**

## **Type Species**

*Cordylodus angulatus* Pander, 1856, *s.f.* from the Early Ordovician glauconitic sandstones of Estonia.

## **Emended Diagnosis**

Euconodonts represented by a bi-elemental apparatus consisting of a numerically predominant cordylodiform element and a subordinate cyrtoniodiform element. Cusp and denticles are albid and the elements lack any surface microsculpture.

## **Discussion**

Previous reconstructions of the *Cordylodus* apparatus (Bergström and Sweet, 1966; Sweet and Bergström, 1972; Barnes and Poplawski, 1973; Nowlan, 1976) are not followed in this report and J. F. Miller's (pers. comm. to E. L., 1977) reconstruction is followed. The *Cordylodus* apparatus is bi-elemental and consists of an element with rounded denticles and cusp and a second element with laterally flattened, basally confluent denticles and cusp. The former, termed the "rounded element" by Miller, is here designated the "cordylodiform element" because this plan is shown by the type form species. The second element, Miller's "flattened element", is termed the "cyrtoniodiform element" because its plan is similar enough to *Cyrtoniodus* Stauffer *s.f.* that some authors (Miller, 1970; Ethington and Clark, 1971) have referred "flattened elements" to that form genus.

Cordylodiform elements are generally more abundant in collections than cyrtioniodiform elements. The former are more variable in a large collection than associated cyrtioniodiform elements and show a more-or-less distinctive symmetry transition series (see also Ethington and Clark, 1971 : 68, pl. 1, figs. 15, 16, 20). Cordylodiform elements designated in the literature as 1) *Cordylodus proavus* Müller *s.f.*, 2) *C. intermedius* Furnish *s.f.*, and 3) "*C. lindstromi*" Druce and Jones *s.f.* are externally identical. They are separable, respectively, by 1) a convex anterior margin of the basal cavity, 2) a straight to concave anterior margin of the basal cavity, and 3) convex to concave anterior profile of the basal cavity and presence of secondary basal tips. The associated cyrtioniodiform elements are 1) *C. oklahomensis* Müller, *s.f.*, 2) an unnamed element often misidentified as *C. oklahomensis* or *C. prion* Lindström *s.f.* and 3) an element included by Druce and Jones (1971) in the definition of "*C. lindstromi*" *s.f.* These cyrtioniodiform elements are distinguished by developments in the anterior profile of the basal cavity which parallel those in the cordylodiform element.

"*Cordylodus lindstromi*" elements are not considered to represent a biologic species. Druce and Jones (1971) illustrated a cyrtioniodiform holotype (pl. 1, figs. 9a, b, text-fig. 23h) and paratype cordylodiform (pl. 1, figs. 7a–8b, pl. 2, figs. 8a–c) elements with secondary basal tips. One paratype (pl. 2, figs. 8a–c) has a convex anterior margin of the basal cavity and is comparable to *C. proavus s.f.* with exception of a second basal tip. A second paratype (pl. 1, figs. 7a, b) has the straight anterior margin of the basal cavity which is present in early elements of *C. intermedius*. Druce and Jones's (1971) holotype of "*C. lindstromi*" is otherwise comparable to the cyrtioniodiform element of *Cordylodus intermedius*. Miller (1970) illustrated in *nomen nudum* forms designated *Cordylodus insertus* sp. nov. *s.f.* and *C. sp. aff. insertus* sp. nov. *s.f.* These elements are closely similar to *C. proavus s.f.* and *C. oklahomensis s.f.*, respectively, but have an additional basal tip.

Accessory apices of the basal cavity are regarded in this report as not of significance in the classification of *Cordylodus* and are developmental variants. The anterior profile of the basal cavity is considered to have primary significance in the classification of *Cordylodus* elements. Although Miller (1975, 1977) has used the first appearance of "*Cordylodus lindstromi*" in defining Ethington and Clark's Fauna B, he has illustrated a *C. oklahomensis s.f.* element from the underlying *Cordylodus oklahomensis* Zone with secondary apices of the basal cavity (Miller, 1969: pl. 65, fig. 53). Nowlan (1976) recovered "*C. lindstromi*" from sequences older than Fauna B.

Advanced *Cordylodus intermedius* gave rise to multi-element *C. angulatus* Pander and *C. rotundatus* Pander of Fauna C. The latter apparatuses have apparently indistinguishable cyrtioniodiform elements referable to *C. prion* Lindström *s.f.* (J. F. Miller, pers. comm. to E. L., 1977). The "phrygian cap" anterior profile of the basal cavity of *C. angulatus s.f.* and *C. rotundatus s.f.* is a more exaggerated condition than that seen in the concave profile of *C. intermedius s.f.*

*Cordylodus* is a characteristic latest Cambrian and Tremadocian genus in the North American, Australasian, Siberian, and Acado-Baltic faunal provinces (Müller, 1959, 1973; Miller, 1969; Druce and Jones, 1971; Abaimova and Markov, 1977; Landing, et al., 1978). Van Wamel (1974) reported the genus in the lower Arenigian of Sweden. Dzik (1976) renamed a Llanvirnian and Llandeilian apparatus containing cordylodiform and ramiform elements *Spinodus spinatus* (Hadding). *Cordylodus horridus*

*s.f.* of Barnes and Poplawski (1973) from the uppermost Arenigian (Landing, 1976) seems to be part of an undescribed apparatus (R. L. Ethington, pers. comm. to E. L. 1978).

The ancestor of the earliest appearing *Cordylodus* species, *Cordylodus oklahomensis*, appears to have been a middle Trempealeauan species consisting of *Proconodontus carinatus* Miller *s.f.* and *P. notchpeakensis* Miller *s.f.*

### ***Cordylodus intermedius* Furnish, 1938, *s.f.***

Figs. 5E, 6A, B

*Cordylodus intermedius* Furnish, 1938:338, pl. 42, fig. 31, text-fig. 2C.

*Cordylodus insertus* Miller, 1970:88, 89 (*nomen nudum*) (*pars*, pl. 1, figs. 37, 38).

*Cordylodus* cf. *C. angulatus*—Druce and Jones, 1971:67, text-fig. 23c.

*Cordylodus caseyi* Druce and Jones, 1971:67, 68, pl. 2, figs. 9a–12c, text-figs. 23d, e.

*Cordylodus intermedius*—Druce and Jones, 1971:68, pl. 3, figs. 1a–3b, text-figs. 23f, g.

*Cordylodus proavus*—Druce and Jones, 1971:70, 71, (*pars*, pl. 1, figs. 1a, b, 3, 5a–6, text-figs. 23p, q, (*non C. proavus* Müller, 1959, *s.f.*).

*Cordylodus* cf. *C. proavus*—Druce and Jones, 1971:71, (*pars*, pl. 1, figs. 10a–11b, *non C. proavus* Müller, 1959, *s.f.*).

*Cordylodus caseyi*—Jones, 1971:46, pl. 2, figs. 1a–c.

*Cordylodus intermedius*—Jones, 1971:46, pl. 2, figs. 2a–3c.

*Cordylodus lindstromi*—Jones, 1971:47, pl. 2, figs. 4a–c.

*Cordylodus intermedius*—Müller, 1973:30, pl. 10, figs. 1a–3, text-figs. 2c, 4a, b.

*Cordylodus lenzi* Müller, 1973:31, pl. 10, figs. 5–9, text-figs. 2f, 5a, b.

*Cordylodus angulatus*—Viira, 1974:63, (*pars*, pl. 1, fig. 8, text-figs. 4a, b, *non C. angulatus* Pander, 1856, *s.f.*).

*Cordylodus angulatus*—van Wamel, 1974:58, 59, (*pars*, pl. 1, figs. 6, 7, *non C. angulatus* Pander, 1856, *s.f.*).

*Cordylodus intermedius*—Repetski, 1975:44, 45, pl. 1, figs. 11, 12.

*Cordylodus intermedius*—Nowlan, 1976:149, 150, pl. 2, figs. 1, 2.

?*Cordylodus* cf. *C. intermedius*—Tipnis et al., 1979:31, pl. 1, fig. 7.

*Cordylodus intermedius*—Landing, 1979:62–64, 133–135, 200–201, pl. II–3, fig. 3, pl. III–1, fig. 8, pl. IV–2, fig. 6 (*pars*, citations listed are only those of *C. intermedius s.f.*).

### **Occurrence and Hypotype**

One element (ROM 38373) from KK 33. The associated conodont fauna represents the upper *Cordylodus oklahomensis* Zone.

### **Remarks**

The shape of the basal cavity of *Cordylodus intermedius s.f.* is intermediate between those of *C. proavus s.f.* and *C. angulatus s.f.* as noted by Druce and Jones (1971) and

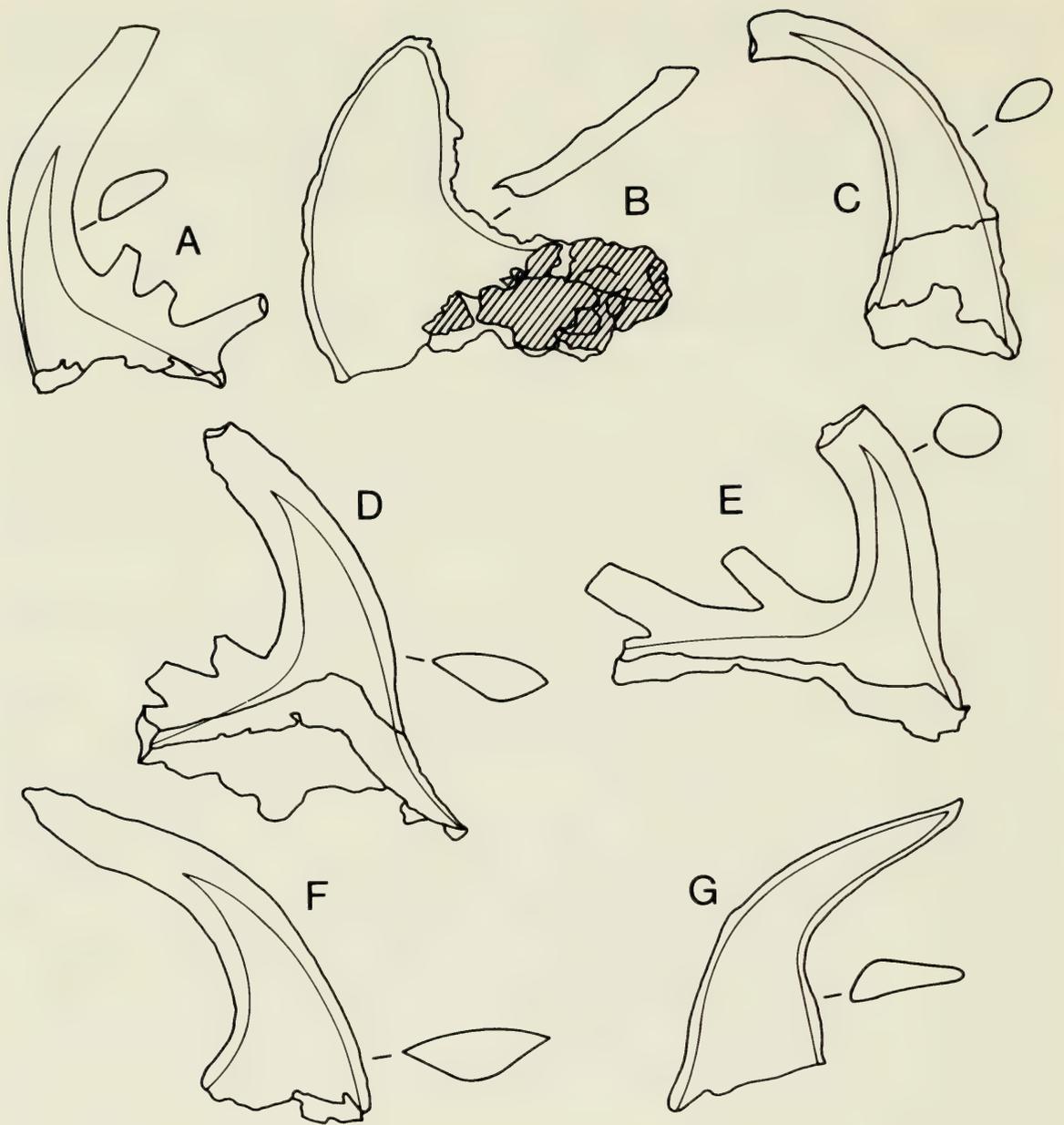


Fig. 5A, D *Cordylodus oklahomensis* Müller, cordylodiform, ROM 38372,  $\times 70$ , and cyrtioniodiform, ROM 38367,  $\times 75$ , elements, respectively.  
 B *Fryxellodontus?* sp. nov. Lateral view of serrated elements with attached pyrite crystals (diagonal ruling), ROM 38366,  $\times 60$ .  
 C, F "*Proconodontus*" *carinatus* Miller, drepanodiform, ROM 38365,  $\times 60$ , and scandodiform, ROM 38362,  $\times 150$ , element, respectively.  
 E *Cordylodus intermedius* Furnish *s.f.*, ROM 38373,  $\times 140$ .  
 G Protoconodont sp. indet. *s.f.*, ROM 38375,  $\times 55$ .

Müller (1973). The element (Fig. 6A) has rounded denticles and cusp and has a straight anterior profile of the basal cavity which differs from the convex profile present in cordylodiform elements of *C. oklahomensis*. The surface of the element has undergone slight dissolution and blocky crystallites are exposed on the surface (Fig. 6B).

## *Cordylodus oklahomensis* Müller, 1959

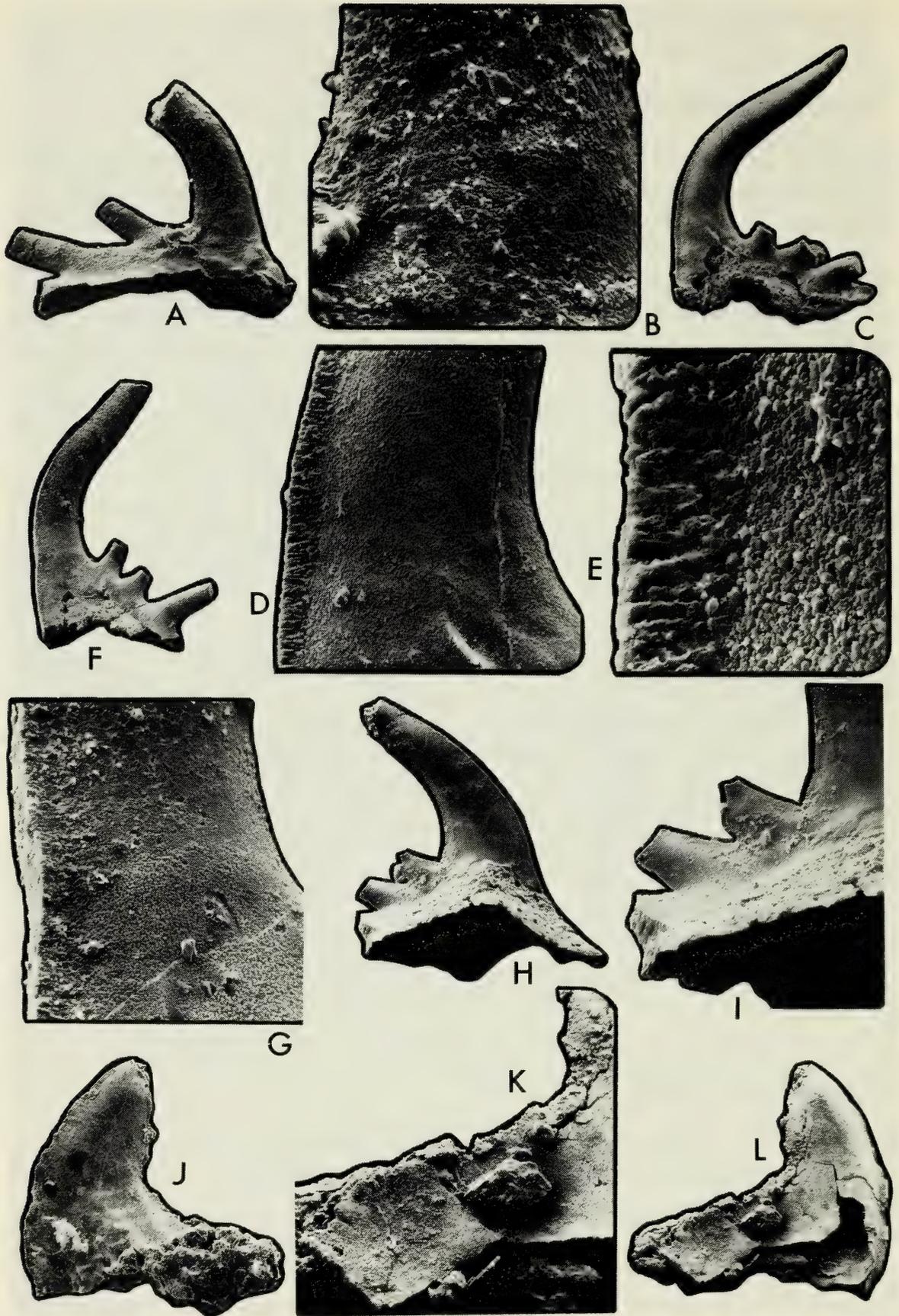
Figs. 5A, D, 6C-E

### **Cordylodiform Element**

- Cordylodus proavus* Müller, 1959:448, 449, pl. 15, figs. 11, 12, 18, text-fig. 3B.  
*Cordylodus proavus*—Miller, 1969:424–426, pl. 65, figs. 37–45, text-fig. 3D.  
*Cordylodus insertus* Miller, 1970:88, 89 (*nomen nudum*), (*pars*, pl. 1, fig. 37, text-fig. 11B).  
*Cordylodus proavus*—Miller, 1970:89, text-fig. 11D.  
*Cordylodus lindstromi* Druce and Jones, 1971:68, 69, pl. 2, figs. 8a–c (*pars*).  
*Cordylodus proavus*—Druce and Jones, 1971:70, 71 (*pars*, pl. 1, figs. 2a, b, 4a, b, text-fig. 23r).  
*Cordylodus* cf. *C. proavus*—Druce and Jones, 1971:71, (*pars*, pl. 1, figs. 12a, b, text-fig. 23s).  
*Cordylodus proavus*—Ethington and Clark, 1971:71, pl. 1, fig. 19.  
*Cordylodus proavus*—Jones, 1971:48, pl. 2, figs. 9a–c.  
*Cordylodus proavus*—Miller and Melby, 1971:120, pl. 1, figs. 18, 19.  
*Cordylodus proavus*—Müller, 1973:35, pl. 9, figs. 1–4, 9, text-figs. 2a, 9a, b.  
*Cordylodus angulatus*—van Wamel, 1974:58, 59 (*pars*, pl. 1, fig. 5, *non C. angulatus* Pander, 1856, *s.f.*).  
*Cordylodus proavus*—Abaimova, 1975:109, 110, pl. 10, fig. 16, text-fig. 8 (27, 28).  
*Cordylodus proavus*—Nowlan, 1974:15, pl. 1, figs. 9, 10, 14–16.  
*Cordylodus proavus*—Abaimova and Markov, 1977:91, pl. 14, fig. 1.  
*Cordylodus proavus*—Landing et al., 1978:76, text-fig. 2F.  
*Cordylodus proavus*—Fåhraeus and Nowlan, 1978:453, pl. 1, figs. 8, 9.  
*Cordylodus proavus*—Tipnis et al., 1979:31, pl. 1, figs. 8, 9.  
?*Cordylodus* cf. *C. proavus*—Tipnis et al., 1979:31, pl. 1, fig. 10.  
*Cordylodus proavus*—Landing, 1979:21, 22, pl. I-1, figs. 10, 13.  
*Cordylodus oklahomensis*—Landing, 1979:64, 65, 135, 136, 202, 203, pl. II-3, fig. 1, pl. III-1, fig. 11, pl. IV-2, fig. 8 (*pars*, cited figures only of *C. proavus s.f.*).

### **Cyrtoniodiform Element**

- Cordylodus oklahomensis* Müller, 1959:447, 448, pl. 15, figs. 15a–16.  
*Cordylodus oklahomensis*—Miller, 1969:423, 424, pl. 65, figs. 46–53.  
*Cordylodus* sp. aff. *C. insertus* Miller, 1970:89, pl. 1, fig. 40, text-fig. 11C.  
*Cyrtoniodus oklahomensis*—Miller, 1970:90, 91, pl. 1, figs. 35, 36, text-fig. 11F.  
*non Cordylodus oklahomensis*—Druce and Jones, 1971:69, pl. 5, figs. 6a–7c, text-fig. 23 (= cyrtoniodiform element of *Cordylodus intermedius* Furnish apparatus).  
*Cordylodus oklahomensis*—Ethington and Clark, 1971:71, pl. 1, fig. 24.  
*Cyrtoniodus prion*—Miller and Melby, 1971:120 (*pars*, pl. 2, fig. 17, *non C. prion* Lindström, 1955, *s.f.*).  
?*Cordylodus oklahomensis*—Jones, 1971:47, 48, pl. 2, figs. 5a–8b.  
*Cordylodus oklahomensis*—Müller, 1973:33, pl. 9, figs. 12–13b, text-figs. 2B, 7a, b.



*Cordylodus prion prion* Nowlan, 1976:154–156, pl. 2, figs. 23–31.

*Cordylodus oklahomensis*—Landing, 1979:64, 65, 135, 136, pl. II–3, fig. 5, pl. III–1, fig. 10.

## Occurrence

A total of 105 cordylodiform and 29 cyrtoniodiform elements from the uppermost Cambrian and lowest Ordovician of Section KK (*Parabolina* Fauna through *Apoplanias* Fauna).

## Hypotypes

Cordylodiform elements ROM 38371 and ROM 38372 from KK 124 and cyrtoniodiform element ROM 38367 from KK 122.5.

## Description

The component form species *Cordylodus proavus* and *C. oklahomensis* have been adequately redescribed by Miller (1969) and only remarks are presented here. Cordylodiform elements have discrete denticles and cusp which have well rounded to laterally flattened cross sections. A rounded carina may be present on the anterior and posterior edges of the cusp (Figs. 6C–G), and the anterior margin may be laterally deflected (Figs. 6F, G). Cyrtoniodiform elements have basally confluent denticles and, generally, a lateral flaring of the base under the cusp (Figs. 6H, I).

Crystallites present in *Cordylodus* elements apparently are oriented radially to the surface of the element. Edges or keels are formed by the elongation of these crystallites along the anterior margin of the cusp (Figs. 6C–G).

Fig. 6A, B *Cordylodus intermedius* Furnish s.f., ROM 38373, sample KK 33.

A Lateral view,  $\times 120$ .

B Detail of slightly etched surface,  $\times 602$ .

C–E *Cordylodus oklahomensis* Müller, cordylodiform element, ROM 38371, sample KK 124.

C Lateral view,  $\times 60$ .

D, E Detail of anterior carina showing orientation of crystallites,  $\times 301$  and  $\times 1204$ , respectively.

F, G *Cordylodus oklahomensis* Müller, cordylodiform element, ROM 38372, sample KK 124.

F Lateral view of asymmetrical element,  $\times 60$ .

G Detail of slightly etched surface and anterior carina,  $\times 301$ .

H, I *Cordylodus oklahomensis* Müller, cyrtoniodiform element, ROM 38367, sample KK 122.5.

H Inner lateral view of element with attached basal plate,  $\times 65$ .

I Detail showing contrasting surface texture of smooth conodont element and porous basal plate,  $\times 129$ .

J–L *Fryxellodontus?* sp. nov., serrated element, ROM 38366, sample KK 146.

J, L Lateral views,  $\times 52$ .

K Right-lateral view showing denticulated oral edge of broken distal end of posterior process,  $\times 103$ .

## Remarks

*Cordylodus proavus s.f.* and *C. oklahomensis s.f.* are considered to be the component form species of multi-element *C. oklahomensis*. The two form species have a comparable stratigraphic range (Miller, 1969:426). Both elements appear at the same stratigraphic level in Utah (Miller, 1978) and Vermont (Landing, 1979), and co-occur in the same samples in Iran (Müller, 1973). The two form species also have nearly coincident ranges in Alberta (Derby et al., 1972) with *C. oklahomensis s.f.* first recovered less than a metre above the lowest occurrence of *C. proavus s.f.* Similarly, *C. proavus s.f.* and "*C. prion prion*" (= *C. oklahomensis s.f.*) of Nowlan (1976) first appear at the same level in the Copes Bay Formation in the Canadian Arctic and have similar stratigraphic ranges.

Druce and Jones (1971, see also Druce, 1978) described a stratigraphic overlap of *Cordylodus oklahomensis s.f.* only in the upper portion of the local range zone of *C. proavus s.f.* However, this stratigraphic non-concordance is probably related to the small number of specimens recovered. The illustrated specimens of *C. oklahomensis s.f.* from Australia (Druce and Jones, 1971) are apparently the cyrtioniodiform elements of multi-element *C. intermedius*.

*Proconodontus notchpeakensis s.f.* and *P. carinatus s.f.* are the apparent "ancestors", respectively, of *Cordylodus proavus s.f.* and *C. oklahomensis s.f.* (Miller, 1969, 1970). The similarity of the elements in bi-element "*Proconodontus*" *carinatus* (discussed below) to those of multi-element *C. oklahomensis* also suggests a comparable apparatus construction in the two species.

*Cordylodus proavus s.f.* appears to have been numerically dominant over *C. oklahomensis s.f.* in the *C. oklahomensis* apparatus. Miller (1978) recovered the elements in the ratio 3287:781 at the Lava Dam North section in Utah. A closely similar ratio 105:29 occurs in the Rabbitkettle collection. These data suggest that the elements occurred in the ratio 4:1 in a *C. oklahomensis* apparatus and that a minimum number of 10 elements was present in a bilaterally symmetrical *C. oklahomensis* animal.

## Genus *Fryxellodontus* Miller, 1969

### Type Species

*Fryxellodontus inornatus* Miller, 1969, from the Notch Peak Limestone, House Range, west-central Utah.

### *Fryxellodontus inornatus* Miller, 1969

Figs. 7C-G

*Fryxellodontus inornatus* Miller, 1969:426, 428, 429, pl. 65, figs. 1-10, 12-16, 23-25, text-figs. 4A, C, D, E (*pars*).

*Fryxellodontus inornatus*—Miller, 1970:97, text-figs. 10Q-T.

Gen. et sp. indet. B Druce and Jones, 1971:102, pl. 12, figs. 9a, b, text-fig. 33.

*Fryxellodontus inornatus*—Nowlan, 1976:237, pl. 1, figs. 17-19.

### Occurrence and Hypotype

One *symmetricus* element (ROM 38368) from the *Apoplanias* Fauna, sample KK 43.

### Remarks

Miller (1969) has provided a thorough description of the elements of the *Fryxellodontus inornatus* apparatus. An additional observation is that the elements lack surficial microsculpture when examined with the scanning electron microscope (Fig. 7C, D, G).

The element recovered from Section KK is composed of acicular crystallites oriented perpendicular to the surface of the specimen (Fig. 7E, F).

### *Fryxellodontus?* sp. nov.

Fig. 5B, 6J-L, 7A, B

### Occurrence and Hypotype

One element (ROM 38366) from the *Bowmania americana* Fauna (KK 146).

### Description

A strongly laterally flattened, completely hollow, sheathlike element with a denticulated posterior process which is much longer than the blunt cusp. A smooth, open arc is formed by the posterior edge of the cusp and the oral edge. Lateral displacement of the anterior keel and slight concavity of the right-lateral surface produce asymmetry in the element.

### Remarks

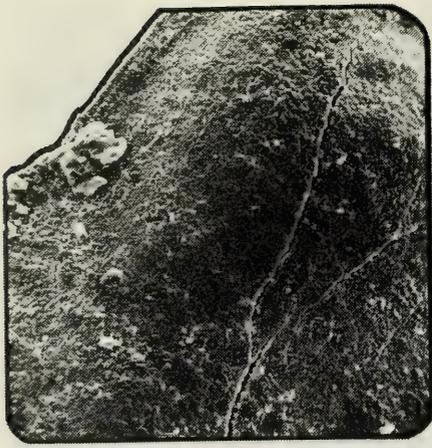
The element is completely hollow and lacks any surface microsculpture. It has some similarity to the *planus* and *serratus* elements of *Fryxellodontus inornatus* (Miller, 1969) although a long posterior process is present. This posterior process, which was broken in preparation, is distally denticulated (Fig. 6K, L).

It is uncertain whether the element actually represents a species of *Fryxellodontus* because associated elements of the apparatus were not recovered. However, if the element does belong to the genus, it is the only known Upper Cambrian representative of the genus.

### Genus *Furnishina* Müller, 1959

### Type Species

*Furnishina furnishi* Müller, 1959, *s.f.* from the Gallatin Limestone, Big Horn Mountains, Wyoming.



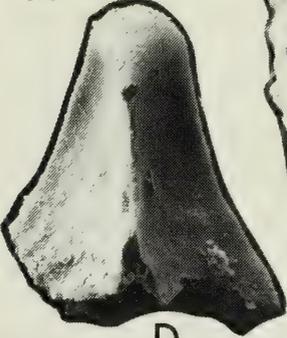
A



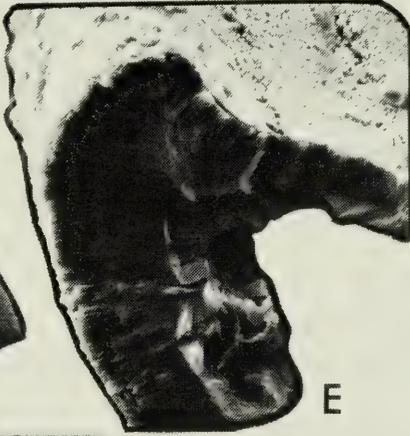
B



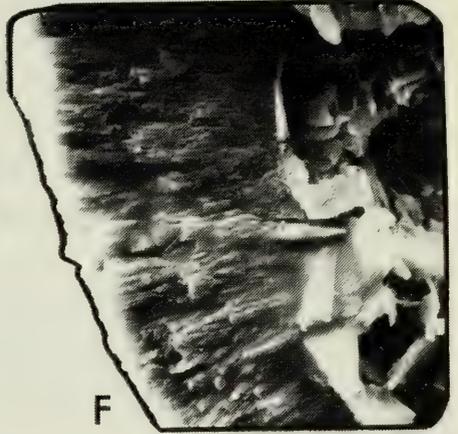
C



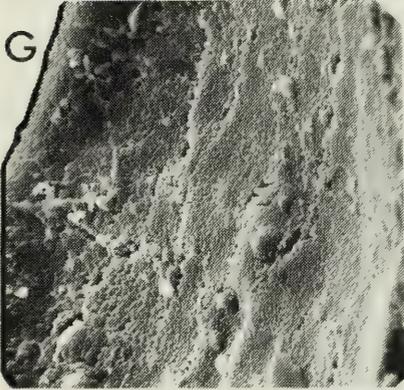
D



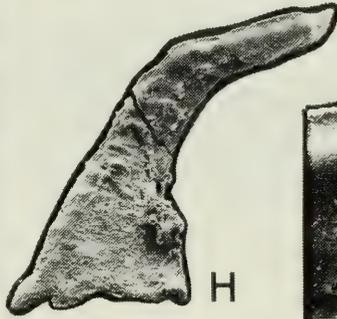
E



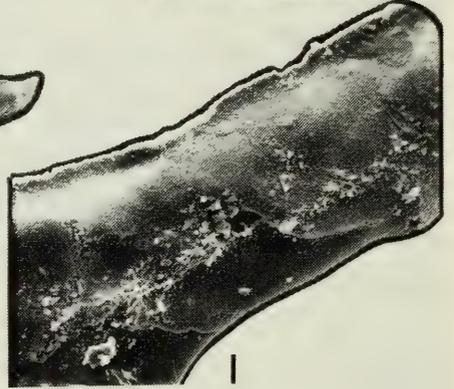
F



G



H



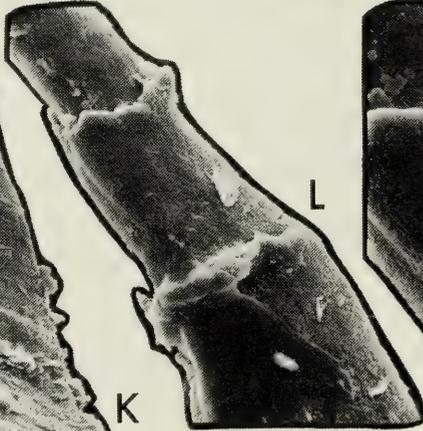
I



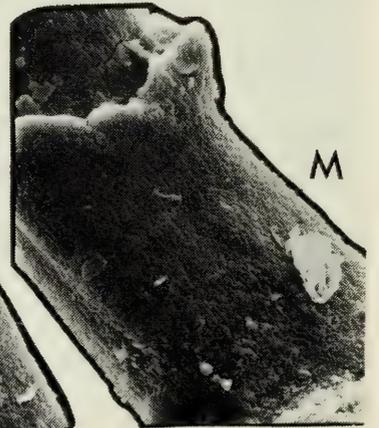
J



K



L



M

*Furnishina asymmetrica* Müller, 1959 *s.f.*

Figs. 7J–M

*Furnishina asymmetrica* Müller, 1959:451, 452, pl. 11, figs. 16a, b, 19.

*Furnishina asymmetrica*—Nogami, 1966:354, pl. 9, figs. 1a–2b.

*Furnishina asymmetrica*—Müller, 1971:8, pl. 1, figs. 13, 16.

*Furnishina asymmetrica*—Müller, 1973:39, pl. 1, figs. 6, 8, 9.

*Furnishina asymmetrica*—Lee, 1975:79, pl. 1, fig. 1, text-fig. 2A.

*Furnishina asymmetrica*—Miller and Paden, 1976:595, pl. 1, figs. 13, 14.

*Furnishina asymmetrica*—Abaimova, 1978:78, pl. 7, fig. 1.

*Furnishina asymmetrica*—Landing, 1979:22, pl. I–1, fig. 7.

### Occurrence and Hypotype

One element (ROM 38374) from the *Cordylodus oklahomensis* Zone (KK 33). Trilobites of the *Apoplanias* Fauna and *Symphysurina brevispicata* Subzone were recovered, respectively, below (KK 43) and above (KK 25) sample KK 33.

### Remarks

*Furnishina asymmetrica s.f.* and *F. furnishi* Müller are probably asymmetrical and subsymmetrical to symmetrical elements of the *F. furnishi* apparatus (Landing, 1979).

Paraconodont structure, or the aboral addition of growth lamellae which do not enclose the distal portion of the element (Bengtson, 1976), is shown by the detachment of the distal portion of growth lamellae from previously secreted portions of the sclerite (Figs. 7K–M).

Fig. 7A, B *Fryxellodontus?* sp. nov., serrated element, ROM 38366, sample KK 146.

A Detail of posterolateral margin of cusp showing prismatic crystallites comprising posterior carina (compare Fig. 6L),  $\times 269$ .

B Detail of lateral surface of cusp showing slightly corroded surface of originally smooth element (compare Fig. 6j),  $\times 269$ .

C–G *Fryxellodontus inornatus* Miller, symmetrical element, ROM 38368, sample KK 43.

C Aboral-lateral view (note broken tip of element, compare Fig. 7D),  $\times 215$ .

D Posterior view,  $\times 151$ .

E, F Detail of crystallites oriented normal to wall of element (compare Fig. 7C),  $\times 731$  and  $\times 1462$ , respectively.

G Detail of corroded outer surface of originally smooth element (compare Fig. 7D),  $\times 753$ .

H, I Protoconodont sp. indet. *s.f.*, ROM 38375, sample KK\* 135–150.

H Lateral view,  $\times 47$ .

I Detail showing lower edges of basally-internally secreted lamellae,  $\times 237$ .

J–M *Furnishina asymmetrica* Müller, *s.f.*, ROM 38374, sample KK 33.

J Posterior view,  $\times 99$ .

K–M Detail of surface of element showing exfoliation of upper portions of paraconodont growth lamellae,  $\times 290$ ,  $\times 247$ ,  $\times 989$ , respectively.

## Genus *Oneotodus* Lindström, 1955

### Type Species

*Distacodus? simplex* Furnish, 1938, *s.f.* from the Oneota Dolostone, Allamakee County, Iowa.

### “*Oneotodus*” *nakamurai* Nogami, 1967

Fig. 8A-C

*Oneotodus* sp. A. Müller, 1959:458, pl. 13, fig. 17.

*Oneotodus nakamurai* Nogami, 1967:216, 217, pl. 1, figs. 9a-13, text-figs. 3A-E.

*Oneotodus nakamurai*—Miller, 1969:435, 436, pl. 63, figs. 1-9, text-fig. 5E (*pars*, pl. 63, fig. 10 = “*Acodus*” *sevierensis* Miller, 1969 *s.f.*).

*Oneotodus simplex*—Miller, 1970:101, 102, text-fig. 9D (*non O. simplex* Furnish, 1938, *s.f.*).

*Oneotodus* sp. aff. *simplex*—Miller, 1970:102, text-fig. 9E (*non O. simplex* [Furnish, 1938] *s.f.*).

*Oneotodus datsonensis* Druce and Jones, 1971:80, pl. 14, figs. 1a-3b, text-fig. 26c (*pars*, pl. 14, figs. 4a, b = “*Acodus*” *housesensis* Miller, 1969, *s.f.*).

*Oneotodus nakamurai*—Druce and Jones, 1971:82, 83, pl. 10, figs. 3a-5c, 7a-8b, text-fig. 26i (*pars*, pl. 10, figs. 1, 2, 6a-c, text-fig. 26j = *Proconodontus notchpeakensis* Miller, 1969, *s.f.*).

Fig. 8A-C “*Oneotodus*” *nakamurai* Nogami, ROM 38370, sample KK\* 135-150.

A Lateral view of long-based element,  $\times 95$ .

B Detail of subparallel striae (compare Fig. 8A),  $\times 946$ .

C Detail of subparallel striae (centre of Fig. 8B),  $\times 2365$ .

D, E “*Proconodontus*” *carinatus* Miller, scandodiform element, ROM 38362, sample KK 119.5.

D Inner lateral view of aborally flaring side,  $\times 129$ .

E Corroded surface or originally smooth element,  $\times 645$ .

F “*Proconodontus*” *carinatus* Miller, drepanodiform element, ROM 38365, sample KK 50,  $\times 52$ .

G, H “*Proconodontus*” *carinatus* Miller, drepanodiform element, ROM 38369, sample KK 43.

G Lateral view,  $\times 108$ .

H Detail of corroded surface of originally smooth element,  $\times 538$ .

I-L *Proconodontus serratus* Miller *s.f.*, ROM 38363, sample KK 86.5.

I, J Lateral views,  $\times 52$  and  $\times 49$ , respectively.

K Detail showing acicular crystallites composing denticulated oral edge (compare Fig. 8i),  $\times 258$ .

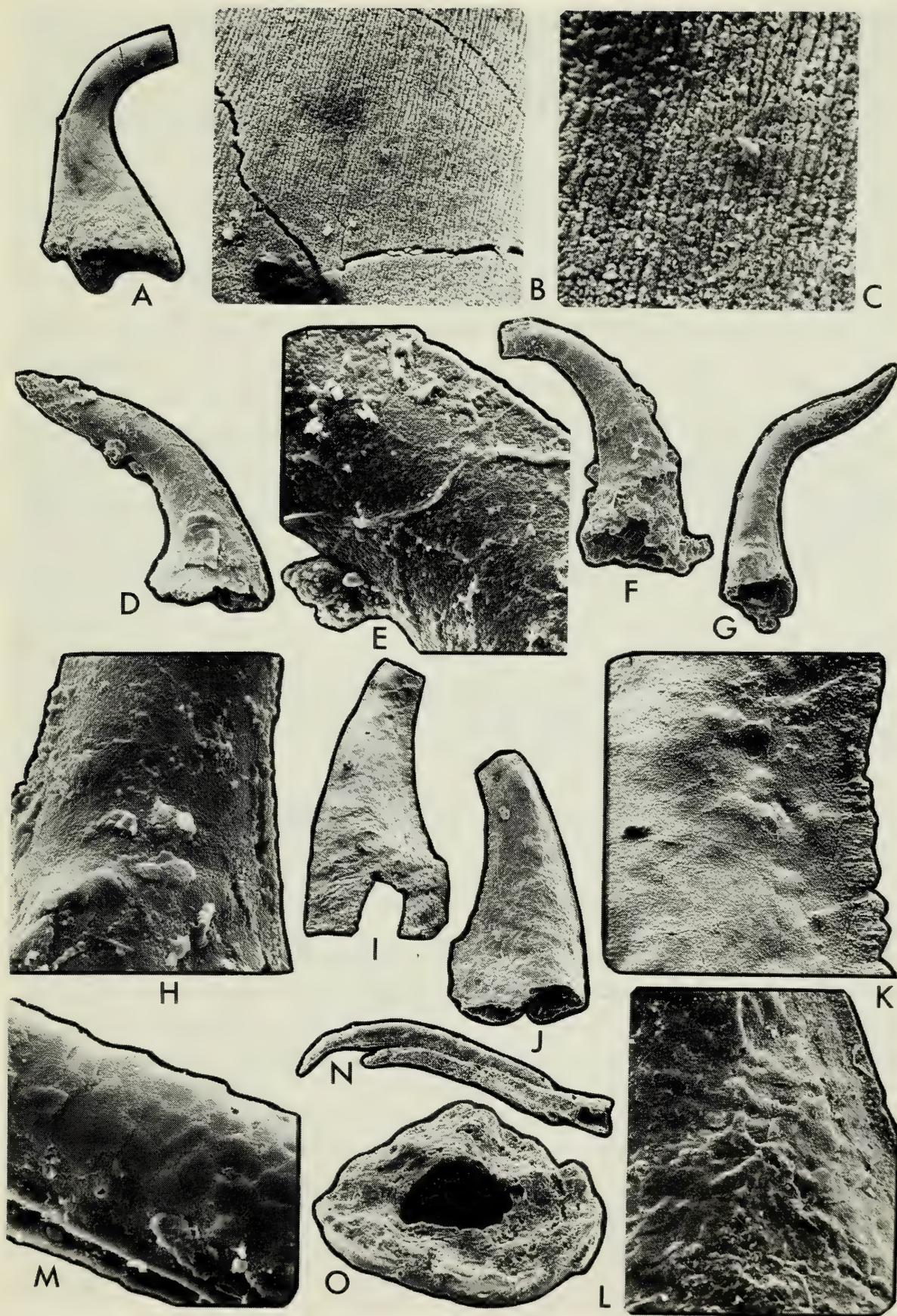
L Detail showing acicular crystallites comprising anterior carina (compare Fig. 8j),  $\times 247$ .

M, N “*Prooneotodus*” *tenuis* (Müller), ROM 38364, sample KK 77.

M Detail showing irregular lower (aboral) edges of basal, internally accreted, growth lamellae,  $\times 58$ .

N Anterior or posterior view of three-element incomplete half-apparatus (Landing, 1977). Third (lower) element largely obscured by upper two elements,  $\times 581$ .

O *Phosphannulus universalis* Müller, Nogami, and Lenz, ROM 38361, sample KK 123. Oblique view of attachment surface,  $\times 112$ .



- Oneotodus datsonensis*—Jones, 1971:56, 57, pl. 3, figs. 5a–c, 7a–c.
- Oneotodus nakamurai*—Jones, 1971:58, pl. 4, figs. 1a–c, 3a–4c (*pars*, pl. 4, figs. 2a–c = “*Acontiodus*” *unicostatus* Miller, 1969, *s.f.*).
- Oneotodus* sp. aff. *simplex*—Miller and Melby, 1971:122, pl. 2, fig. 9 (*non O. simplex* [Furnish, 1938] *s.f.*).
- Oneotodus nakamurai*—Müller, 1971:10, text-fig. 1e.
- Oneotodus nakamurai*—Müller and Nogami, 1971:76, pl. 7, fig. 1, text-fig. 14B.
- Oneotodus nakamurai*—Müller, 1973:41, pl. 5, fig. 4.
- Oneotodus nakamurai*—Lee, 1975:81, pl. 1, figs. 6, 9, 10, text-figs. 2E, G.
- Oneotodus nakamurai*—Nowlan, 1976:294, 295, pl. 1, figs. 24–28.
- Oneotodus nakamurai*—Abaimova and Markov, 1977:92, 93, pl. 14, figs. 12–14, 16.
- Oneotodus variabilis*—Abaimova and Markov, 1977:93, pl. 14, fig. 11, pl. 15, fig. 4 (*non O. variabilis* Lindström, 1955, *s.f.*).
- “*Oneotodus*” *nakamurai*—Landing, 1979:72, 73, 146, 147, 206, 207, pl. II–2, figs. 13–15, 17, pl. III–1, figs. 6, 7, pl. IV–1, figs. 8, 9.
- Oneotodus simplex*—Tipnis et al., 1979:31, pl. 1, fig. 18 (*non O. simplex* [Furnish, 1938] *s.f.*).
- Oneotodus variabilis* Lindström, Tipnis et al., 1979:31, pl. 1, figs. 20, 22.

### Occurrence and Hypotype

Two elements from the *Bowmania americana* Fauna, samples KK\* 135–150 (ROM 38370) and KK 78 (specimen lost).

### Remarks

Miller (1969) restricted his concept of *Oneotodus nakamurai* to elements with a length:width ratio of the basal margin of 2:3 to 3:2. He assigned one of Nogami’s figured specimens (Nogami, 1967: pl. 1, fig. 13) to *Semiacontiodus nogamii* Miller because of the strong anteroposterior flattening of the aboral margin of the element. Miller’s (1969) taxonomic restriction stems from a failure to recover the species below the *Cordylodus oklahomensis* Zone. Landing (1979) noted that “*O.*” *nakamurai* elements from the upper *Proconodontus* Zone in Vermont and New York tend to have longer bases than those from higher strata. In addition, “*O.*” *nakamurai* elements with long bases from the *Proconodontus* Zone are often strongly aborally flattened or have a rounded triangular cross section of the aboral margin (Landing, 1979). The narrowly rounded anterolateral and oral margins of the illustrated specimen from the Rabbitkettle produce a triangular aboral cross section (Fig. 8A).

### Discussion

“*Oneotodus*” *nakamurai* specimens are covered with fine, subparallel striations (Fig. 8B, C) and are consequently unique among conodont elements from *Proconodontus* and lower *Cordylodus oklahomensis* zones. The restriction of this surface microstructure to “*O.*” *nakamurai* suggests that the apparatus is mono-elemental.

Although “*Oneotodus*” *nakamurai* elements may appear to be similar to *Proconodontus notchpeakensis* Miller *s.f.* (Miller, 1969:436), the latter are devoid of surface microsculpture (Landing, 1979; this report). “*Oneotodus*” *nakamurai* appears in uppermost Cambrian faunas without known ancestors. Long-based elements in the *Proconodontus* Zone are replaced by short-based forms in the *Cordylodus oklahomensis* Zone (Landing, 1979). These short-based elements were apparently ancestral to upper *C. oklahomensis* Zone forms such as Miller’s (1969) “*Acodus*” *housensis s.f.*, “*A.*” *sevierensis s.f.*, *Semiacontiodus*, and “*Paltodus*” *utahensis* Miller, 1969 *s.f.*, all of which are finely striated and albid (Landing, 1979).

## Taxonomy

“*Oneotodus*” *nakamurai* elements are provisionally referred to *Oneotodus*. R. L. Ethington (pers. comm., 1979) notes that elements of the type species, *O. simplex*, have low lateral costae, a shallower basal cavity than that illustrated by Furnish (1938), and coarser striae than forms referred by other authors to *Oneotodus*. The basal cavity of “*O.*” *nakamurai* extends to the point of maximum curvature of the finely striated element.

### Genus *Proconodontus* Miller, 1969

#### Type Species

*Proconodontus muelleri* Miller, 1969, from the Notch Peak Limestone, House Range, west-central Utah.

#### “*Proconodontus*” *carinatus* Miller, 1969

Fig. 5C, F, 8D–H

#### Drepanodiform Element

*Oneotodus* sp. indet. Müller, 1959:458, pl. 13, fig. 15.

*Proconodontus notchpeakensis* Miller, 1969:458, pl. 66, figs. 21–29, text-fig. 5G.

*Proconodontus notchpeakensis*—Miller, 1970:105, 106, text-fig. 9M.

*Oneotodus gallatini*—Druce and Jones, 1971:81, 82, pl. 9, figs. 9a–c, pl. 10, figs. 9a–10c, text-figs. 26f, g (*non Proconodontus gallatini* [Müller, 1959] *s.f.*).

*Proconodontus notchpeakensis*—Müller, 1971:43, pl. 4, fig. 6.

*Oneotodus nakamurai*—Lee, 1975:81, (*pars*, pl. 1, fig. 9, *non* “*O.*” *nakamurai* Nogami, 1966).

*Proconodontus notchpeakensis*—Nowlan, 1976:351, pl. 1, figs. 6, 7.

“*Proconodontus*” *carinatus*—Landing, 1979:78, 151, 152, 209, pl. II–3, fig. 12, pl. III–1, fig. 16, pl. IV–1, figs. 10, 11 (*pars*, cited figures are only of drepanodiform element).

*Proconodontus notchpeakensis*—Tipnis et al., 1979:31, pl. 1, fig. 14.  
? *Proconodontus* cf. *P. notchpeakensis*—Tipnis et al., 1979:31, pl. 1, fig. 15.

### Scandodiform Element

*Proconodontus carinatus* Miller, 1969:437, pl. 66, figs. 13–20, text-fig. 51.  
*Proconodontus carinatus*—Miller, 1970:104, text-fig. 51.  
*Proconodontus carinatus*—Miller and Melby, 1971:122, pl. 2, figs. 16, 17.  
*Proconodontus* aff. *carinatus*—Ozgül and Gedik, 1973:49, pl. 1, fig. 15.  
*Proconodontus carinatus*—Nowlan, 1976:349, pl. 1, figs. 11, 12.  
*Proconodontus carinatus*—Landing et al., 1978:76, fig. 2A.  
*Proconodontus carinatus*—Landing, 1979:24, pl. I–1, fig. 8.  
‘*Proconodontus*’ *carinatus*—Landing, 1979:78, 204, pl. II–3, fig. 9, pl. IV–1, fig. 14 (*pars*, cited figures are only of scandodiform element).

### Occurrence

Thirteen scandodiform and 41 drepanodiform elements recovered in association with *Bowmania americana* Fauna through *Apoplanias* Fauna trilobites. A scandodiform element from KK\* 0–12 occurs above the highest known trilobites (*Symphysurina brevispicata* Subzone) from KK 20.

### Hypotypes

Scandodiform hypotype ROM 38362 from KK 119.5 and drepanodiform hypotypes ROM 38365 and 38369 from KK 50 and KK 43, respectively.

### Remarks

*Proconodontus carinatus s.f.* and *P. notchpeakensis s.f.* have basal cavities which do not extend to the tip of the elements, and the cusps are albid above the basal cavity. The two form species differ from the completely hollow elements of *P. muelleri s.f.* and *P. serratus s.f.* although all four form species lack any surface microsculpture (Landing, 1979).

*Proconodontus carinatus s.f.* and *P. notchpeakensis s.f.* regularly appear together at the base of the *P. notchpeakensis* Subzone (Miller, 1970; Derby et al., 1972) and persist into Fauna B (Miller, 1970, 1978). The two form species regularly occur together in continental slope deposits in the Appalachians (Landing, 1979). Similarity of range zones and regular association suggests that the two elements are part of a multi-element species (Miller, 1978; Landing, 1979). *Proconodontus notchpeakensis s.f.* and *P. carinatus s.f.* represent the bilaterally symmetrical (drepanodiform) and the aborally laterally flared (scandodiform) elements of the apparatus. These two elements are homologous, respectively, to the cordylodiform and cyrtionodiform elements of bi-elemental *Cordylodus oklahomensis*. A further similarity between these two apparatuses is that the bilaterally symmetrical to subsymmetrical drepanodiform

and cordylodiform elements are numerically dominant. However it is possible that the element ratio differs between the two species. Miller (1978) recovered the elements in a drepanodiform:scandodiform ratio of 3837:1471 (1:0.38) at the Lava Dam Five section in the Notch Peak Limestone, Utah. The ratio in the sparse Rabbitkettle collection is 41:13 (1:0.32). These data suggest that scandodiform elements were proportionately better represented in "*Proconodontus*" *carinatus* than the corresponding cyrtoniodiform elements in *Cordylodus oklahomensis*.

"*Proconodontus*" *carinatus* is here provisionally referred to *Proconodontus*. The elements of this bi-elemental apparatus differ strongly from the type species *Proconodontus muelleri* s.f. In addition, the *P. muelleri* apparatus appears to have been mono-elemental (Landing, 1979).

### *Proconodontus serratus* Miller, 1969, s.f.

Fig. 8I-L

*Proconodontus mülleri serratus* Miller, 1969:438, pl. 66, figs. 41-44.

*Proconodontus muelleri serratus*—Miller, 1969:105, text-fig. 9L.

*Coelocerodontus burkei* Druce and Jones, 1971:61, 62, pl. 11, figs. 5a-6c, 8a-c, text-fig. 22e (*pars*, pl. 11, figs. 7a-c, 9-12b, text-fig. 22a = *Proconodontus muelleri* Miller, 1969, s.f.).

*Proconodontus serratus*—Müller, 1973:44, pl. 4, figs. 1a-2.

*Proconodontus serratus*—Landing, 1979:79, 80, 153, 210, 211, pl. II-3, fig. 16, pl. III-1, fig. 4, pl. IV-1, figs. 12, 15.

### Occurrence and Hypotype

Recovered from the *Bowmania americana* Fauna, sample KK 86.5 (two elements) and KK\* 135-150 (one element). Hypotype ROM 38363 from KK 86.5.

### Remarks

*Proconodontus muelleri* Miller, s.f. and *P. serratus* s.f. have basal cavities reaching almost to the tip of the elements, differ in the serrated posterior edge of the latter (Miller, 1969), and lack surface microsculpture (Landing, 1979). The posterior edge of *P. serratus* s.f. may be almost completely serrated (Fig. 8I, J) or may have only a few denticles near the aboral margin or distally (Landing, 1979). The co-occurrence of *P. muelleri* s.f. and *P. serratus* in the upper *Saukia* Zone (Miller, 1969-1978; Landing, 1979) may mean that one conodont animal bore both types of elements. The absence of *P. serratus* s.f. in the lower *Saukia* Zone (Miller, 1975, 1977) possibly means that denticulation has not appeared in some of the elements of an essentially mono-elemental *P. muelleri* apparatus.

Dissolution of the surface of the elements from Section KK reveals that the anterior carina (Fig. 8L) and posterior serrated edge (Fig. 8K) are comprised of acicular crystallites oriented parallel to the plane of lateral flattening of the elements.

## Genus *Prooneotodus* Müller and Nogami, 1971

### Type Species

*Oneotodus gallatini* Müller, 1959, *s.f.* from the Gallatin Limestone, Big Horn Mountains, Wyoming.

### “*Prooneotodus*” *tenuis* (Müller, 1959)

Fig. 8M, N

- Oneotodus tenuis* Müller, 1959:457, 458, pl. 13, figs. 11, 13, 14, 20.  
*Oneotodus tenuis*—Nogami, 1966:356, pl. 9, figs. 11, 12.  
*Oneotodus tenuis*—Clark and Robison, 1969:1045, text-fig. 1a.  
*Oneotodus tenuis*—Miller, 1969:436, pl. 64, figs. 43–45, text-fig. 5C.  
*Oneotodus tenuis*—Müller, 1971:8, pl. 1, figs. 1a, v, 4–6.  
*Prooneotodus tenuis*—Müller, 1973:45, pl. 1, figs. 1–36.  
*Oneotodus tenuis*—Ozgül and Gedik, 1973:48, pl. 1, figs. 2, 10, 12.  
*Prooneotodus tenuis*—Lee, 1975:83, 84, pl. 1, figs. 14–17, text-figs. 2K, L.  
*Prooneotodus tenuis*—Miller and Paden, 1976:596, pl. 1, figs. 20–23.  
*Prooneotodus tenuis*—Müller and Andres, 1976:193–200, pl. 22, figs. A, B, text-figs. 1a–3.  
“*Prooneotodus*” *tenuis*—Landing, 1977:1072–1084, pl. 1, fig. 1–9, pl. 2, figs. 1–11, text-fig. 1  
“*Prooneotodus*” *tenuis*—Landing et al., 1978:76, text-fig. 2B.  
*Prooneotodus tenuis*—Abaimova, 1978:83, pl. 8, figs. 2, 4, 9.  
*Prooneotodus savitskyi* Abaimova, 1978:82, 83, pl. 7, figs. 13, 14, pl. 8, fig. 1.  
“*Prooneotodus*” *tenuis*—Landing, 1979:25, 82, 83, 153, 154, 212, 225–250, pl. I–1, fig. 12, pl. II–3, fig. 18, pl. III–1, fig. 3, pl. IV–1, fig. 3, pl. V–1, figs. 1–9, pl. V–2, figs. 1–11, text-fig. V–1.  
*Oneotodus tenuis*—Tipnis et al., 1979:31, pl. 1, fig. 6.

### Occurrence and Hypotype

Two elements from the *Missisquoia depressa* Subzone, samples KK 50 and KK 116, and the hypotype (ROM 38364) three element incomplete half-apparatus (Landing, 1977) from the *Bowmania americana* Fauna, sample KK 77.

### Remarks

The elements of “*Prooneotodus*” *tenuis* have protoconodont structure and the species cannot be brought to the paraconodont genus *Prooneotodus* (Landing, 1977).

Dissolution of the exterior surface of the elements from Section KK has apparently obscured the fine longitudinal striations present in elements of the species (Müller, 1971; Landing, 1977) and caused irregular exfoliation of the growth lamellae (Fig. 8M).

**Protoconodont sp. indet. s.f.**

Fig. 5G, 7H, I

?*Furnishina*? sp. Tipnis et al., 1979:31, pl. 1, fig. 5.

**Occurrence and Hypotype**

Two specimens (hypotype ROM 38375) from the *Bowmania americana* Fauna (KK\* 135–150).

**Description**

The form is known from gently curved, asymmetrical, conelike, proclined elements with sharp posterior costa. The anterior costa becomes rounded aborally and a rounded anterolateral costa is present. The internal cavity extends nearly to the end of the thin-walled elements.

**Remarks**

The specimens have a superficial resemblance to the euconodont *Proconodontus muelleri* Miller s.f. and to the paraconodont *Furnishina primitiva* Müller s.f. However, examination of the surface of the elements (Fig. 5I) shows that they grew by basal-internal addition of growth lamellae and have protoconodont structure (Bengtson, 1976).

Tipnis et al. (1979) illustrated a similar element from section K (sample K 525).

**Order Hyolithelminthes Fisher, 1962**

**Family Phosphannulidae Müller, Nogami, and Lenz, 1974**

**Genus *Phosphannulus* Müller, Nogami, and Lenz, 1974**

**Type Species**

*Phosphannulus universalis* Müller, Nogami, and Lenz from the Upper Silurian Beyrichien-Kalke, Berlin Spandau-West.

***Phosphannulus universalis* Müller, Nogami, and Lenz, 1974**

Fig. 80

Form B Webers, 1966:72, pl. 14, figs. 3, 6.

*Phosphannulus universalis* Müller, Nogami, and Lenz, 1974:91, 92, pl. 18, figs. 1–12, pl. 19, figs. 1–13, pl. 20, figs. 1–7, pl. 21, figs. 1–9, text-figs. 1–6.

*Phosphannulus* sp. Winder, 1976:654, pl. 2, fig. 11.

*Phosphannulus universalis*—Landing, 1979:28, 215, pl. I–1, fig. 2, pl. IV–1, fig. 7.

### **Occurrence and Hypotype**

Recovered from the *Yukonaspis kindlei* Fauna through *Missisquoia* sp. nov. Fauna. Four specimens from KK 33 occur in an interval lying below the *Symphysurina brevispicata* Subzone and above the *Apoplanias* Fauna. Hypotype ROM 38361 from the *Missisquoia* sp. nov. Fauna (KK 123).

### **Remarks**

The form, an attachment structure secreted by a possible hyolithelminthoid epizoan (Müller et al., 1974), ranges from the Late Cambrian through Late Devonian. It has been reported from North America, Iran, and Baltoscandia.

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