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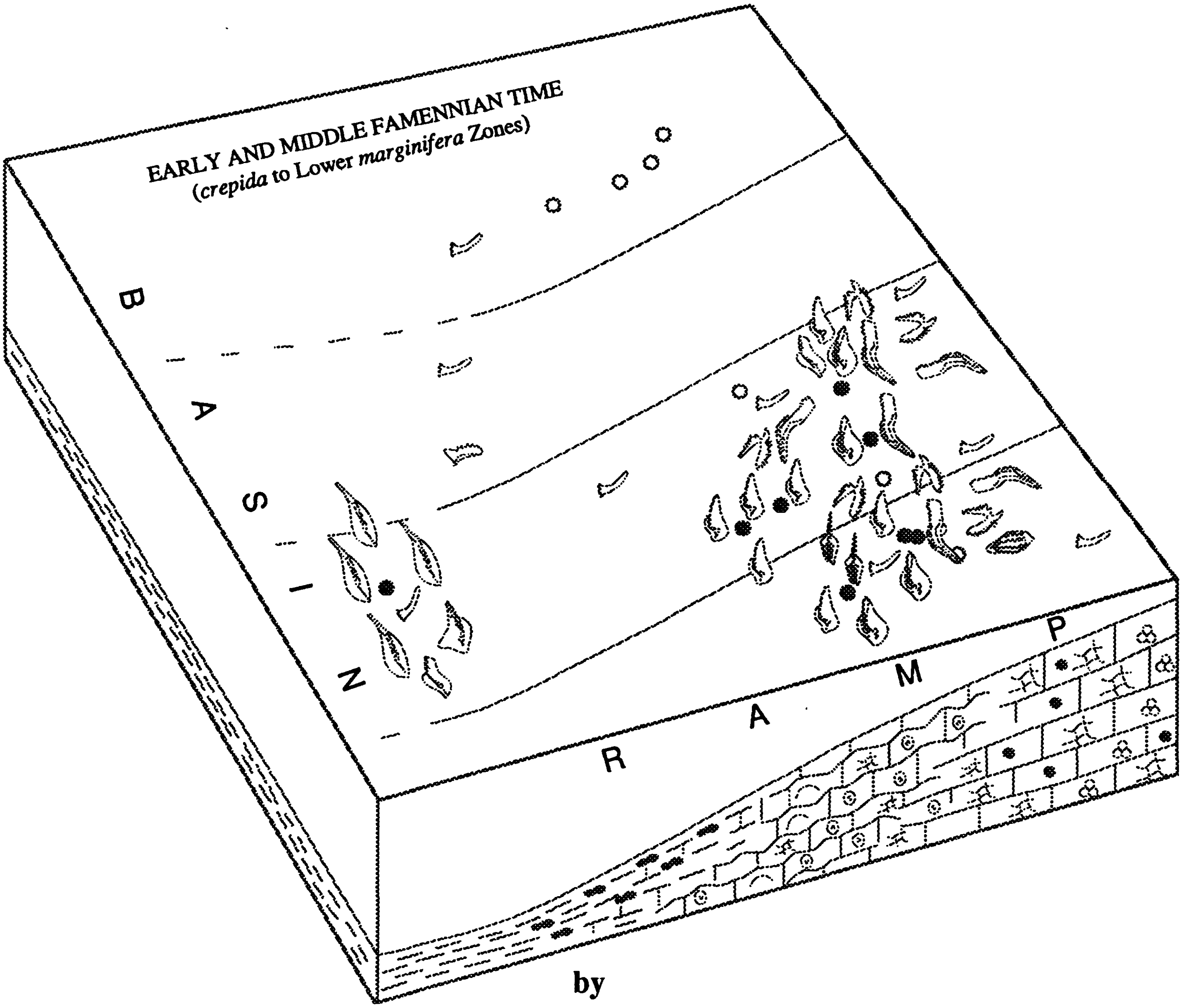
Conodont biofacies in a ramp to basin setting (latest Devonian and earliest Carboniferous) in the Rocky Mountains of southernmost Canada and northern Montana



by

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ABSTRACT

Analyses of conodont biofacies and taphonomic patterns have helped to define age-environment relationships of uppermost Devonian and lowermost Carboniferous (Famennian and Tournaisian) sedimentary rocks in the southeasternmost Canadian Cordillera and adjacent Montana. These miogeoclinal strata record striking environmental changes involving the onset and termination of low-oxygen conditions in epicontinental and shelf seas dominated by carbonate deposition. Several distinct and environmentally diagnostic Famennian and Tournaisian conodont biofacies representative of deep basin to shallow ramp settings were recognized on the basis of conodont distribution and preservation patterns.

During early and middle Famennian time, the study region was the site of a westward-deepening carbonate ramp (Palliser Formation) that was bordered to the west by a deep, shale basin (Lussier strata). Relatively shallow-water carbonate deposits (skeletal and peloidal lime wackestone, mudstone, and packstone) of the Palliser have yielded a low-diversity conodont fauna characterized by indigenous to transported *Apatognathus*-, *Palmatolepis*-, and *Polygnathus*-dominated assemblages. Palmatolepids include *Palmatolepis glabra*, *Pa. marginifera marginifera*, and *Pa. stoppeli*; polygnathids include *Polygnathus communis*, *P. experplexus*, *P. nodocostatus*, and *P. semicostatus*. Only at certain levels in the Palliser are there minor incursions of icriodontids. The deep-water basinal shales and radiolarian mudstones produced indigenous representatives of the pelagic palmatolepid biofacies. In contrast, the middle and late Famennian interval is marked by the termination of carbonate ramp sedimentation and initial flooding of the margin by water derived from the oxygen minimum zone during an areally extensive transgression. Deposition of organic-rich facies began in the *expansa* Zone under oxygen-stressed conditions in shelfal to basinal environments (Exshaw Formation and correlative units). These deposits contain indigenous pelagic *Palmatolepis*- and (or) *Bispathodus*-dominated assemblages; identifiable reworked or transported fragments are primarily polygnathids and icriodontids.

Deposition of anaerobic to marginally aerobic, deep-water, lower Banff facies occurred intermittently until middle Tournaisian and locally into late Tournaisian time (*anchoralis-latus* Zone) prior to the westward progradation of carbonate deposits of the middle and upper Banff Formation. Characteristic deep-water units include sequences of biogenic chert, black and gray shale, phosphatic and siliceous mudstone, and glauconitic and phosphatic clastic sediments. Although limited, middle Tournaisian conodont faunas include transported and indigenous assemblages of siphonodellids (deep-middle ramp). Distinct late Tournaisian biofacies distributions parallel major lithofacies changes associated with progressive shallowing of the Banff sequence. This shallowing sequence is characterized, in stratigraphic order, by the following indigenous to displaced biofacies: scaliognathid-doliognathid (basin to deep ramp), polygnathid and polygnathid-bactrognathid (deep to middle ramp), and bactrognathid-hindeodid (middle to shallow ramp). The spatial relations of these Famennian and Tournaisian biofacies are generally consistent with models developed by other workers for correlative strata in the western United States.

INTRODUCTION

This study was part of a larger investigation to interpret the paleoceanography of the middle Paleozoic western margin of Euramerica, in particular, the uppermost Devonian and lowermost Carboniferous of the southeasternmost Canadian Cordillera and adjacent Montana (Savoy, 1990, 1992). The succession is exposed in the Front and Main ranges of the foreland thrust and fold belt (fig. 1), and includes the Palliser, Exshaw, and Banff formations and unnamed pelitic rocks (fig. 2). These strata represent some of the westernmost preserved, Devonian and Mississippian miogeoclinal rocks in this part of the Cordillera, and are critical to paleogeographic and paleotectonic interpretations of the middle Paleozoic outer craton and continental margin. This report makes available the data set for earlier and ongoing biofacies and taphonomic studies of latest Devonian and earliest Carboniferous conodonts in this region.

The Exshaw and lower Banff strata in the Front Ranges represent a shale-dominated interval between Devonian and Mississippian carbonate sequences. To the west, in the eastern Main Ranges of British Columbia (figs. 1 and 2, Lussier syncline), this tripartite division does not persist, and the entire Famennian to middle Tournaisian succession is shale. The middle Paleozoic sequence in the study area records significant environmental changes: (1) the termination of Palliser carbonate ramp deposition; (2) the onset and termination of low-oxygen conditions, represented by the Exshaw, and, locally, lower Banff formations; and (3) the subsequent progradation of a mixed siliciclastic-carbonate ramp represented by the middle and upper Banff Formation. A more detailed discussion of the sedimentology and environmental conditions is presented in Savoy (1990, 1992).

Seventeen sections (18-415 m thick) of this sequence and correlative strata (fig.1, Appendix 1) were measured and sampled for sedimentologic and conodont biostratigraphic and biofacies analysis to determine age and environmental relationships. For ease of reference, sections south of 50.5°N. latitude are included in the southern study area (SA), the primary focus of this investigation; those to the north are part of the northern study area (NA).

LITHOSTRATIGRAPHY AND DEPOSITIONAL SETTING

The lower member of the Palliser Formation, the Morro Member, was only examined in the southern area. This member consists of peloidal, grapestone-bearing, lime mudstone to packstone that was deposited on a partly restricted, shallow ramp (fig. 3*A*). The Morro is extensively burrowed and contains numerous *Thalassinoides* galleries. Near the international border, the upper part of the Palliser, the Costigan Member, consists mainly of thin-bedded to nodular skeletal wackestone that was deposited under more open marine conditions than the underlying Morro (fig. 3*B*).

The Exshaw Formation is chiefly laminated to wavy laminated black shale and siliceous mudstone and, in its type area (Bow Valley, NA), contains an upper member of burrowed siltstone (fig. 4). The black shale formed in oxygen-depleted (anaerobic to dysaerobic) conditions in an inferred relatively deep-water setting. The overlying Banff Formation is lithologically variable in the study area (fig. 5). It formed along a prograding mixed siliciclastic-carbonate ramp. Its lower, deeper water deposits may consist of black and dark-gray shale; siltstone; phosphatic and siliceous mudstone; phosphatic and glauconitic, peloidal siltstone; and bedded radiolarian and spicular chert.

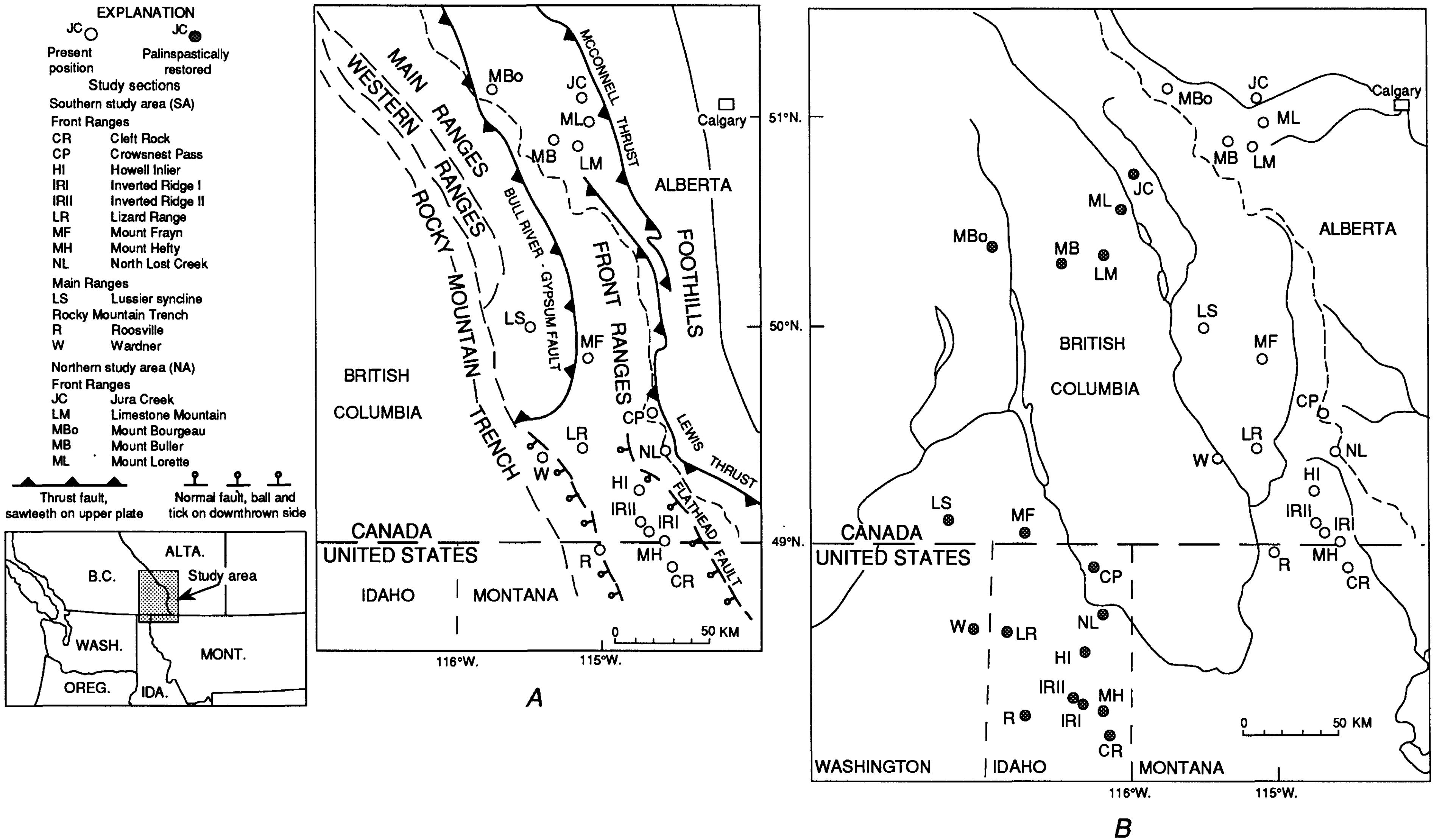


Figure 1. *A*, Index map showing the location of sections examined in this study and major structural features of the Cordilleran thrust and fold belt in southeastern British Columbia, and adjacent Alberta and Montana. Geographic coordinates for sections are given in Appendix 1. *B*, Palinspastic base map showing the restored and present positions of sections examined in this study. Palinspastic restoration based on Norris (1964, 1971), Gibson (1985), and Aitken (1988). Modified from Savoy (1992).

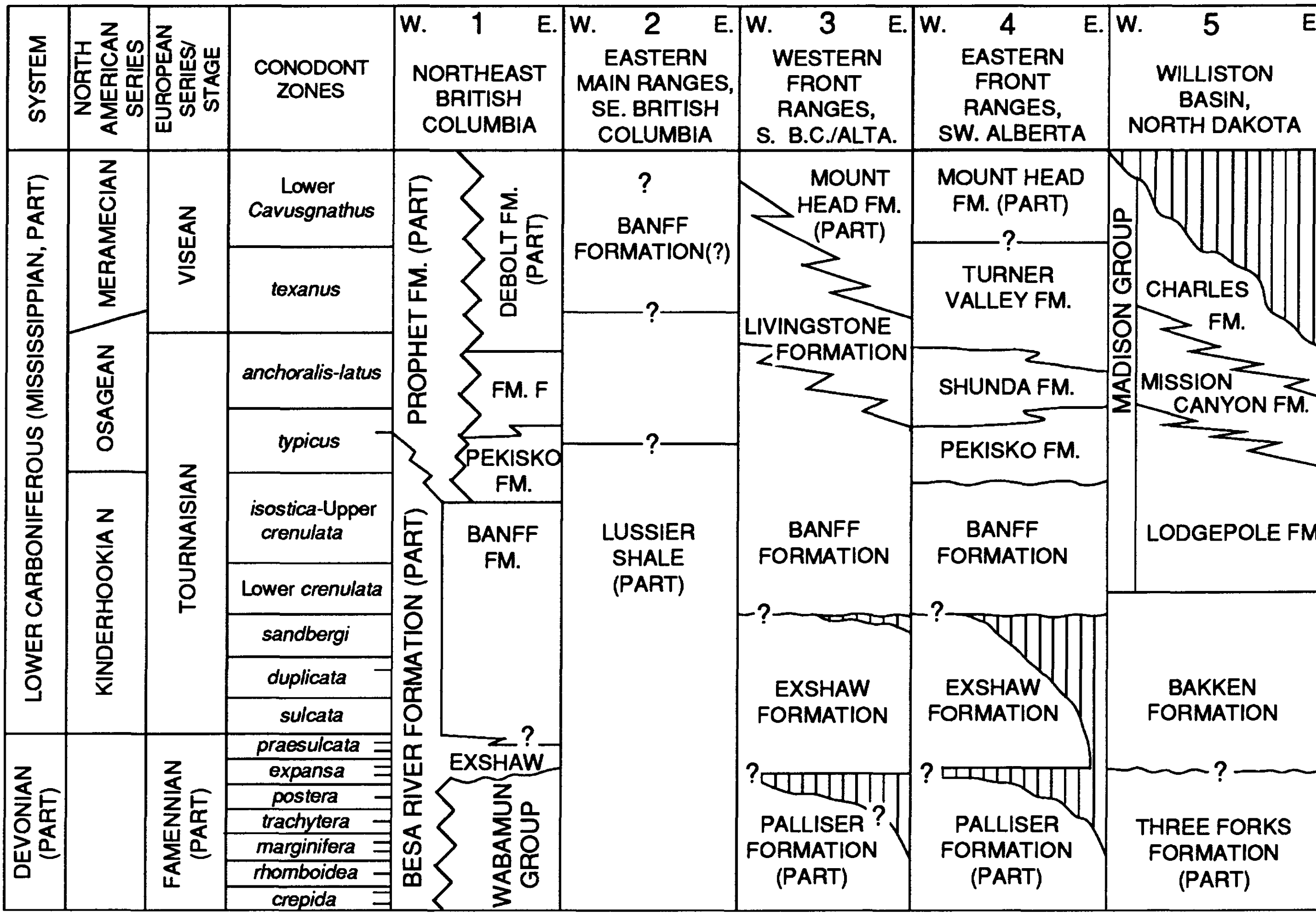
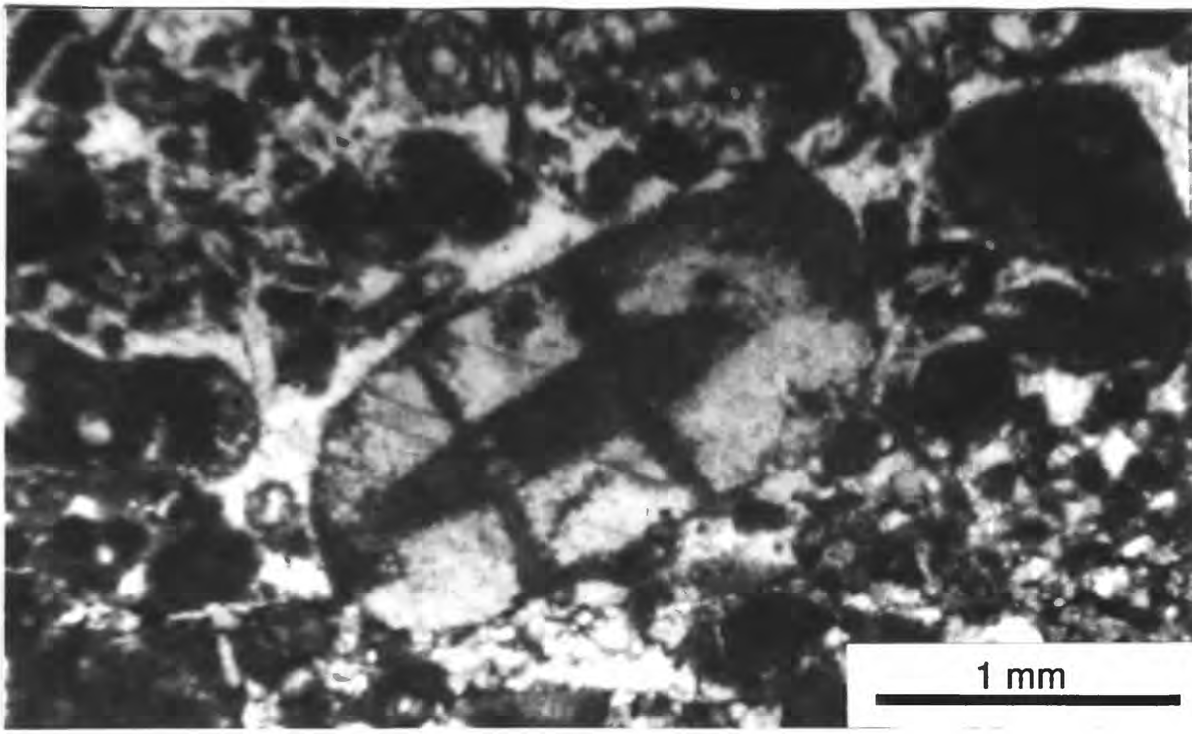


Figure 2. Correlation chart of Upper Devonian and Lower Mississippian stratigraphic units in western Canada and northwestern United States. Ticks on the right side of the conodont zones indicate subzonal boundaries. Chart is based on the following sources: (1) Richards and others (1991); (2) Savoy (1990) and this report; (3, 4) Higgins and others (1991), Richards and others (1991), and Savoy (1990); (5) Carlson and LeFever (1987), Holland and others (1987), and Richards and others (1991).



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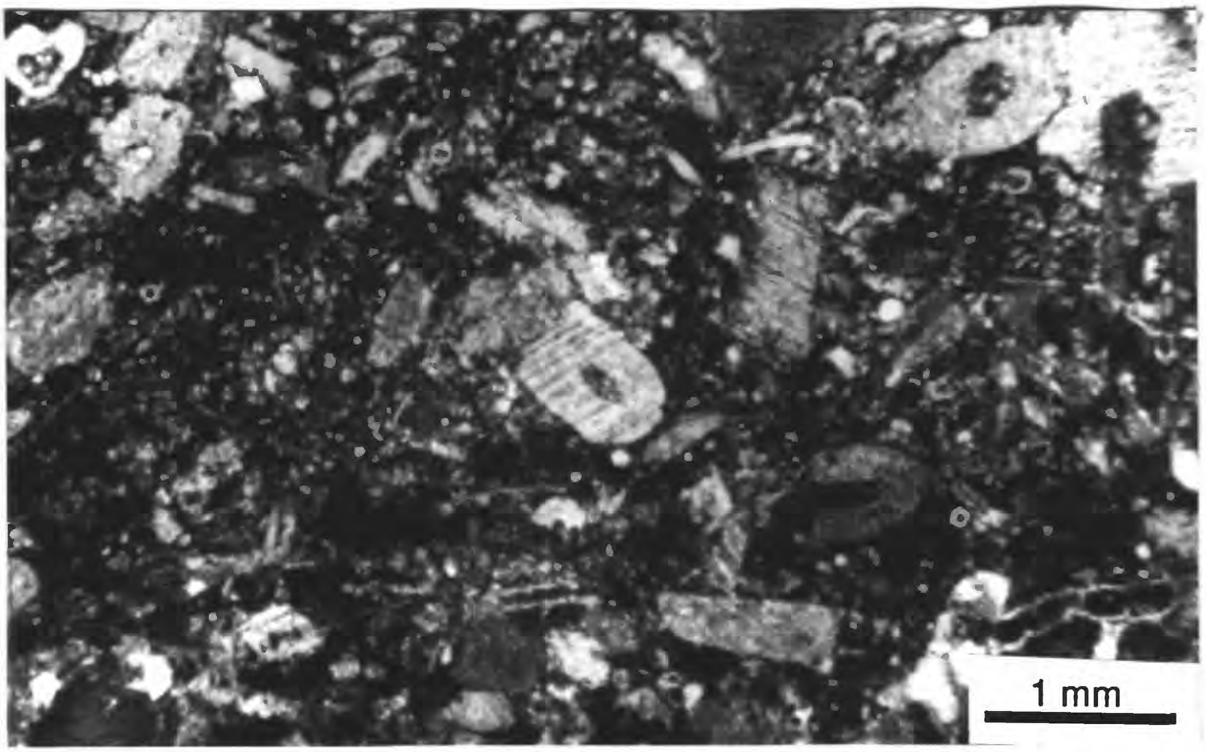

B

Figure 3. Selected microfacies of the Palliser Formation. *A*, Peloidal packstone/grainstone from the lower part of the Morro Member at Inverted Ridge. Micritized and coated grains and aggregate grains are common in this facies. *B*, Partially dolomitized bioclastic packstone of the Costigan Member at Inverted Ridge. Bioclasts are chiefly pelmatozoan fragments, with lesser brachiopod and bryozoan fragments.

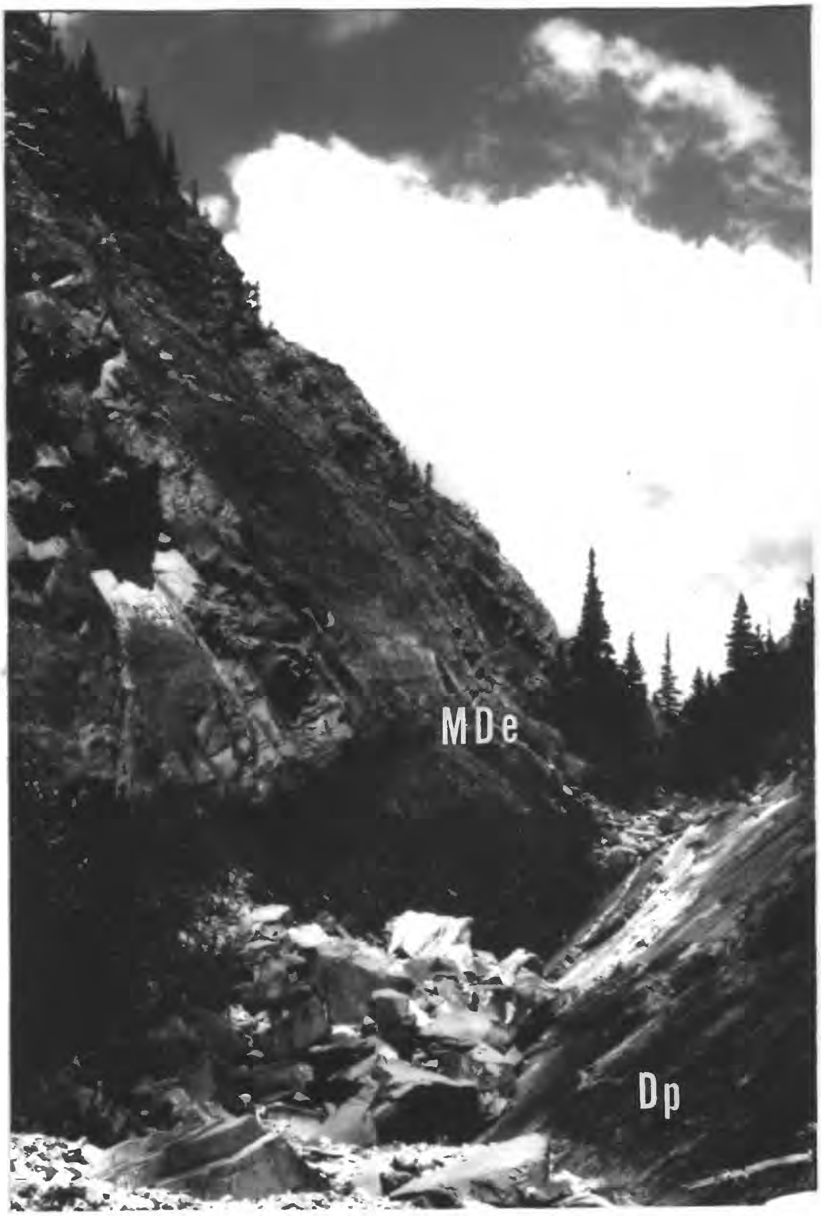

Figure 4. The type section of the Exshaw Formation at Jura Creek. The Exshaw (MDe) sharply overlies the Palliser Formation (Dp) and consists of a lower black shale member (9-10 m thick) and an upper siltstone member at this section.

Figure 5. The lower part of the Banff Formation at North Lost Creek. The basal Banff consists of recessive black and dark-gray shale and siliceous mudstone. These facies are gradationally overlain by more resistant, skeletal carbonate.

The deep-water succession was deposited in anaerobic to marginally aerobic conditions. The clastic units in the lower Banff locally contain distal turbidites. The middle to upper Banff is primarily bioclastic packstone to grainstone that formed on an aerobic, middle to shallow ramp.

CONODONT BIOSTRATIGRAPHY AND BIOFACIES

The Palliser, Exshaw, and Banff formations, and the Lussier units produce distinct conodont assemblages that can generally be dated with reference to the standard Late Devonian and Early Carboniferous zonations (e.g., Sandberg and Ziegler, 1973; Sandberg and others, 1978; Klapper and Ziegler, 1979; Sandberg and Ziegler, 1979; Lane and others, 1980; Ziegler and Sandberg, 1984, 1990). Many samples could be restricted to a single zone and at least one-third of the productive samples could be placed within a two-zone interval. With few exceptions, only samples with at least fourteen generically determinate elements were considered for biofacies evaluation. Table 1 lists all species identified for biofacies analysis in this study (in alphabetical order) and table 2 gives the age range of most of these species.

Of the several generalized Famennian and Tournaisian biofacies designated by other workers for inner platform to basin environments (e.g., Sandberg, 1976; Austin, 1976; Sandberg and Ziegler, 1979; Sandberg and Gutschick, 1979, 1983, 1984; Austin and Davies, 1984; Sandberg and Dreesen, 1984; Varker and Sevastopulo, 1985), only the more seaward biofacies were recognized in the Palliser, Exshaw, and Banff formations and correlative strata in this study. On the other hand, we have been able to subdivide these biofacies along a gentle bathymetric gradient. Although uncertainty concerning the ecologic preference(s) of the conodont animal makes interpretations of hard-part distribution tentative at best, these associations provide important information for developing depositional models. Conodont species lists, species distribution, and age and biofacies interpretation are given in tables 1-6.

Palliser Formation

Our best coverage for the Morro Member is in the Inverted Ridge area (figs. 1, 6). Here, the Morro is ~120 m thick; its lower 90 m are poorly productive of conodonts. These indicate a Lower *crepida* Zone to Lower *marginifera* Zone age (table 3). Lower Morro conodonts, in order of decreasing abundance, are chiefly *Apatognathus varians* and *Polygnathus semicostatus*. These and a few other species were undoubtedly transported into, as well as within, this mainly shallow-ramp environment, although *Apatognathus varians* and *Polygnathus semicostatus* may have lived in low numbers within this setting. Original biofacies patterns have been substantially disrupted by postmortem hydraulic transport. Bioturbation resulted in additional biofacies mixing. We infer substantial postmortem disruption because (1) 55% of the conodonts are indeterminate fragments and many are abraded; (2) of the 45% generically identifiable conodonts, most are incomplete platform elements; and (3) only a few ramiform elements are recognizable to morphotype. The highest samples from the Morro at Inverted Ridge produced representatives of *Palmatolepis stoppeli* that indicate an Upper *rhomboidea* or Lower *marginifera* age. The most abundant species are *Polygnathus semicostatus, Pa. stoppeli, Pa.* aff. *Pa. stoppeli*, and lesser *Apatognathus varians* , *Pelekysgnathus* sp., and other species of *Polygnathus*. *Palmatolepis marginifera marginifera* was recovered from the top of the Morro Member in the Lizard Range, indicating an age range of Lower to Uppermost *marginifera* Zones. Even though the percent of indeterminate fragments is high in Morro samples, *P. semicostatus* and the palmatolepids probably lived in this somewhat deeper part of the Palliser ramp

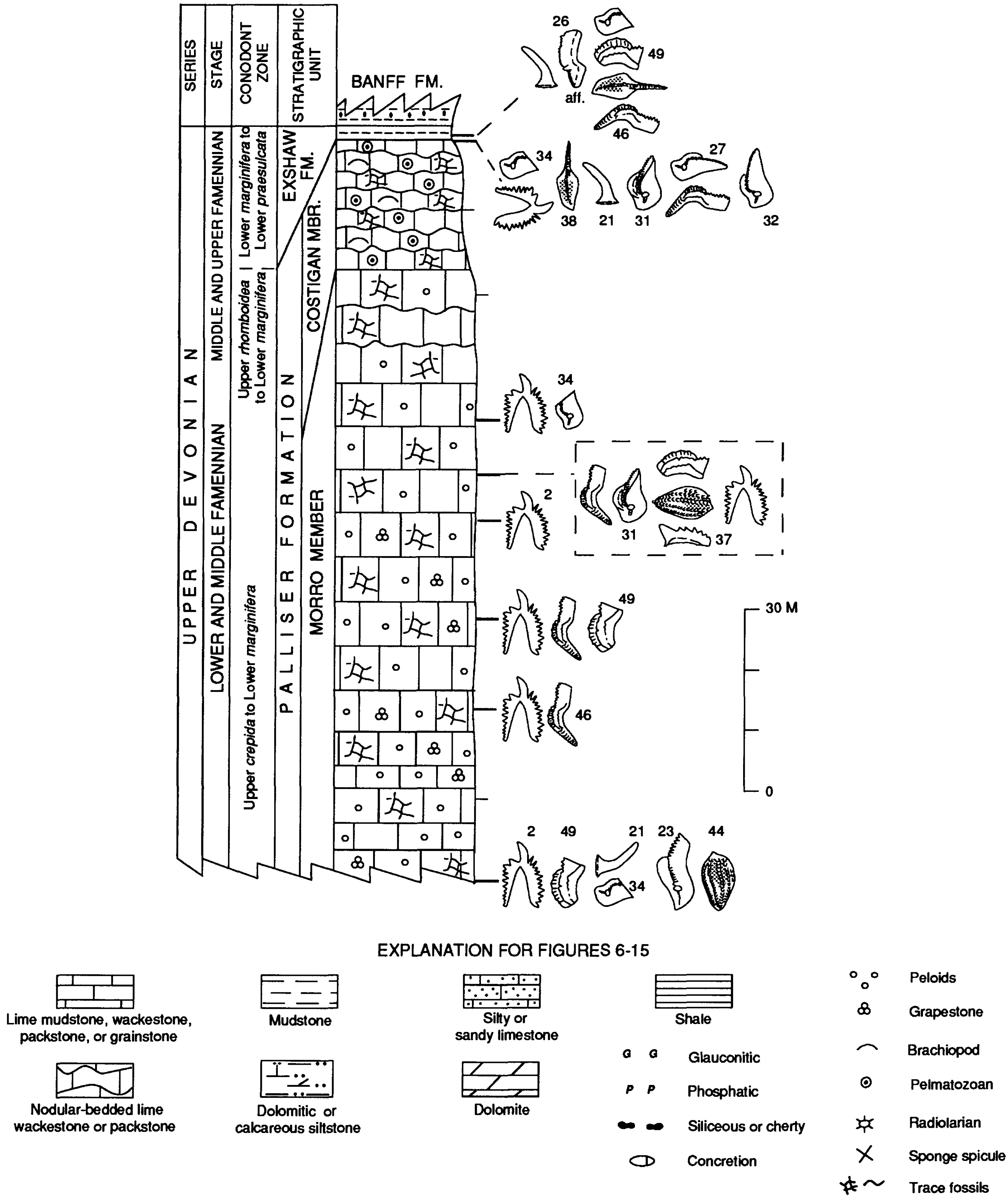

Figure 6. Conodont distribution in the upper Palliser and Exshaw formations in composite section for Inverted Ridge I and II, western Front Ranges (SA). Long, heavy tick on right of lithologic column indicates conodont sample; short tick indicates barren sample or yield inappropriate for biofacies analysis. Conodont species are shown in order of decreasing abundance from left to right; vertically stacked species are equally abundant. Species number is keyed to species named in tables 1 and 2. Tables 3 and 4 give species distribution and abundance for all samples, including those not used for biofacies analysis. Thickness of Exshaw Formation exaggerated; unit is 1 m thick at this section.

because elements of these species are more abundant and better preserved than in underlying, shallower water Morro deposits.

The overlying Costigan Member is <20-35 m thick near the international border, and contains a greater abundance of more open-marine skeletal benthos than the Morro in this area (fig. 3*B*). Conodont abundance and preservation are also slightly better. About 50% of the conodonts are indeterminate fragments but more ramiform elements are taxonomically identifiable. A collection from the highest Costigan at Inverted Ridge II (table 3, fig. 6) contains chiefly *Palmatolepis* sp. indet., *Apatognathus varians, Polygnathus communis,* icriodontids, *Pa. stoppeli, Pa. marginifera marginifera, P. semicostatus,* and *Pa. stoppeli* transitional to *Pa. m. marginifera* This association indicates a Lower *marginifera* Zone age. A sample from the upper Costigan at Inverted Ridge I yielded *Pa. marginifera marginifera, P. semicostatus, A. varians* and *Pa.* sp. This association indicates an age range of Lower to Uppermost *marginifera* Zones. Most collections from the highest Costigan from other sections near the international border contain varying ratios of the same general species. *Pa. stoppeli* transitional to *Pa. m.marginifera* was recovered from the uppermost Palliser at North Lost Creek, suggesting a Lower *marginifera* Zone age . The highest Palliser at Crowsnest Pass, on the same thrust sheet but to the north (fig. 7) also produced *Pa. m. marginifera* (Lower to Uppermost *marginifera* Zones); Johnston and Chatterton (1991) also recovered this species in the highest Palliser at this locality. Because apparatuses and some elements are more complete and more abundant than in the Morro Member, at least near the international border it is likely that the palmatolepids and *A. varians* lived at moderate to shallow depths on the Palliser ramp and that *P. communis* and *P. semicostatus* probably lived here as well. Samples from the highest Costigan in the Lizard Range contain chiefly *P. semicostatus* and rare *A. varians, Bispathodus stabilis, P. communis* and *P.* aff. *P. experplexus. Polygnathus* aff. *P. experplexus* suggests an *expansa* Zone age which is younger than the top of the Costigan in sections to the east and southeast. Specimens from these samples are very large and abraded suggesting hydraulic reworking. It may be that the top of the Palliser at this locality contains scattered lag concentrates that are considerably younger than the top of the Morro Member and, possibly, most of the Costigan Member in the southern area.

The highest Costigan was also sampled at sections in the northern area near the Bow Valley (fig. 1, table 3, and Appendix 1). These samples are likewise younger than those near the international border. *Polygnathus experplexus*, recovered 0.05 and 4 m below the top of the member at Mount Lorette and reported by Richards and Higgins (1988) from the highest Costigan at Jura Creek (fig. 8), indicates a Lower to Middle *expansa* Zone age. The sample 4 m below the top also contains other nodose polygnathids including *P.* cf. *P. subirregularis* and *P.* aff. *P. homoirregularis.* If the form identified as cf. *P. subirregularis* has the same range as *P. subirregularis*, then the sample would be restricted to the Lower *expansa* Zone. *Alternognathus regularis* was recovered from the uppermost Costigan at Limestone Mountain, about 10 km south of Mount Lorette, and indicates an age range of Uppermost *marginifera* through Upper *postera* Zones (C.A. Sandberg, oral communication, 1992). A sample ~35 m lower produced abundant polygnathids and lesser numbers of *Apatognathus varians, Palmatolepis marginifera marginifera,* and *Polylophodonta* cf. *Pol. linguiformis*. This faunule indicates an interval within the *marginifera* Zone, possibly Lower *marginifera* Zone. The top of the Palliser at Limestone Mountain is older than the highest Palliser at Mount Lorette. Conodonts assignable to the *trachytera* to Middle *expansa* Zones occur in the highest Palliser at Mount Buller. At nearby Jura Creek (fig. 8), however, conodonts restrict the age of the top of the Palliser to the Lower or Middle *expansa* Zone (Richards and Higgins, 1988). Only one of our collections from the top of the Palliser (table 3, Mount Lorette) in the northern study area is biostratigraphically restrictive, and indicates the same age as at Jura Creek, about 15 km to the north.

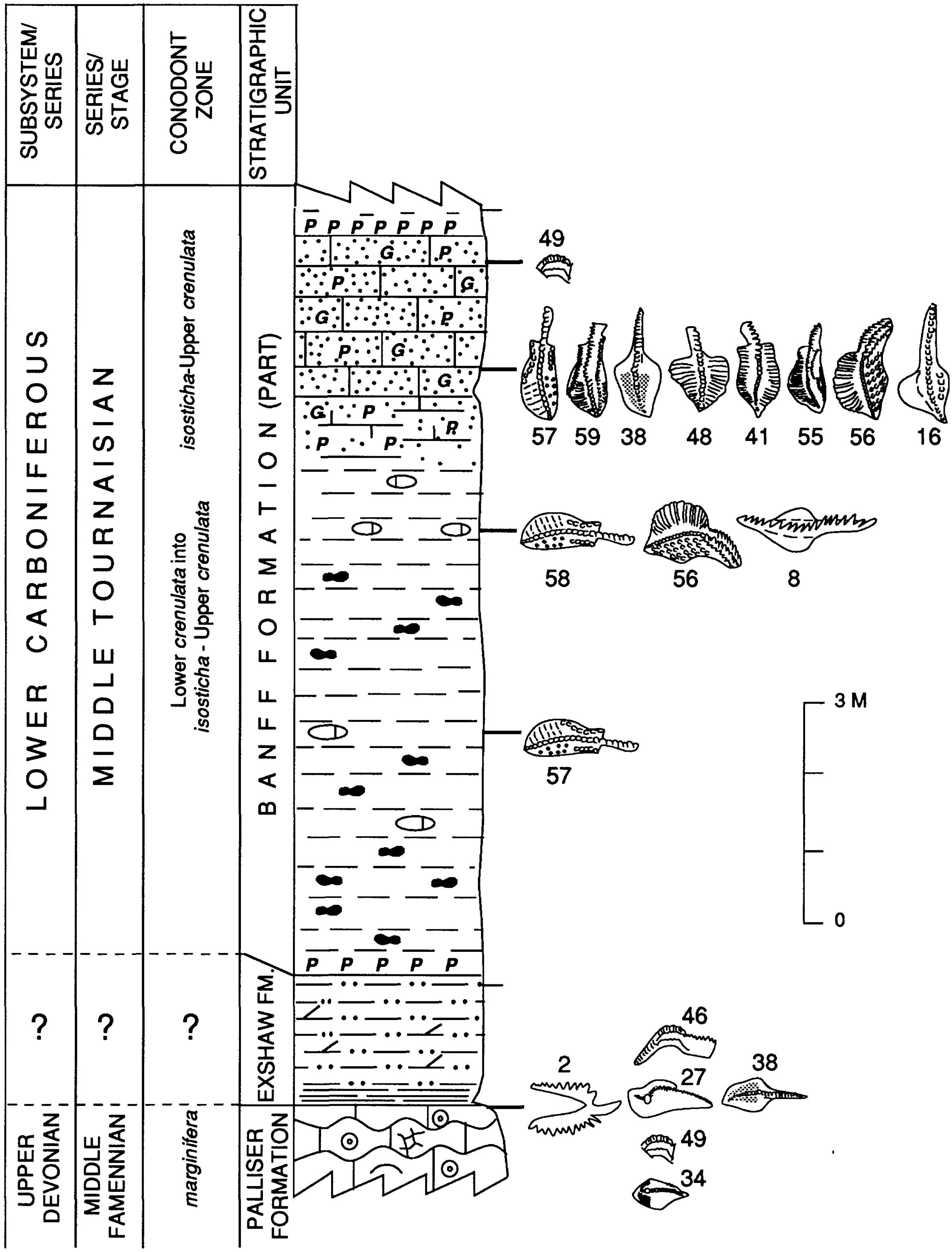

Figure 7. Conodont distribution in the upper Palliser, Exshaw, and lower Banff formations at Crowsnest Pass, eastern Front Ranges (SA). Long, heavy tick on right of lithologic column indicates conodont sample; short tick indicates barren sample or yield inappropriate for biofacies analysis. Conodont species are shown in order of decreasing abundance from left to right; vertically stacked species are equally abundant. See figure 6 for explanation of all symbols and tables 1 and 2 for species identification.

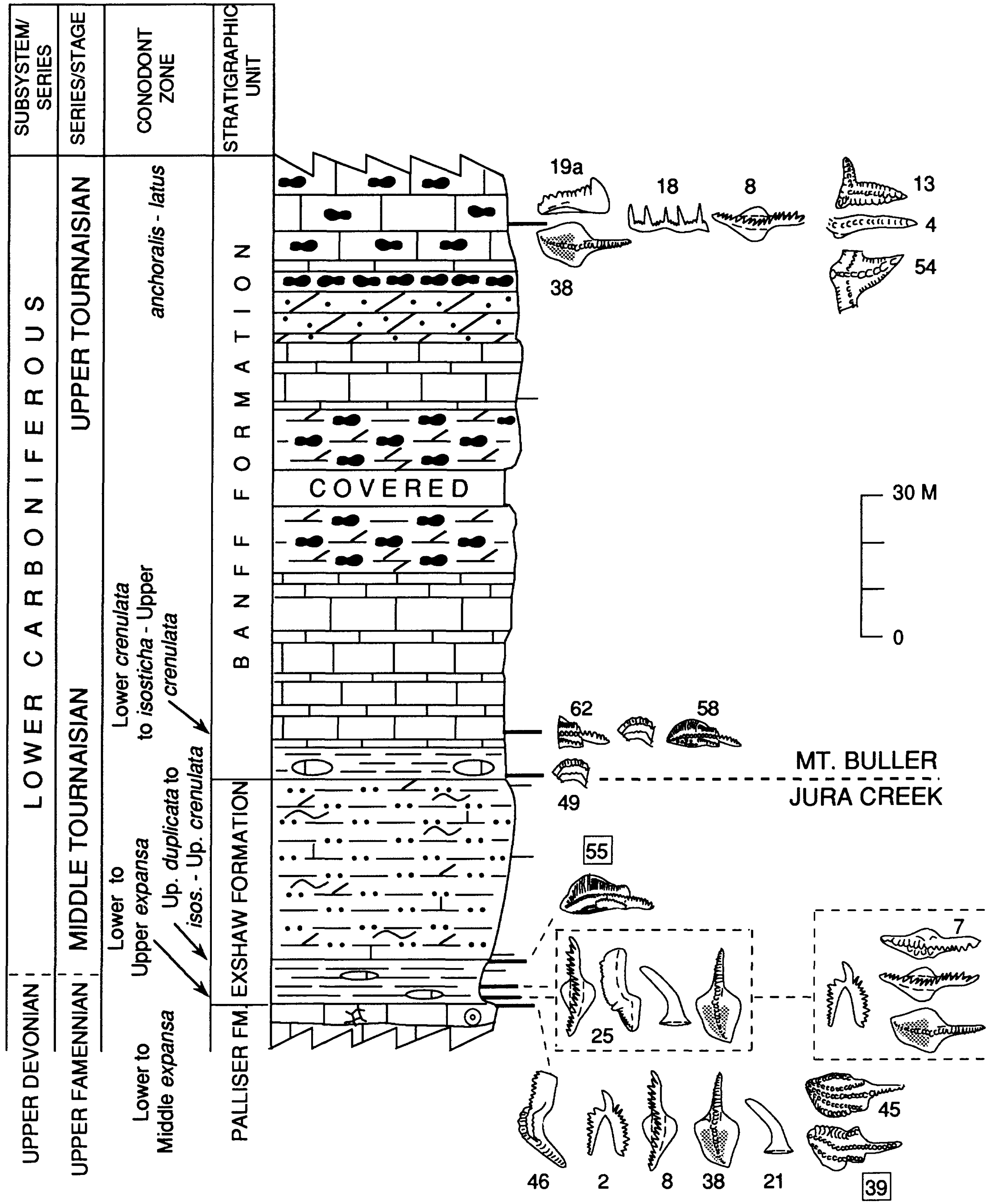

Figure 8. Conodont distribution in the upper Palliser, Exshaw, and Banff formations at a composite section for Jura Creek and Mount Buller, Front Ranges (NA). Long, heavy tick on right of lithologic column indicates conodont sample; short tick indicates barren sample or yield inappropriate for biofacies analysis. Conodont species are shown in order of decreasing abundance from left to right; vertically stacked species are equally abundant. See figure 6 for explanation of all symbols and tables 1 and 2 for species names. Species number enclosed in square indicates index species not found in this study but reported elsewhere; 39, *Polygnathus experplexus* (from Richards and Higgins, 1988); 55, *Siphonodella cooperi* (from Macqueen and Sandberg, 1970).

Our samples from the northern area contain mainly *Polygnathus semicostatus,* icriodontids, *Apatognathus varians, P. communis,* and *Bispathodus stabilis.* These faunas represent a polygnathid biofacies with postmortem addition of chiefly shallower water icriodontids.

Exshaw Formation

Few samples from the Exshaw Formation produced conodonts (table 4). At Jura Creek, the type section of the Exshaw, conodonts indicating a latest Famennian age, Lower to Upper *expansa* Zone, were found in concretions in the lower black shale member (fig. 8). One concretion produced *Bispathodus stabilis, Palmatolepis gracilis sigmoidalis,* icriodontid coniform elements, and *Polygnathus communis.* Another, slightly higher, concretion produced *Apatognathus varians, B. bispathodus, B. stabilis,* and *P. communis.* On the basis of paleogeographic distribution, it is likely that *Bispathodus stabilis* and *Palmatolepis gracilis* lived here in either low numbers or nearby. Most other taxa recovered from this lithofacies are probably not indigenous. Richards and Higgins (1988) recovered conodonts representative of Middle *expansa* to *praesulcata* Zones, including *Bispathodus costatus,* from the lower part of the black shale at Jura Creek. Macqueen and Sandberg (1970) reported early to middle Tournaisian siphonodellids from the upper black shale at Jura Creek, and lower part of the overlying siltstone member elsewhere in the Bow Valley.

Conodonts from the upper part of the 50-meter-thick Exshaw at Mount Frayn (fig. 1 and table 4) near the northern limit of the southern study area indicate a Lower *expansa* Zone into Middle *praesulcata* Zone age. The very thin Exshaw at Inverted Ridge, near the international boundary, produced *Palmatolepis gracilis* subsp. indet. and other long-ranging forms which merely indicate a middle to late Famennian (fig. 6).

Banff Formation

The Banff Formation, near the international border, is a progradational, shallowing-upward, mixed chert-siliciclastic-carbonate succession of chiefly late Tournaisian age. *"Hindeodella" segaformis, Doliognathus latus,* and *Scaliognathus anchoralis* in the phosphatic and siliceous mudstone and limestone 17 m above the top of the Palliser at North Lost Creek (table 5) indicate the Upper *typicus* to upper *anchoralis-latus* Zones; *"H". segaformis,* bactrognathids, and bispathodids also occur in the basal Banff at Inverted Ridge (fig. 9 and table 5). Most specimens are broken and abraded. If these taxa lived in this basinal to deep ramp environment, it is likely that they did so in small numbers. Interestingly, only bactrognathids increase in abundance higher in the section. The succeeding 80 m of siliceous mudstone, limestone, and siltstone are even more poorly productive of conodonts. Samples produced *Polygnathus communis,* and rare *Hindeodus crassidentatus* and *Bispathodus* aff. *B. stabilis.* These taxa may have lived in small numbers along this deep to middle part of the ramp. The upper 90 m of the Banff are chiefly crinoidal packstone that produced a more abundant but low-diversity fauna (fig. 9 and table 5). Varying ratios of three species dominate-- *Bactrognathus hamatus, Polygnathus communis,* and *H. crassidentatus*; *Synclydognathus geminus* and *Bispathodus* aff. *B. stabilis* form minor components. These conodonts also are of a late Tournaisian age (uppermost *typicus* to upper *anchoralis-latus* Zones). *Polygnathus communis* decreases as *H. crassidentatus* increases upsection; likewise *S. geminus,* a relatively shallow-water form, increases in the highest part of the section. These conodonts probably lived in this hydraulically active regime of the shallow ramp. This litho- and biofacies succession is consistent for most sections studied in the international boundary area. At Crowsnest Pass (fig. 7), however, an interval 3 to 10 m above the base of the Banff yielded rare to abundant conodonts of middle

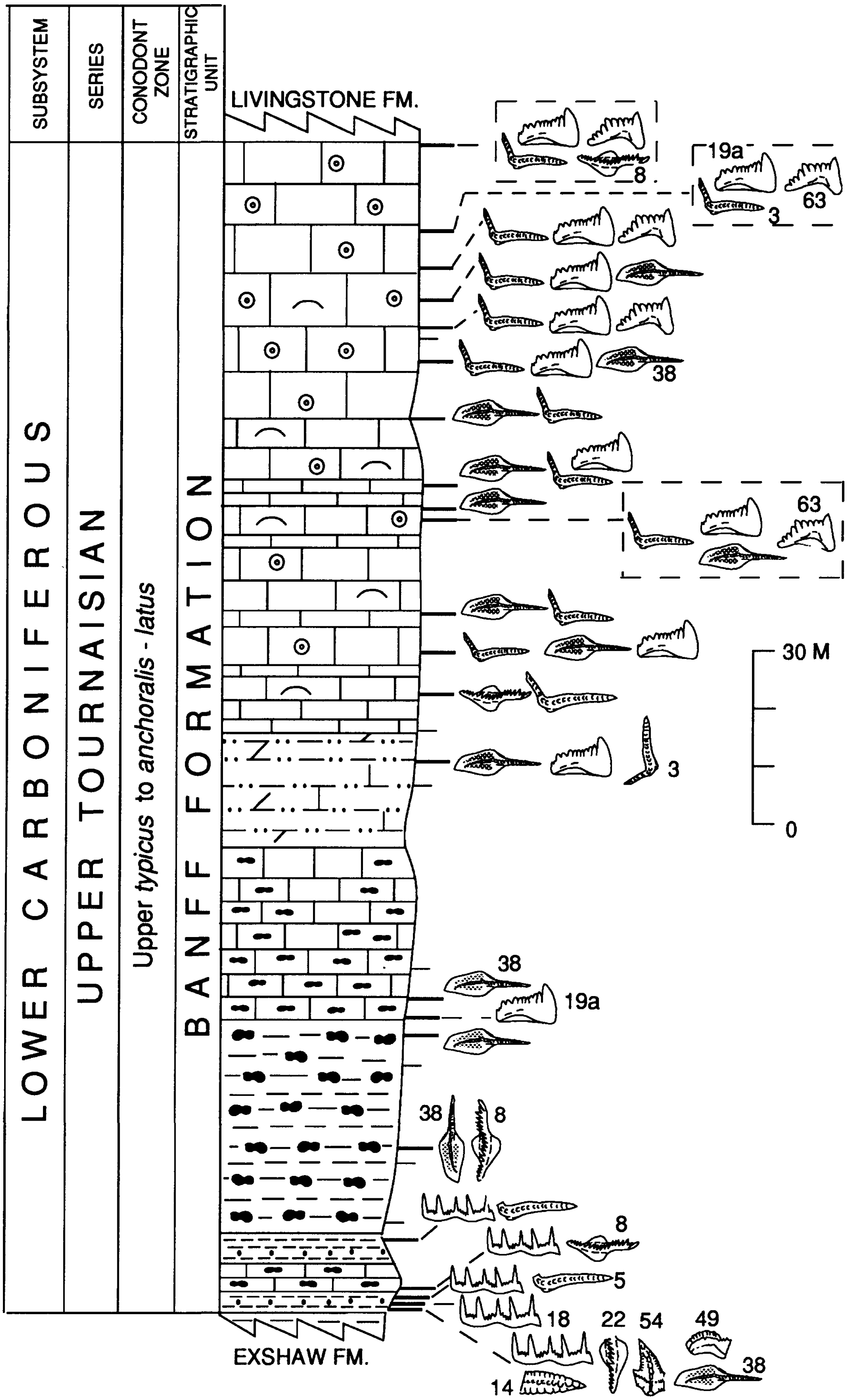

Figure 9. Conodont distribution in the Banff Formation at composite section for Inverted Ridge I and II, western Front Ranges (SA). Long, heavy tick on right of lithologic column indicates conodont sample; short tick indicates barren sample or yield inappropriate for biofacies analysis. Conodont species are shown in order of decreasing abundance from left to right; vertically stacked species are equally abundant. See figure 6 for explanation of all symbols and tables 1 and 2 for species identification.

Tournaisian age. All samples but the highest contain siphonodellids such as *Siphonodella isosticha, S. isosticha-obsoleta,* and *S. crenulata.* Siphonodellids also occur 25 m above the base of the Banff at Mount Frayn (table 5). All these middle Tournaisian samples represent the siphonodellid biofacies, with postmortem admixtures of shallower water forms. Lithofacies and abundant *Siphonodella* indicate deep-water deposition.

The Banff is well exposed at sections in the northern area. *Siphonodella* cf. *S. isosticha* occurs 10 m above the base of the formation at Mount Buller indicating a middle Tournaisian age similar to the lowermost Banff in some southern sections (fig. 8). A productive sample 105 m higher contains chiefly *Polygnathus communis, Hindeodus crassidentatus,* and *"Hindeodella" segaformis,* as well as rare doliognathids, bactrognathids, bispathodids, scaliognathids, and gnathodids. The fauna indicates the *anchoralis-latus* Zone and is comparable in age to most of the Banff in southern sections. A sample collected 65 m above the base of the Exshaw Formation at Limestone Mountain yielded a middle(?) Tournaisian fauna dominated by siphonodellids, including *Siphonodella obsoleta, S. cooperi,* and *S.* aff. *S. crenulata* and *Bispathodus stabilis.* These conodonts probably represent the Lower *crenulata* to *isosticha*-Upper *crenulata* Zones. The upper Banff at Jura Creek (136 m above its base) yielded *Polygnathus communis*, specimens of *Polygnathus inornatus - P. bischoffi* plexus, *Hindeodus* cf. *H. penescitulus,* and rarer *H. crassidentatus*, siphonodellids, and bispathodids (*B. stabilis* and *B. aculeatus*) (table 5). This association indicates a middle Tournaisian age (Lower *crenulata* into *isosticha*-Upper *crenulata* Zones). Conodont faunas of this age have been reported from the Banff Formation and correlative strata elsewhere in the southern Canadian Rocky Mountains (e.g., Macqueen and Sandberg, 1970; Richards and Higgins, 1988; Higgins and others, 1991). Higgins and others (1991) provide a biofacies analysis for basin to restricted shelf deposits during Early Carboniferous time for an extensive part of the Canadian Cordillera primarily north of our study area. A direct comparison between their biofacies models and ours cannot be made because the same environments in each area are not time equivalent and are thus represented by different species associations.

Correlative units in the Lussier syncline

The Lussier syncline lay in a basinal setting during Famennian through at least middle Tournaisian time. The lower 125 m of the section are poorly exposed, laminated black to wavy-laminated dark-gray shale and radiolarian mudstone. One concretion from the lower part of this interval yielded abundant palmatolepid apparatuses as well as very rare *Polygnathus* sp., and icriodontids, which, on the basis of taphonomy, were winnowed from shallower water (fig. 10 and table 3). The palmatolepids indicate an Upper *crepida* or lowermost *rhomboidea* Zone age. Another collection, ~40 m higher in the shale sequence, produced *Gnathodus punctatus* indicating an *isosticha*-Upper *crenulata* Zone to Lower *typicus* Zone age (table 5). Thus, the Devonian-Carboniferous boundary is within the shale. A concealed interval of ~100 m is followed by partly dolomitized and silicified bioclastic packstone and chert that are assigned to the Banff Formation(?). Samples from near the base of the Banff(?) produced chiefly *Bispathodus* sp., *Cloghergnathus* sp., *Hindeodus crassidentatus*, and *Taphrognathus varians* indicating an age probably no older than the *texanus* Zone and thus the youngest Banff(?) in the study area. Westward-prograding carbonate facies should be younger in this westernmost section.

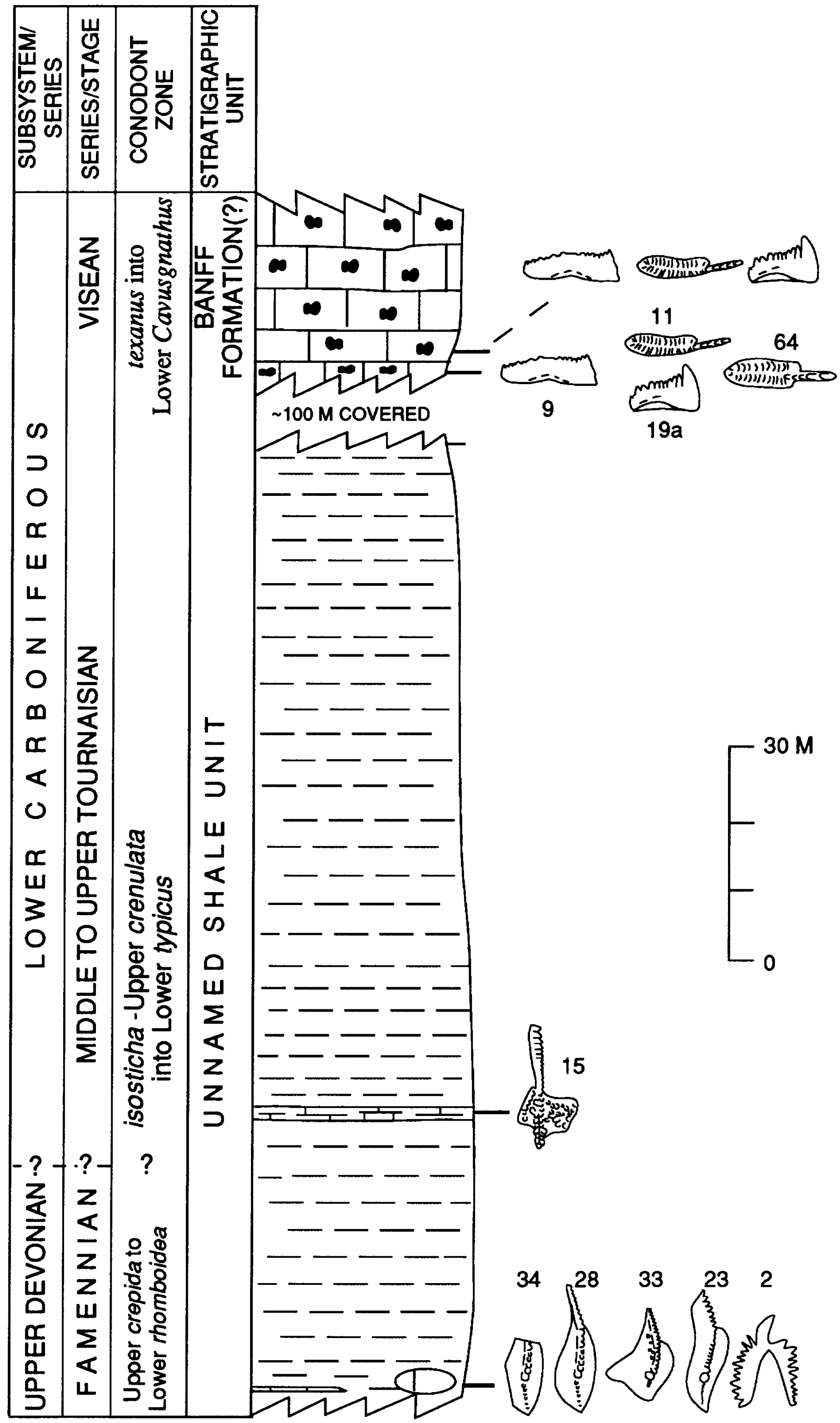

Figure 10. Conodont distribution in an unnamed shale unit and overlying Banff Formation(?) in the Lussier syncline, eastern Main Ranges (SA). Long, heavy tick on right of lithologic column indicates conodont sample; short tick indicates barren sample or yield inappropriate for biofacies analysis. Lowest tick in unnamed shale unit represents composite of two samples; one from a concretion and another from the carbonate bed; the carbonate bed produced only *Palmatolepis* sp. and *Apatognathus varians* (34 and 2). Conodont species are shown in order of decreasing abundance from left to right; vertically stacked species are equally abundant. See figure 6 for explanation of all symbols and tables 1 and 2 for species identification.

PALEOGEOGRAPHIC SETTING

Lithologic and conodont biostratigraphic, taphonomic, and biofacies analyses were used to interpret the latest Devonian and earliest Carboniferous paleogeography of this part of the Cordillera (figs. 11-15 and table 6). Figure 11 is a composite paleographic diagram for early and middle Famennian time (Upper *crepida* through Lower *marginifera* Zones). The Morro and Costigan lithofacies formed on the shallow to middle part of a carbonate ramp and the Lussier shales formed in the basin to the west. During Upper *crepida* to Lower *marginifera* time, icriodontids lived in the shallowest ramp facies with low numbers of nodose polygnathids and apatognathids. *Apatognathus varians, Polygnathus semicostatus* and lesser *Palmatolepis stoppeli - Pa. marginifera* lived in a deeper part of the shallow ramp. Icriodontid coniform elements were winnowed into this and even deeper parts of the ramp; more rarely, storms contributed robust polygnathids and icriodontid platform elements. The palmatolepids and relatively smooth polygnathids predominated over the middle ramp. This environment appears to have been the outer range for *P. semicostatus* and *A. varians* and possibly the inner range for *Pa. glabra*. Typical, more delicate palmatolepids lived, from time to time, in the basin. Generally, middle Paleozoic basin shales contain relatively few indigenous conodonts except as a consequence of postmortem concentration.

The top of the Costigan is of middle to late Famennian age (*trachytera* to *expansa* Zones) in the northern area, and formed on the shallow to middle ramp (fig. 12). Although species associations are somewhat different than during older Costigan time to the south, morphotypes are similar. *Polygnathus semicostatus* and *P. communis* and possibly *Apatognathus varians* lived along this part of the ramp. *Bispathodus stabilis* is rare and icriodontid winnows are common. *P. experplexus* is common in the uppermost Costigan only at Mount Lorette.

Two Exshaw localities produced conodonts of latest Famennian age (fig. 13). The conodonts are representative of the palmatolepid-bispathodid biofacies. *Palmatolepis gracilis sigmoidalis* is most common and probably lived in low numbers in and near this environment and the same may apply to *Polygnathus communis* and the bispathodids. Rarer icriodontids and apatognathids are considered postmortem winnows.

Four lower Banff localities indicate the *isosticha*-Upper *crenulata* Zone of middle Tournaisian age and another locality at Limestone Mountain may be the same or slightly older age (fig. 14). These deposits formed on the deep ramp. A lag concentrate from Crowsnest Pass represents a siphonodellid-polygnathid biofacies that strongly suggests these forms lived in low numbers within and (or) close to this environment. The lower to middle Banff near the international border also formed in a deep ramp to basin setting in late Tournaisian time (fig. 15*A*). This was the outer range for winnowed *"Hindeodella" segaformis* fragments even though the conodont probably lived nearby. *Doliognathus, Scaliognathus, Bispathodus*, and polygnathids were living in low to moderate numbers in this or nearby environments (fig. 15*A*). Higher in the Banff, and on the carbonate ramp, these same localities are within the bactrognathid-polygnathid-hindeodid biofacies composed of *Bactrognathus hamatus, Polygnathus communis,* and *Hindeodus crassidentatus* (fig. 15*B*) The dominance and consistent association of these species indicate they lived in this environment. Samples of late Tournaisian age from the upper Banff in the northern area represent a polygnathid-hindeodid biofacies (fig. 15*B*).

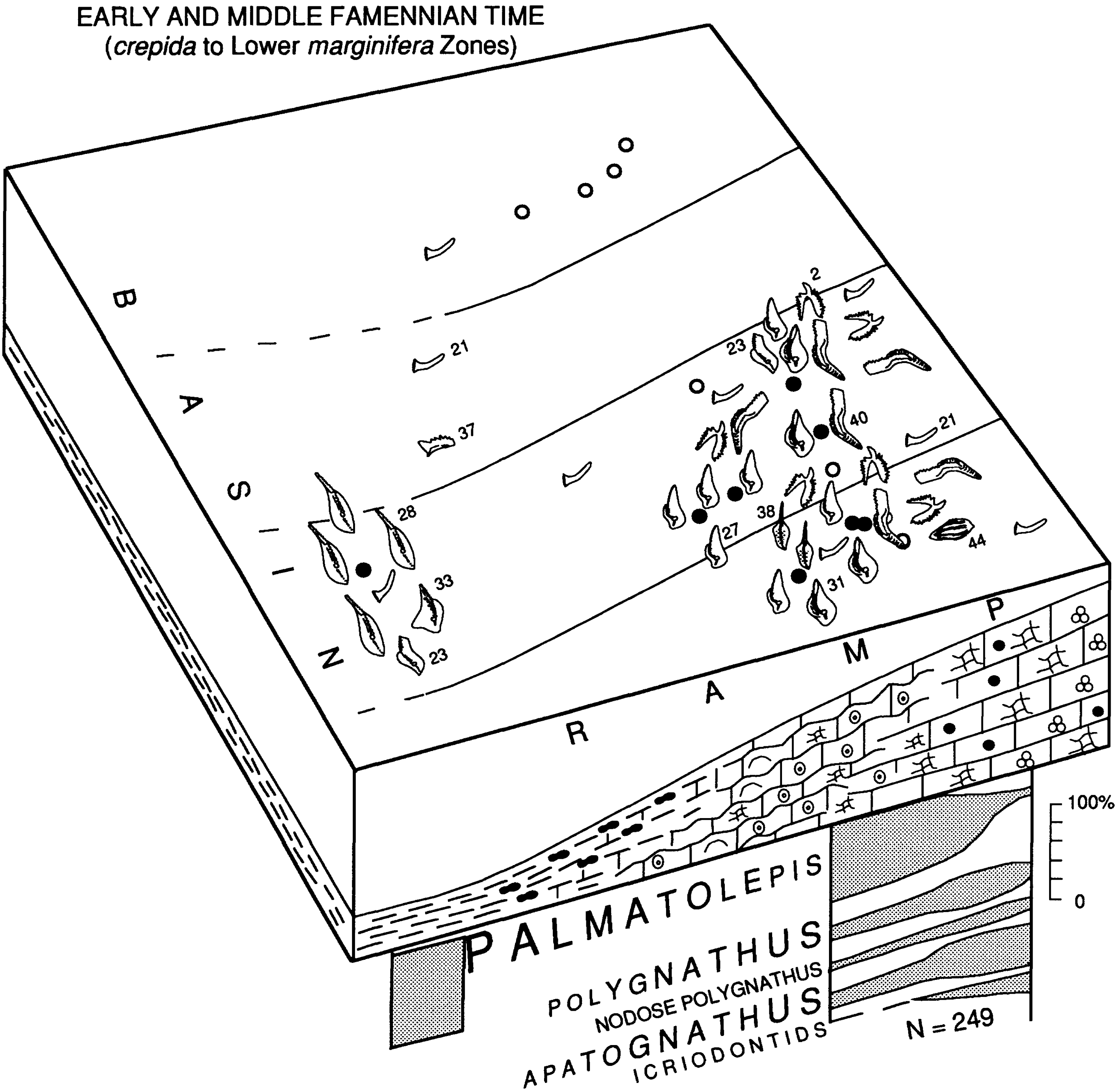

Figure 11. Cartoon showing conodont species associations (biofacies) in a ramp to basin setting (Palliser to Lussier shale facies) during early to middle Famennian time (*crepida* to Lower *marginifera* Zones). All samples are from the southern area. Sections (circles) palinspastically restored; solid circles indicate sections that produced diagnostic conodonts for biofacies and biostratigraphic analysis for this time interval. The number of conodonts in an area is proportional to species distribution in our samples. N = number of specimens identified to genus. Conodonts interpreted as indigenous and lacking significant postmortem transport are oriented parallel to depositional strike. Those transported into or within an environment are oriented at various angles; conodonts perpendicular to depositional strike have moved the farthest; posterior end of element indicates direction of postmortem transport. See table 1 for species identification, figure 6 for identification of lithologic symbols, and figure 13 for identification of sections.

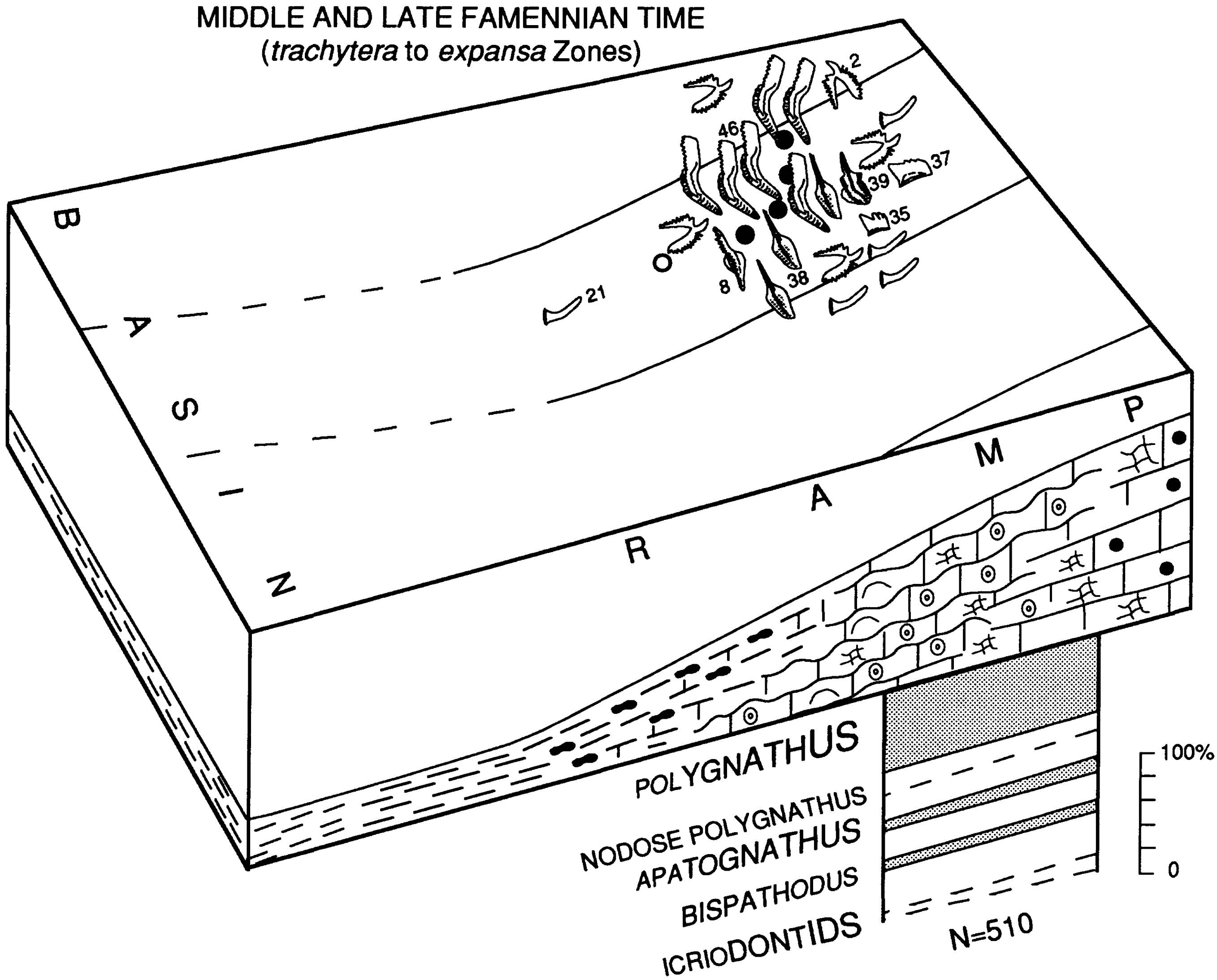

Figure 12. Cartoon showing conodont species associations (biofacies) in a ramp setting (Palliser facies) during middle and late Famennian time (*trachytera* to *expansa* Zones). All samples are from the northern area. Sections (circles) palinspastically restored; solid circles indicate sections that produced diagnostic conodonts for biofacies and biostratigraphic analysis for this time interval. The number of conodonts in an area is proportional to species distribution in our samples. N = number of specimens identified to genus. Conodonts interpreted as indigenous and lacking significant postmortem transport are oriented parallel to depositional strike. Those transported into or within an environment are oriented at various angles; conodonts perpendicular to depositional strike have moved the farthest; posterior end of conodont indicates direction of postmortem transport. See figure 11 for explanation of symbols, figure 13 for section identification, and table 1 for species identification.

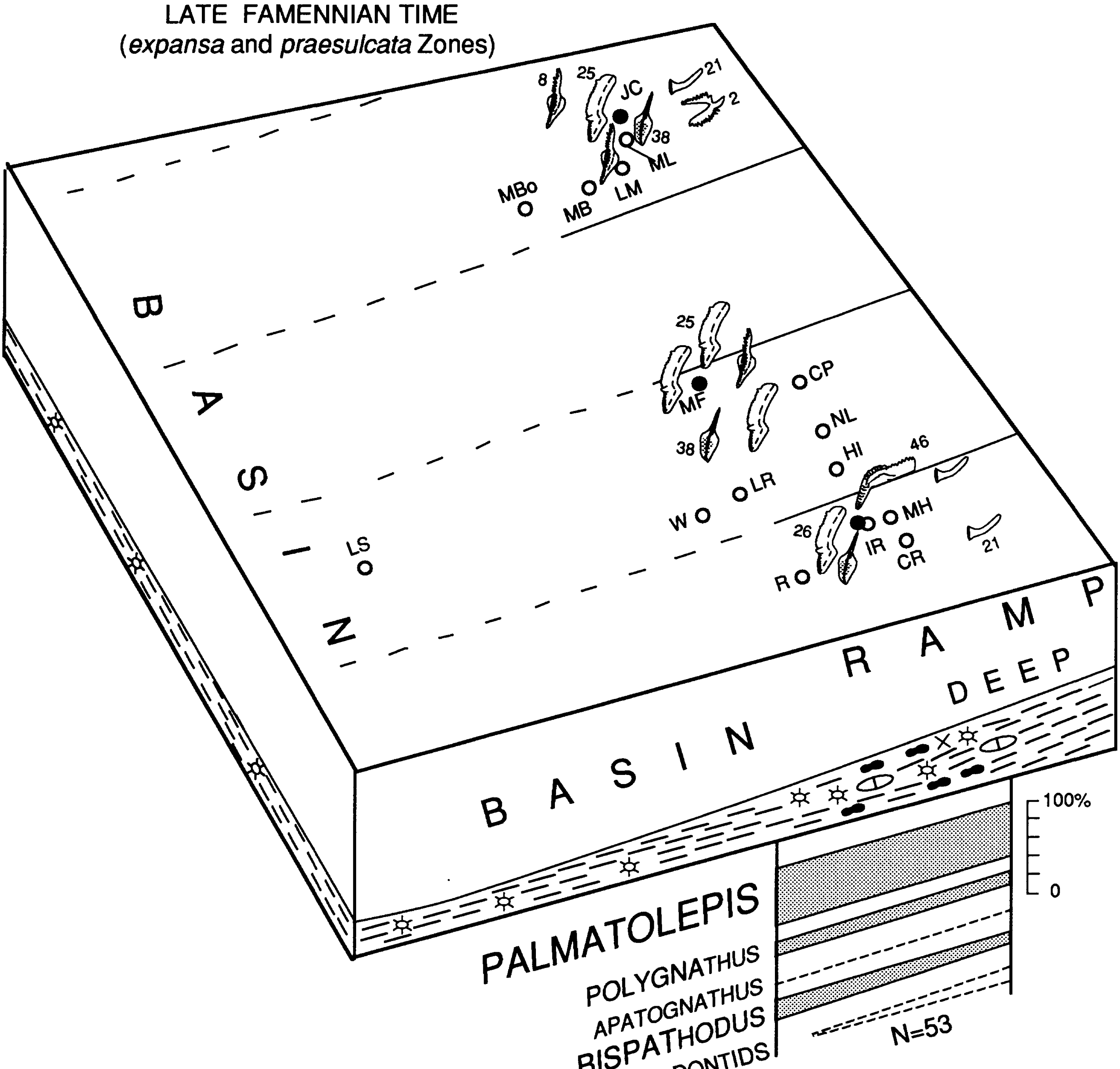

Figure 13. Cartoon showing conodont species association (biofacies) in a deep ramp to basin (Exshaw facies) setting during late Famennian time (*expansa* and *praesulcata* Zones). The collection from the lower Exshaw Formation at Inverted Ridge II may represent the same or a somewhat older interval. Sections (circles) palinspastically restored; solid circles indicate sections that produced diagnostic conodonts for biofacies and biostratigraphic analysis for this time interval. The number of conodonts in an area is proportional to species distribution in our samples. N = number of specimens identified to genus. Conodonts interpreted as indigenous and lacking significant postmortem transport are oriented parallel to depositional strike. Those transported into or within an environment are oriented at various angles; conodonts perpendicular to depositional strike have moved the farthest; posterior end of conodont indicates direction of postmortem transport. Lettered sections are: CR, Cleft Rock; CP, Crowsnest Pass; HI, Howell Inlier; IR, Inverted Ridge I and II; JC, Jura Creek; LM, Limestone Mountain; LR, Lizard Range; LS, Lussier syncline; MBo, Mount Bourgeau; MB, Mount Buller; MF, Mount Frayn; MH, Mount Hefty; ML, Mount Lorette; NL, North Lost Creek; R, Roosville; W, Wardner. See figure 6 for identification of lithologic symbols and table 1 for species identification.

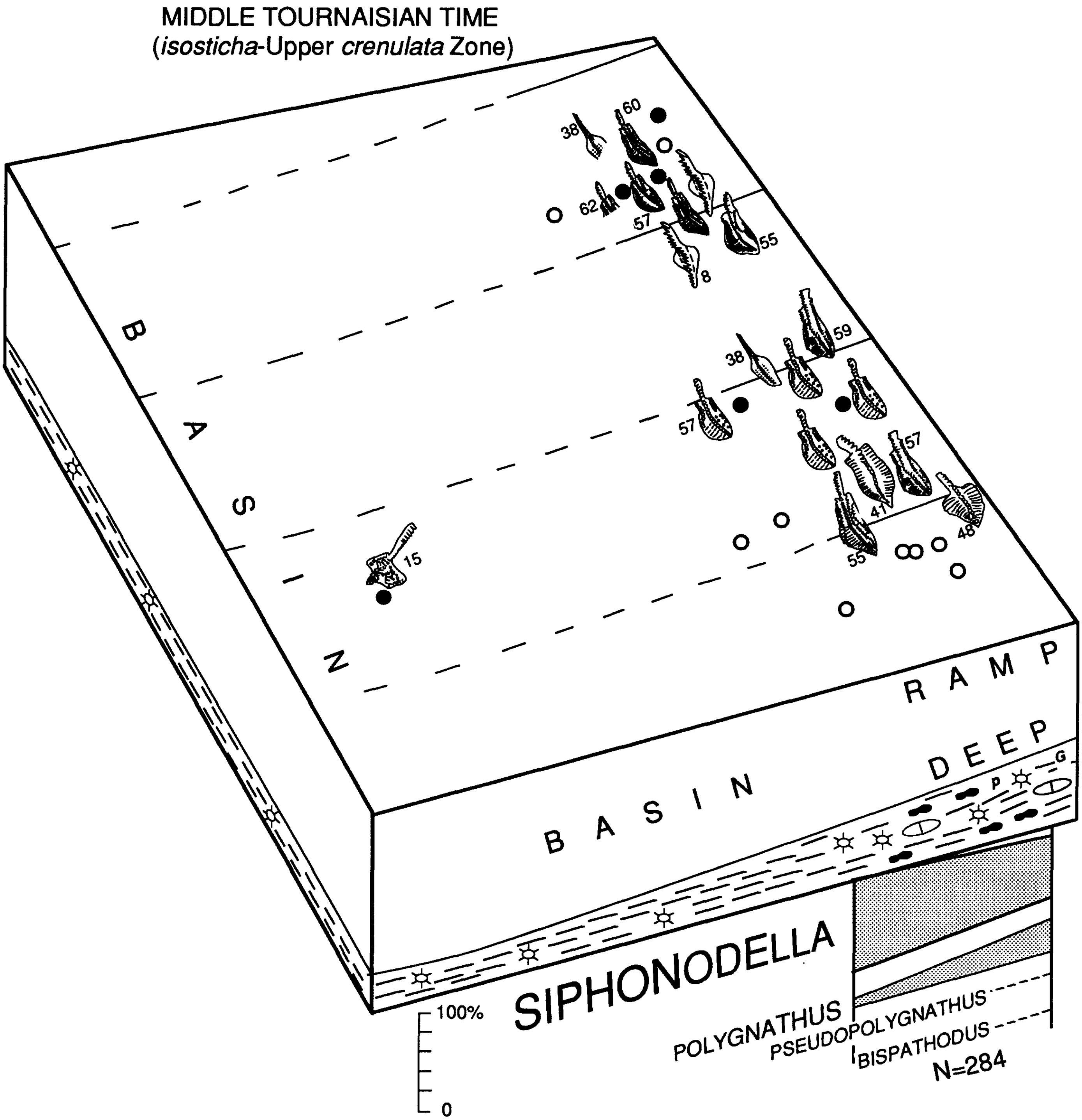

Figure 14. Cartoon showing conodont species association (biofacies) in a deep ramp to basin setting (lower Banff facies) during middle Tournaisian time (*isosticha*-Upper *crenulata* Zone). The collection from the lower Banff at Limestone Mountain may represent the same or a slightly older interval. Sections (circles) palinspastically restored; solid circles indicate sections that produced diagnostic conodonts for biofacies and biostratigraphic analysis for this time interval. The number of conodonts in an area is proportional to species distribution in our samples. N = number of specimens identified to genus. Conodonts interpreted as indigenous and lacking significant postmortem transport are oriented parallel to depositional strike. Those transported into or within an environment are oriented at various angles; conodonts perpendicular to depositional strike have moved the farthest; posterior end of conodont indicates direction of postmortem transport. See table 1 for species identification, figure 6 for identification of lithologic symbols, and figure 13 for identification of sections.

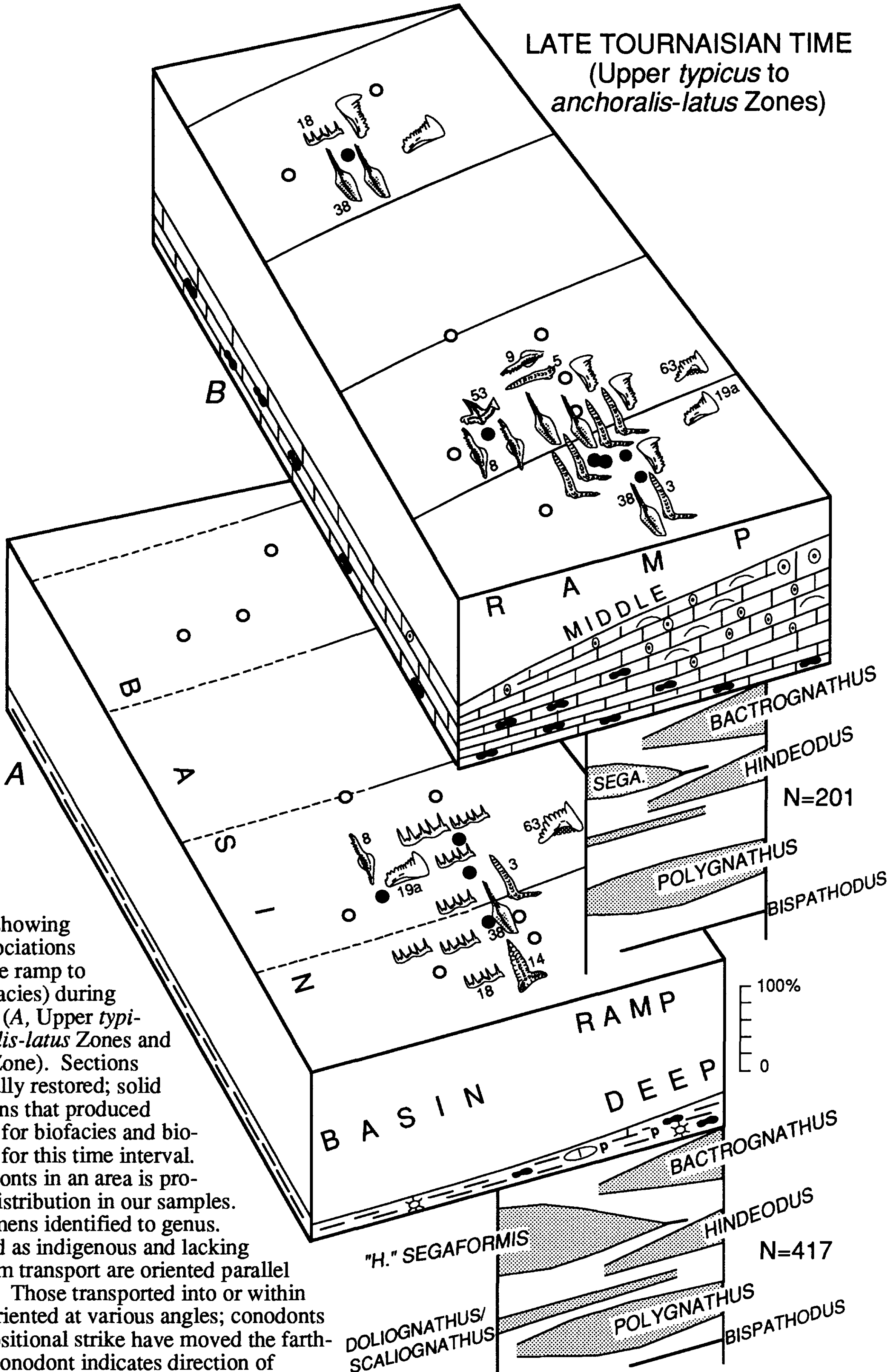

Figure 15. Cartoon showing conodont species associations (biofacies) in a middle ramp to basin setting (Banff facies) during late Tournaisian time (*A*, Upper *typicus* to lower *anchoralis-latus* Zones and *B*, *anchoralis-latus* Zone). Sections (circles) palinspastically restored; solid circles indicate sections that produced diagnostic conodonts for biofacies and biostratigraphic analysis for this time interval. The number of conodonts in an area is proportional to species distribution in our samples. N = number of specimens identified to genus. Conodonts interpreted as indigenous and lacking significant postmortem transport are oriented parallel to depositional strike. Those transported into or within an environment are oriented at various angles; conodonts perpendicular to depositional strike have moved the farthest; posterior end of conodont indicates direction of postmortem transport. See table 1 for species identification, figure 6 for identification of lithologic symbols, and figure 13 for identification of sections.

CONCLUSION

The Palliser to Banff depositional succession formed in dynamic environments that produced comparatively few determinate conodonts possibly due to movement of material downslope and turbidity, as well as bioturbation. In addition, a substantial volume of this succession contains rock types from which conodonts cannot be adequately recovered. Temporally and spatially, parts of the ramp probably did not support large conodont populations. The remains of conodonts that did live along the ramp underwent abrasive and possibly long-term transport that tended to grind and break elements into indeterminate fragments. Moreover, extensive burrowing and some boring wreaked additional havoc on elements that had barely survived hydraulic transport.

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TABLE 1.--CONODONT SPECIES IDENTIFIED FROM THE PALLISER, EXSHAW, AND BANFF FORMATIONS AND CORRELATIVE UNITS

[Species numbers are keyed to tables 3-5 and figures 6-15]

SPECIES NO.	SPECIES NAME
1	*Alternognathus regularis* Ziegler & Sandberg
2	*Apatognathus varians* Branson & Mehl
3	*Bactrognathus hamatus* Branson & Mehl + cf. *B. hamatus*
4	*Bactrognathus* sp.
5	bactrognathids
6	*Bispathodus aculeatus* (Branson & Mehl)
7	*Bispathodus bispathodus* Ziegler, Sandberg & Austin
8	*Bispathodus stabilis* (Branson & Mehl) + aff. or *B. utahensis* Sandberg & Gutschick
9	*Bispathodus* sp.
10	cavusgnathids
11	*Cloghergnathus* sp.
12	*Clydagnathus* sp.
13	*Doliognathus latus* Branson & Mehl
14	*Doliognathus* sp.
15	*Gnathodus punctatus* (Cooper)
16	*Gnathodus* cf. *G. typicus* Cooper
17	*Gnathodus* sp.
18	*Hindeodella segaformis* Bischoff s.f.
19a	*Hindeodus crassidentatus* (Branson & Mehl)
19b	*Hindeodus* cf. *H. penescitulus* (Rexroad & Collinson)
20	"*Icriodus*" sp.
21	icriodontids
22	ozarkodinids
23	*Palmatolepis glabra* Ulrich & Bassler subsp.
24	*Palmatolepis gracilis expansa* Sandberg & Ziegler
25	*Palmatolepis gracilis sigmoidalis* Ziegler
26	*Palmatolepis gracilis* subsp.
27	*Palmatolepis marginifera marginifera* Helms + aff.
28	*Palmatolepis minuta minuta* Branson & Mehl
29	*Palmatolepis quadrantinodosalobata* Sannemann
30	*Palmatolepis* cf. *Pa. regularis* Cooper
31	*Palmatolepis stoppeli* Sandberg & Ziegler + aff. + cf.
32	*Palmatolepis stoppeli* transitional to *Pa. marginifera*

SPECIES NO.	SPECIES NAME
33	*Palmatolepis subperlobata* Branson & Mehl + cf.
34	*Palmatolepis* sp.
35	*Pelekysgnathus* cf. *Pe. brevis* Sandberg & Dreesen
36	*Pelekysgnathus* aff. *Pe. inclinatus* Thomas
37	*Pelekysgnathus* spp.
38	*Polygnathus communis* Branson & Mehl subspp.
39	*Polygnathus experplexus* Sandberg & Ziegler + aff.
40	*Polygnathus* aff. *Po. homoirregularis* Ziegler
41	*Polygnathus inornatus* Branson
42	*Polygnathus inornatus* Branson-*P. bischoffi* Rhodes, Austin & Druce
43	*Polygnathus longiposticus* Branson & Mehl
44	*Polygnathus nodocostatus* Branson & Mehl + cf.
45	*Polygnathus* aff. *P. perplexus* Thomas
46	*Polygnathus semicostatus* Branson & Mehl
47	*Polygnathus* cf. *P. subirregularis* Sandberg & Ziegler
48	*Polygnathus triangulus* (Voges)
49	*Polygnathus* spp.
50	*Polylophodonta* spp.
51	*Pseudopolygnathus multistriatus* Mehl & Thomas
52	*Pseudopolygnathus* sp.
53	*Scaliognathus anchoralis* Branson & Mehl
54	*Scaliognathus* sp.
55	*Siphonodella cooperi* Hass
56	*Siphonodella crenulata* (Cooper) +aff.
57	*Siphonodella isosticha* (Cooper) + aff.
58	*Siphonodella* cf. *S. isosticha* (Cooper)
59	*Siphonodella isosticha-S. obsoleta* Hass
60	*Siphonodella obsoleta* Hass
61	*Siphonodella quadruplicata* (Branson & Mehl)
62	*Siphonodella* spp.
63	*Synclydognathus geminus* (Hinde)
64	*Taphrognathus varians* Branson & Mehl

TABLE 2.--AGE RANGE AND NUMBER DESIGNATION OF SPECIES SHOWN IN FIGURES 6-15

SPECIES NO.	SPECIES NAME AND ELEMENT TYPE USED FOR BIOFACIES ANALYSIS[1]	AGE RANGE[2]
2	*Apatognathus varians* Branson & Mehl and (or) *Apatognathus* sp. (P, R)	Middle *crepida* Zone into Upper *expansa* Zone
3	*Bactrognathus hamatus* Branson & Mehl + cf. (P)	Lower *typicus* Zone through most of *anchoralis-latus* Zone
5	Bactrognathids (P, R and fragments)	Lower *typicus* Zone through at least *anchoralis-latus* Zone
7	*Bispathodus bispathodus* Ziegler, Sandberg & Austin (P)	Within Upper *postera* Zone to within Middle *praesulcata* Zone
8	*Bispathodus stabilis* (Branson & Mehl) or *B. utahensis* Sandberg & Gutschick (P)	Within Uppermost *marginifera* Zone into late Kinderkookian (*B. stabilis*); late Kinderhookian into late Meramecian (*B. utahensis*)
9	*Bispathodus* sp.	Within Uppermost *marginifera* Zone into Lower *Cavusgnathus* Zone (late Meramecian)
11	*Cloghergnathus* sp. (P)	At least *texanus* Zone
13	*Doliognathus latus* Branson & Mehl (P)	Through most of *anchoralis-latus* Zone
14	*Doliognathus* sp. (P)	From at least Upper *typicus* through most of *anchoralis-latus* Zone
15	*Gnathodus punctatus* (Cooper) (P)	*isosticha*-Upper *crenulata* Zone into Upper *typicus* Zone
16	*Gnathodus* cf. *G. typicus* Cooper (P)	Within *isosticha*-Upper *crenulata* Zone through at least *anchoralis-latus* Zone
18	"*Hindeodella*" *segaformis* Bischoff s.f. (R)	At least within Upper *typicus* Zone through most of *anchoralis-latus* Zone
19a	*Hindeodus crassidentatus* (Branson & Mehl) (P, R)	*sandbergi* Zone into Lower *Cavusgnathus* Zone
19b	*Hindeodus* cf. *H. penescitulus* (Rexroad & Collinson) (P)	Lower *crenulata* Zone at least into *typicus* Zone
21	Icriodontids (P, C)	Silurian and Devonian
23	*Palmatolepis glabra* Ulrich & Bassler subsp. (P)	Upper *crepida* Zone into Upper *trachytera* Zone
24	*Palmatolepis gracilis expansa* Sandberg & Ziegler (P)	Lower *expansa* Zone into Middle *praesulcata* Zone
25	*Palmatolepis gracilis sigmoidalis* Ziegler (P)	Within Upper *trachytera* Zone through Upper *praesulcata* Zone
27	*Palmatolepis marginifera marginifera* Helms + aff.	Lower to Uppermost *marginifera* Zones
28	*Palmatolepis minuta minuta* Branson & Mehl (P)	Upper *triangularis* Zone into Upper *trachytera* Zone
31	*Palmatolepis stoppeli* Sandberg & Ziegler + aff. + cf. (P, R)	Within Upper *rhomboidea* Zone to with Lower *marginifera* Zone
33	*Palmatolepis subperlobata* Branson & Mehl + cf.(P)	Within Lower *triangularis* Zone into lowest Lower *rhomboidea* Zone

SPECIES NO.	SPECIES NAME AND ELEMENT TYPE USED FOR BIOFACIES ANALYSIS[1]	AGE RANGE[2]
34	*Palmatolepis* spp. (P, R)	Late Devonian
37	*Pelekysgnathus* spp. (P)	Silurian and Devonian
38	*Polygnathus communis* Branson & Mehl (P) subspp.	Middle *crepida* Zone into *texanus* Zone
39	*Polygnathus experplexus* Sandberg & Ziegler + aff. (P)	Lower *expansa* Zone into Middle *expansa* Zone
41	*Polygnathus inornatus* E. R. Branson (P)	From within *expansa* Zone through *anchoralis-latus* Zone
44	*Polygnathus nodocostatus* Branson & Mehl + cf. (P)	Lower *crepida* Zone into Upper *postera* Zone
45	*Polygnathus* aff. *P. perplexus* Thomas (P)	From at least Upper *trachytera* Zone to within Upper *expansa* Zone
46	*Polygnathus semicostatus* Branson & Mehl (P, R)	Within Middle *crepida* Zone to within Lower *praesulcata* Zone
47	*Polygnathus* cf. *P. subirregularis* Sandberg & Ziegler (P)	Lower *trachytera* Zone through Middle *expansa*
48	*Polygnathus triangulus* (Voges) (P)	From at least *sulcata* Zone through *isosticha*-Upper *crenulata* Zone
49	*Polygnathus* spp. (P)	Within Early Devonian into *texanus* Zone
53	*Scaliognathus anchoralis* Branson & Mehl (P)	*anchoralis-latus* Zone
54	*Scaliognathus* spp. (P)	Within Upper *typicus* Zone through *anchoralis*-
55	*Siphonodella cooperi* Hass (P)	Upper *duplicata* Zone through middle part of *isosticha*-Upper *crenulata* Zone
56	*Siphonodella crenulata* (Cooper) + aff. (P)	Lower *crenulata* Zone through middle part of *isosticha*-Upper *crenulata* Zone
57	*Siphonodella isosticha* (Cooper) + aff. (P)	Within Lower *crenulata* Zone through *isosticha*-Upper *crenulata* Zone
58	*Siphonodella* cf. *S. isosticha* (Cooper) (P)	upper *sandbergi* Zone into *isosticha*-Upper *crenulata* Zone
59	*Siphonodella isosticha* (Cooper) trans. to *S. obsoleta* Hass (P)	Within Lower *crenulata* Zone through middle part of *isosticha*-Upper *crenulata* Zone
62	*Siphonodella* spp. (P, R)	*sulcata* Zone through middle part of *isosticha*-Upper *crenulata* Zone
63	*Synclydognathus geminus* (Hinde)	*typicus* Zone into *bilineatus*-Upper *Cavusgnathus* Zone
64	*Taphrognathus varians* Branson & Mehl (P)	*texanus* Zone through Lower *Cavusgnathus* Zone

[1]P, platform element; R, ramiform element; C, coniform element.

[2]See figure 2 for conodont zonal succession.

TABLE 3.--CONODONT SPECIES DISTRIBUTION IN THE PALLISER FORMATION AND CORRELATIVE UNITS

[Numbers in top row are keyed to names of species listed in tables 1 and 2; P indicates Pa and (or) Pb elements; R indicates M and (or) S elements; C indicates coniform elements]

FORMATION (MEMBER); STRATIGRAPHIC LEVEL	SECTION, FIELD NO. (GEOL. SURVEY CANADA LOC. NO./USGS COLLN. NO.)	AGE	1/8	2	20/21	22	23	27	28/29	30	31	32	33	34	35/36	37	38	39/40	44	45	46	47/49	50
Unnamed black shale[1] (carbonate bed)	LS 7-29-3Q (GSC C-195726)	Famennian(?)		3R										1P,4R									
Do. (carbonate concretion)	LS 7-29-3A (GSC C-195727)	early-middle Famennian (Upper *crepida*-lmst. *rhomboidea*)			/4C		8P		122P/1P	6P			62P	77P,148 R		1P						/2P	
Palliser Formation[2] (Morro?); -1.0	CR 7-30-2F (USGS 12018-SD)	Famennian		3R										9P									2P
Do.; ?	MH 7-19-2A (GSC C-195651)	early-middle Famennian (Upper *crepida*-Upper *trachytera*)		2R			8P							20P							4P	/6P	
Do.; -145.0	IR I 7-29-1R (GSC C-195660)	early-middle Famennian (Lower *crepida*-Lower *marginifera*)																	1P				
Do.; -135.0	IR I 7-29-1Q (GSC C-195661)	do.		2R										1P								/3P	4P
Do.; -119.8	IR I 7-29-1P (GSC C-195662)	early-middle Famennian (Upper *crepida*-Lower *marginifera*)		18R	/2C		1P							2P					1P			/3P	
Do.; -90.8	IR I 7-29-1N (GSC C-195664)	do.		2R																	1P		
Do.; -75.6	IR I 7-29-1M (GSC C-195665)	do.		7R																	3P	/2P	
Do.; -60.3	IR I 7-29-1L (GSC C-195666)	do.		1R																			
Do.; -54.2	IR I 7-21-2A (GSC C-195667)	middle Famennian (Upper *rhomboidea*-Lower *marginifera*)		4R							15P,10R					2P,6C			7P		27P	/8P	
Do.; -45.1	IR 1 7-29-1K (GSC C-195668)	middle Famennian (Upper *rhomboidea*-Uppermost *marginifera*)		4R	1P/									2R					1P			/1P	
Palliser Formation[2] (Costigan); -0.8	IR 1 7-29-1H (GSC C-195669)	middle Famennian (Lower-Uppermost *marginifera*)		7R				11P						2R							5P,3R		
Do.; -0.05	IR II 7-24-3A (GSC C-195689)	middle Famennian (Lower *marginifera*)		29R	/12C	3P		3P			6P	1P		15P, 17R			20P				2P		
Palliser Formation[2] (Costigan?); -0.05	HI 7-26-4A (GSC C-195702)	early-middle Famennian (Upper *crepida*-Upper *trachytera*)		4R	/2C		1P							2P							3P		
Palliser Formation[2]; -0.05	NL 8-7-3A (GSC C-195704)	middle Famennian (Lower *marginifera*)		2R								2P		1R								/4P	
Palliser Formation[2] (Morro?); -76.0	CP 7-13-2A (GSC C-195707)	middle Famennian (Upper *rhomboidea*-Lower *marginifera*)									12P			10P					3P		12P	/1P	
Palliser Formation[2]; -36.0	CP 7-13-2C (GSC C-195708)	middle Famennian (Upper *rhomboidea*-Uppermost *marginifera*)		9R			6P							2R							2P,3R	/1P	
Do.; -0.05	CP 7-13-2D (GSC C-195709)	middle Famennian (Lower-Uppermost *marginifera*)		7R				3P						2P, 2R			1P				4P	/4P	
Palliser Formation[2] (top of Morro); -78.0	LR 7-23-4A (GSC C-195714)	middle Famennian (Lower-Uppermost *marginifera*)		7R			1P	23P						88P, 2R							3P	/1P	1P
Palliser Formation[2] (Costigan); -0.6	LR 7-23-4B (GSC C-195715)	late Famennian (possibly Middle *expansa*)	/1P		/1C									2P				1P/			18P	/6P	
Do.; -0.05	LR 8-5-3A (GSC C-195716)	do.		1R													1P				6P	/2P	
Palliser Formation[2]; -0.05	R 7-17-4D (USGS 12019-SD)	middle Famennian (Lower-Uppermost *marginifera*)		14R		1P		16P			1P			43P, 12R			46P					/4P	
Do.; ?	W 7-17-4E (GSC C-195720)	Famennian		3R	/2C									41P,2R					2P			/13P	
Palliser Formation[2] (top of Morro); -143.0	MF 7-24-4A (GSC C-195721)	Famennian (probably *crepida*-Upper *trachytera*)							1P/					13P,1R								/1P	17P
Palliser Formation[2] (Costigan); -1.5	MF 7-24-4B (GSC C-195722)	middle-late Famennian (Lower *marginifera*-Upper *expansa*)		3P,3R	/1C												8P				6P	/3P	

TABLE 3. (CONTINUED)

FORMATION (MEMBER); STRATIGRAPHIC LEVEL	SECTION, FIELD NO. (GEOL. SURVEY CANADA LOC. NO./USGS COLLN. NO.)	AGE	1/8	2	20/21	22	23	27	28/29	30	31	32	33	34	35/36	37	38	39/40	44	45	46	47/49	50
Palliser Formation[2]; -35.0	LM 8-5-6B (GSC C-195746)	middle Famennian (*marginifera*, possibly Lower *marginifera*)		37R										18R	/3P, 3C						11P	/104P	7P
Palliser Formation[2] (Costigan); -0.05	LM 8-6-5A (GSC C-195742)	middle-late Famennian (Uppermost *marginifera*-Upper *postera*)	1P/	24R											5P, 19C/	1C	17P				91P, 66R		
Do.[2]; -0.05	MB 8-26-3Q (GSC C-195732)	middle-late Famennian (*trachytera*-Middle *expansa*; possibly Upper *trachytera*)		3R	4P/22C	4P										5P	12P			1P	22P	/2P	
Do.[2]; -4.0	ML 8-5-5A (GCS C-195744)	late Famennian (Lower-middle *expansa*)		19R	2P/		4P								/2P			6P/1P			26P	2P/5P	
Do.; -0.05	ML 8-5-5B (GCS C-195745)	do.														1P	3P	1P/			12P	/2P	
Do.[2]; -0.05	JC 8-22-3A (GSC C-195737)	middle-late Famennian (*trachytera*-Upper *expansa*)	/7P	20R	/5C											1P	6P			1P	70P	/2P	

[1]Base and top of shale not exposed; sample from base of section.

[2]Stratigraphic position below top of Palliser Formation in meters; samples at -0.05 m were collected from the top of the formation.

TABLE 4.--CONODONT SPECIES DISTRIBUTION IN THE EXSHAW FORMATION

[Numbers in top row are keyed to names of species listed in tables 1 and 2; P indicates Pa and (or) Pb elements; R indicates M and (or) S elements; C indicates coniform elements]

FORMATION (MEMBER); STRATIGRAPHIC LEVEL[1]	SECTION, FIELD NO. (GEOL SURVEY CANADA LOC. NO./USGS COLLN. NO.)	AGE	2	7	8	9	21	24	25	26	34	38	46	49
Black shale member; +0.4	IR II 7-24-3C (GSC C-195690)	Famennian (no younger than Lower *praesulcata*)					3C			2P	1P	1P	1P	1P
Do.; + 37.0	MF 7-24-4G (GSC C-195723)	late Famennian (Lower *expansa*-into Middle *praesulcata*)				3P		1P	16P		2P			3P
Do.; + 21.5	MB 8-26-3E (GSC C-195733)	middle Famennian - middle Tournaisian										1P		
Do.; + 1.0	JC 7-19-4A (GSC C-195738)	late Famennian (Lower - Upper *expansa*)	5R	1P	1P	1P						1P		
Do.; + 3.0	JC 7-19-4C (GSC C-195739)	late Famennian (Lower - Upper *expansa*)			6P		3C		4P			1P		

[1]Stratigraphic position above base of Exshaw Formation.

TABLE 5.--CONODONT SPECIES DISTRIBUTION IN THE BANFF FORMATION AND ITS CORRELATIVES

[Numbers in top row are keyed to names of species listed in tables 1 and 2; P indicates Pa and (or) Pb elements; R indicates M and (or) S elements]

FORMATION (MEMBER); STRATIGRAPHIC LEVEL	SECTION, FIELD NO. (GEOL. SURVEY CANADA LOC. NO./USGS COLLN. NO.)	AGE	3	4/5	6/8	9/12	10/11	13/14	15/16	17/18	19a/ 19b	22/42	38	41/43	48	49/51	52/53	54/55	56/57	58/59	60/61	62	63/64
Unnamed calc. shale[1]; ~+39	LS 7-29-3C (GSC C-195728)	middle Tournaisian (*isosticha*-Upper *crenulata* into Lower *typicus*)							1P/														
Banff Formation[2]; +67	CR 7-30-2G (USGS 30855-PC)	late Tournaisian (Lower *typicus*-upper *anchoralis-latus*)		1P,1R/							3P/		11P,1R										
Do.; +120	CR 7-30-2H (USGS 30856-PC)	do.	13P,7R								7P,3R/		21P,1R										
Banff Formation[3]; +0.05	MH 7-19-2B (GSC C-195652)	late Tournaisian (Lower *typicus*-upper *anchoralis-latus*)		5P/									8P										
Do.; +4.6	MH 8-3-1H (GSC C-195653)	do.																					2R/
Do.; +19.8	MH 8-3-1G (GSC C-195654)	do.											1P										
Do.; +45.7	MH 8-3-1E (GSC C-195656)	do.											4P										
Do.; +76.2	MH 8-3-1C (GSC C-195657)	do.	3P								1P/		9P										1R/
Banff Formation[2]; +50	IR I 7-29-1D (GSC C-195670)	late(?) Tournaisian											1P										
Do.; +52	IR I 7-21-2E (GSC C-195671)	do.									1P/												
Do.: +56	IR I 7-29-1C (GSC C-195672)	do.											2P										
Do.: +99	IR I 7-21-2G (GSC C-195675)	late Tournaisian (uppermost(?) *typicus*-upper *anchoralis-latus*)	1P								2P/		7P										
Do.; +118	IR I 7-21-2H (GSC C-195677)	do.	5P,4R								2P,1R/		5P,2R										
Do.; +125	IR I 7-28-1T (GSC C-195678)	do.	3P,1R										7P,1R										
Do.; +144	IR I 7-28-1S (GSC C-195679)	do.											6P										
Do.; +148	IR I 7-22-2C (GSC C-195680)	do.	2P								2P/		11P										
Do.; +159	IR I 7-28-1R (GSC C-195681)	do.	1P										2P										
Do.; +170	IR I 7-22-2A (GSC C-195682)	do.	2P,9R								2P,2R/		2P										
Do.; +182	IR I 7-21-2M (GSC C-195684)	do.	32P,47R								6P,3R/		1P										
Do.; +188	IR I 7-28-1P (GSC C-195685)	do.	2P,6R								3P,1R/												2P,4R/
Do.; +194	IR I 7-21-2L (GSC C-195686)	do.	2P,10R								7P,3R/												3R/
Banff Formation[2]; +2.8	IR II 7-24-3O (GSC C-195691)	late Tournaisian (uppermost *typicus*-upper *anchoralis-latus*)						/13P		/12R		3P/	1P			1P/		2P/					
Do.; +4	IR II 7-24-3S' (GSC C-195692)	do.	1P							/31R													
Do.; +5.2	IR II 7-24-3W' (GSC C-195693)	do.		/9P						/36R								2P/					
Do.; +7.8	IR II 7-24-3AH (GSC C-195694)	do.			/1P					/2R													
Do.; +14.8	IR II 7-24-3AI (GSC C-195696)	do.		/1P						/2R													
Do.; +31.5	IR II 7-25-3N (GSC C-195697)	do.			/1P								5P										
Do.; +110.2	IR II 7-26-3B (GSC C-195698)	do.			/1P																		
Do.; +142.5	IR II 7-26-3C (GSC C-195699)	do.	9P,2R								2P,4R/		4P										2R/

TABLE 5 (CONTINUED)

FORMATION (MEMBER); STRATIGRAPHIC LEVEL	SECTION, FIELD NO. (GEOL. SURVEY CANADA LOC. NO./USGS COLLN. NO.)	AGE	3	4/5	6/8	9/12	10/11	13/14	15/16	17/18	19a/ 19b	22/42	38	41/43	48	49/51	52/53	54/55	56/57	58/59	60/61	62	63/64
Banff Formation[2]; +176.3	IR II 7-26-3D (GSC C-195700)	late Tournaisian (uppermost *typicus*-upper *anchoralis-latus*)	13P,12R								3P,1R/												2P/
Do.; +209.8 and 0.3 m below top of Banff	IR II 7-26-3E (GSC C-195701)	do.	6P,1R		/1P						5P,3R/												1P/
Banff Formation[2]; +25.9	HI 7-26-4G (GSC C-195703)	do.								/6R		1P/											1R/
Banff Formation[2]; +16.9	NL 8-7-3O (GSC C-195705)	late Tournaisian (lower-middle *anchoralis-latus*)			/1P			2P/		/63R			3P				/1P						
Banff Formation[4]; +3.5	CP 8-1-3F (GSC C-195710)	middle Tournaisian (upper Lower *crenulata*-into *isosticha*-Upper *crenulata*)																	/2P				
Do.; +6.1	CP 7-13-2F (GSC C-195711)	middle Tournaisian (upper Lower *crenulata*-middle *isosticha*-Upper *crenulata*)			/1P														3P/	10P/	/2R	2R	
Do.; +8.5	CP 8-4-3C (GSC C-195712)	middle/late Tournaisian (uppermost *isosticha*-Upper *crenulata* to lowermost *typicus*?)			/3P	3P/			/1P				25P	10P/4P	15P	/3P	2P/	/8P	4P/70P	/35P	10P/4P		
Do.; +10.1	CP 8-4-3J (GSC C-195713)	do.?														1P/							
Banff Formation[2]; +19.0	LR 8-5-3T (GSC C-195717)	late Tournaisian? (Upper *typicus-anchoralis-latus*?)		2P/																			
Do.; +20.6	LR 8-5-3(3) (GSC C-195718)	late Tournaisian (Upper *typicus-anchoralis-latus*)			/4P						1P/						/1R						
Do.; +87.0	LR 8-5-3AJ (GSC C-195719)	do. ?			/1P	/1P					32P,8R/												
Banff Formation[2]; +4.2	R 7-17-4C (USGS 30858-PC)	middle Famennian-late Tournaisian (probably late Tournaisian)											6P										
Banff Formation[2]; +77.4	MF 7-24-4J (GSC C-195724)	middle Tournaisian (*sandbergi-isosticha*-Upper *crenulata*)																				3P	
Banff Formation[2]; +64.8	LM 8-6-5C (GSC C-195743)	early-middle Tournaisian (*duplicata* - *isosticha*-Upper *crenulata*, likely Lower *crenulata* - *isosticha*-Upper *crenulata*)			/13P								1P	/2P				/4P	1P/		9P/	15P,7R	
Banff Formation[2]; +44.6	MB 8-26-3M (GSC C-195735)	early-middle Tournaisian (Lower *crenulata*-*isosticha*-Upper *crenulata*)														2P/				1P/		11P,1R	
Do.; +150.0	MB 8-26-3P (GSC C-195736)	late Tournaisian (lower-middle *anchoralis-latus*)		1P/	/2P			1P/		1P/7R	8P,6R/		13P					1P/					
Banff Formation[4]; +136.5	JC 8-23-3I (GSC C-195740)	middle Tournaisian (Lower *crenulata* - *isosticha*-Upper *crenulata*)			4P/7P						3P,1R/ 11P	/16P	96P			2P/	1P/		1P/			2P,2R	
Do.; +160.6	JC 8-23-3J (GSC C-195741)	middle Tournaisian (late Kinderhookian)			/2P								3P									1P	
Banff Formation(?)[5]; ~+225	LS 7-29-3K & 7-12-2A (GSC C-195729, 30)	Visean (*texanus* into Lower *Cavusgnathus*))				7P/	1P/3P				3P/	1P/											/1P
Do.; ~+228	LS 7-12-2B (GSC C-195731)	do.				14P/	/4P				1P/												

[1]Base and top of shale not exposed; collection ~39 m above base of exposed section.
[2]Stratigraphic position above base of Exshaw Formation, in meters.
[3]Base of Banff Formation not exposed; measurement given in meters above base of lowest exposed Banff.
[4]Stratigraphic position above base of Banff Formation, in meters.
[5]Stratigraphic position above base of section, in meters; lower ~125 m are shale unit and succeeding ~100 m are covered.

TABLE 6.--CONODONT BIOFACIES, MICROLITHOFACIES, AND INFERRED DEPOSITIONAL ENVIRONMENTS OF THE PALLISER, EXSHAW, AND BANFF FORMATIONS AND CORRELATIVE UNITS

FORMATION (MEMBER); STRATIGRAPHIC LEVEL	SECTION, FIELD NO. (GEOL. SURVEY CANADA LOC. NO./ USGS COLLN. NO.)	AGE	TOTAL CONODONTS	% DET.[7]	% INDET.	BIOFACIES[8] (I, indigenous; T, transported)	MICROLITHOFACIES	DEPOSITIONAL ENVIRONMENT
Unnamed black shale[1]	LS 7-29-3Q (GSC C-195726)	Famennian(?)	34	65	35	Indet. (winnow)	Lime mudstone (bioturbated)	Basin
Do.	LS 7-29-3A (GSC C-195727)	early-middle Famennian (Upper *crepida*-lmst. *rhomboidea*)	562	90	10	Palmatolepid (I)	Calcitized radiolarian mudstone	Basin
Palliser Formation (Morro?)[2]; -1.0	CR 7-30-2F (USGS12018-SD)	Famennian	41	51	49	Palmatolepid (T, broken and abraded)	Skeletal, grapestone/peloidal packtone	Shallow to middle ramp
Do.; ?	MH 7-19-2A (GSC C-195651)	early-middle Famennian (Upper *crepida*-Upper *trachytera*)	94	45	55	Palmatolepid-polygnathid (T, broken and abraded)	Skeletal, grapestone/peloidal wackestone/packstone	Shallow to middle ramp
Do.-145.0	IR I 7-29-1R (GSC C-195660)	early-middle Famennian (Lower *crepida*-Lower *marginifera*)	3	33	67	Indet.	Skeletal/peloidal packstone	Shallow ramp
Do.; -135.0	IR I 7-29-1Q (GSC C-195661)	do.	29	45	55	Indet.	do.	do.
Do.; -119.8	IR I 7-29-1P (GSC C-195662)	early-middle Famennian (Upper *crepida*-Lower *marginifera*)	56	54	46	Apatognathid (I)	Skeletal peloidal wackestone/ packstone	do.
Do.; -106.1	IR I 7-29-1O (GSC C-195663)	do.	18	5	95	Indet.	Peloidal lime mudstone	do.
Do.; -90.8	IR I 7-29-1N (GSC C-195664)	do.	24	21	79	Indet.	Skeletal peloidal wackestone/ mudstone	do.
Do.; -75.6	IR I 7-29-1M (GSC C-195665)	do.	23	78	22	Indet.	Grapestone peloidal wacke-stone/packstone	do.
Do.; -60.3	IR I 7-29-1L (GSC C-195666)	do.	15	27	73	Indet.	do.	do.
Do.; -54.2	IR I 7-21-2A (GSC C-195667)	middle Famennian (Upper *rhomboidea*-Lower *marginifera*)	224	43	57	Polygnathid-palmatolepid(I)	Peloidal bioclastic mudstone/ wackestone	do.
Do.; -45.1	IR I 7-29-1K (GSC C-195668)	middle Famennian (Upper *rhomboidea*-Uppermost *marginifera*)	37	38	62	Indet. (wide mixture of chiefly shallow-water forms)	Lime mudstone	do.
Palliser Formation (Costigan)[2]; -0.8	IR I 7-29-1H (GSC C-195669)	middle Famennian (Lower-Uppermost *marginifera*)	67	61	39	Palmatolepid-polygnathid-apatognathid (I)	Skeletal wackestone	Shallow to middle ramp
Do.; -0.05	IR II 7-24-3A (GSC C-195689)	middle Famennian (Lower *marginifera*)	196	75	25	Palmatolepid-apatognathid-polygnathid (I)	do.	do.
Palliser Formation (Costigan?)[2]; -0.05	HI 7-26-4A (GSC C-195702)	early-middle Famennian (Upper *crepida*-Upper *trachytera*)	36	44	56	Indet.	do.	do.
Palliser Formation[2]; -0.05	NL 8-7-3A (GSC C-195704)	middle Famennian (Lower *marginifera*)	38	53	47	Indet.	do.	do.
Palliser Formation (Morro?)[2]; -76.0	CP 7-13-2A (GSC C-195707)	middle Famennian (Upper *rhomboidea*-Lower *marginifera*)	107	39	61	Palmatolepid-polygnathid (I-T, abraded and broken)	Bioclastic, grapestone/peloidal packstone	Shallow ramp
Palliser Formation[2]; -36.0	CP 7-13-2C (GSC C-195708)	middle Famennian (Upper *rhomboidea*-Uppermost *marginifera*)	39	64	36	Apatognathid-palmatolepid-polygnathid (T)	Skeletal wackestone	Shallow to middle ramp
Do.; -0.05	CP 7-13-2D (GSC C-195709)	middle Famennian (Lower-Uppermost *marginifera*)	68	47	53	Polygnathid-apatognathid-palmatolepid (T)	Peloidal, skeletal wackestone	do.
Palliser Formation (top of Morro)[2]; -78.0	LR 7-23-4A (GSC C-195714)	middle Famennian (Lower-Uppermost *marginifera*)	265	55	45	Palmatolepid (T-I; abraded and broken)	Pelmatozoan grainstone	do.
Palliser Formation (Costigan)[2]; -0.6	LR 7-23-4B (GSC C-195715)	late Famennian (possibly Middle *expansa*)	120	30	70	Polygnathid (T-I)	Skeletal wackestone/packstone	do.
Do.; -0.05	LR 8-5-3A (GSC C-195716)	do.	36	42	58	Indet.	Skeletal wackestone	do.

TABLE 6 (CONTINUED)

FORMATION (MEMBER) STRATIGRAPHIC LEVEL	SECTION, FIELD NO. (GEOL. SURVEY CANADA LOC. NO./ USGS COLLN. NO.)	AGE	TOTAL CONODONTS	% DET.[7]	% INDET.	BIOFACIES[8] (I, indigenous; T, transported)	MICROLITHOFACIES	DEPOSITIONAL ENVIRONMENT
Palliser Formation[2]; -0.05	R 7-17-4D (USGS 12019-SD)	middle Famennian (Lower-Uppermost *marginifera*)	227	71	29	Palmatolepid-polygnathid (I)	do.	do.
Do.; ?	W 7-17-4E (GSC C-195720)	Famennian	196	39	61	**Palmatolepid-polygnathid (T-I)**	do.	do.
Palliser Formation (top of Morro)[2]; -143.0	MF 7-24-4A (GSC C-195721)	Famennian (probably *crepida*-Upper *trachytera*)	46	78	22	Polygnathid-palmatolepid (T)	Bioclastic (chiefly pelmatozoan) grainstone	do.
Palliser Formation (Costigan)[2]; -1.5	MF 7-24-4B (GSC C-195722)	middle-late Famennian (Lower *marginifera*-Upper *expansa*)	86	58	42	Polygnathid (T)	Skeletal wackestone	Middle ramp
Palliser Formation[2]; -35.0	LM 8-5-6B (GSC C-195746)	middle Famennian (*marginifera*, possibly Lower *marginifera*)	356	50	50	Polygnathid (I-T)	do.	Shallow to middle ramp
Palliser Formation (Costigan)[2]; -0.05	LM 8-6-5A (GSC C-195742)	middle-late Famennian (Uppermost *marginfera*-Upper *postera*)	352	75	25	Polygnathid (I-T)	do.	Middle ramp.
Do.[2]; -0.05	MB 8-26-3Q (GSC C-195732)	middle-late Famennian (Upper *trachytera*-Upper *expansa;* possibly Upper *trachytera*)	177	77	23	Polygnathid (I)	do.	Shallow to middle ramp
Do.[2]; -4.0	ML 8-5-5A (GSC C-195744)	late Famennian (Lower-Middle *expansa*)	330	35	65	Polygnathid-icriodid (T-I) (possible lag concentrate)	Bioclastic (chiefly pelmatozoan grainstone)	do.
Do.; -0.05	ML 8-5-5B (GSC C-195745)	do.	37	60	40	indet.	Skeletal wackestone/packstone	do.
Do.[2]; -0.05	JC 8-22-3A (GSC C-195737)	middle-late Famennian (*trachytera*-Upper *expansa*)	191	66	34	Polygnathid (I)	do.	Shallow to middle ramp
Exshaw Formation (black shale)[3]; +0.4	IR II 7-24-3C (GSC C-195690)	Famennian (noyounger than Lower *praesulcata*)	40	25	75	indet. (T, abraded palmatolepids and polygnathids)	Black shale	Deep ramp to basin
Do.[3]; +37.0	MF 7-24-4G (GSC C-195723)	late Famennian (Lower *expansa*-into Middle *praesulcata*)	48	63	37	Palmatolepid (I)	Radiolarite	do.
Do.[3]; +21.5	MB 8-26-3E (GSC C-195733)	Middle Famennian - Middle Tournaisian	1	100	0	Indet.	Calcareous mudstone	do.
Do.[3]; +1.0	JC 7-19-4A (GSC C-195738)	late Famennian (Lower to Upper *expansa*)	17	41	59	Indet.	Black shale	do.
Do.; +3.0	JC 7-19-4C (GSC C-195739)	late Famennian (Upper *postera*-highest *praesulcata*)	76	42	58	Bispathodid-palmatolepid (I)	do.	do.
Unnamed calcareous shale[4]; ~+39	LS 7-29-3C (GSC C-195728)	middle Tournaisian (*isosticha*-Upper *crenulata* into Lower *typicus*)	2	50	50	indet. (I?)	Calcareous shale/mudstone	Basin
Banff Formation[3]; +67.0	CR 7-30-2G (USGS 30855-PC)	late Tournaisian (Lower *typicus*-upper *anchoralis-latus*)	94	27	73	Polygnathid (T)	Dolomitized carbonate	Middle to deep ramp
Do.; +120.0	CR 7-30-2H (USGS 30856-PC)	do.	193	43	57	Polygnathid-bactrognathid- (T-I)	Skeletal packstone	do.
Do.[5]; +0.05	MH 7-19-2B (GSC C-195652)	late Tournaisian (Lower *typicus*-upper *anchoralis-latus*)	57	23	77	Indet.	Skeletal wackestone	Middle to deep ramp
Do.; +4.6	MH 8-3-1H (GSC C-195653)	do.	27	52	48	Indet. (winnow)	Spicular siliceous mudstone	do.
Do.; +19.8	MH 8-3-1G (GSC C-195654)	do.	9	11	89	Indet.	Skeletal lime mudstone	do.
Do.; +45.7	MH 8-3-1E (GSC C-195656)	do.	28	36	64	Indet.	Skeletal wackestone	do.
Do.; +76.2	MH 8-3-1C (GSC C-195657)	do.	65	25	75	**Polygnathid-bactrognathid (T-I)**	Skeletal packstone	Middle ramp
Do.[3]; +50.0	IR I 7-29-1D (GSC C-195670)	late(?) Tournaisian	3	33	67	Indet.	Spicular siliceous mudstone	Middle to deep ramp
Do.; +52.0	IR I 7-21-2E (GSC C-195671)	do.	6	50	50	Indet.	do.	do.
Do.; +56.0	IR I 7-29-1C (GSC C-195672)	do.	9	22	78	Indet.	do.	do.

TABLE 6 (CONTINUED)

FORMATION (MEMBER) STRATIGRAPHIC LEVEL	SECTION, FIELD NO. (GEOL. SURVEY CANADA LOC. NO./ USGS COLLN. NO.)	AGE	TOTAL CONODONTS	% DET.[7]	% INDET.	BIOFACIES[8] (I, indigenous; T, transported)	MICROLITHOFACIES	DEPOSITIONAL ENVIRONMENT
Do.; +99.0	IR I 7-21-2G (GSC C-195675)	late Tournaisian (uppermost(?) *typicus*-upper *anchoralis-latus*)	46	35	65	Indet.	Spicular lime mudstone	do.
Do.; +118.0	IR I 7-21-2H (GSC C-195677)	do.	174	22	78	Bactrognathid-polygnathid (T-I)	Silty/sandy, skeletal carbonate	Middle to deep ramp
Do.; +125.0	IR I 7-28-1T (GSC C-195678)	do.	59	37	63	Indet.	do.	do.
Do.; +144.0	IR I 7-28-1S (GSC C-195679)	do.	68	22	78	Indet.	Silty/sandy, skeletal packstone	do.
Do.; +148.0	IR I 7-22-2C (GSC C-195680)	do.	138	24	76	Polygnathid	do.	do.
Do.; +159.0	IR I 7-28-1R (GSC C-195681)	do.	87	23	77	Indet.	do.	do.
Do.; +170.0	IR I 7-22-2A (GSC C-195682)	do.	94	46	54	Bactrognathid-hindeodid (T-I)	do.	Middle ramp
Do.; +182.0	IR I 7-21-2M (GSC C-195684)	do.	436	22	78	Bactrognathid (T-I)	Skeletal packstone	do.
Do.; +188.0	IR I 7-28-1P (GSC C-195685)	do.	62	39	61	Hindeodid-bactrognathid (T-I)	do.	Shallow to middle ramp
Do.; +194.0	IR I 7-21-2L (GSC C-195686)	do.	81	42	58	do.	do.	do.
Do.[3]; +2.8	IR II 7-24-3O (GSC C-195691)	late Tournaisian (Uppermost *typicus*-upper *anchoralis-latus*)	179	18	82	Doliognathid-*H. segaformis* (T-I)	Calcitized, phosphatic peloidal mudstone	Deep ramp to basin
Do.; +4.0	IR II 7-24-3S' (GSC C-195692)	do.	45	76	24	*H. segaformis* (T-I; winnow)	do.	do.
Do.; +5.2	IR II 7-24-3W' (GSC C-195693)	do.	125	49	51	*H. segaformis* (T-I; winnow)	do.	do.
Do.; +7.8	IR II 7-24-3AH (GSC C-195694)	do.	18	61	39	Indet.	Calcitized, siliceous, spicular mudstone	do.
Do.; +14.5	IR II 7-25-3A (GSC C-195695)	do.	40		100	Indet. (lag concentrate)	do.	do.
Do.; +14.8	IR II 7-24-3AI (GSC C-195696)	do.	17	29	71	Indet.	do.	do.
Do.; +31.5	IR II 7-25-3N (GSC C-195697)	do.	34	35	65	Indet.	do.	Deep ramp
Do.; +110.2	IR II 7-26-3B (GSC C-195698)	do.	16	19	81	Indet.	Sandy, skeletal wackestone`	Middle to deep ramp
Do.; +142.5	IR II 7-26-3C (GSC C-195699)	do.	114	60	40	Bactrognathid-hindeodid (T-I)	Skeletal packstone	Middle ramp
Do.; +176.3	IR II 7-26-3D (GSC C-195700)	do.	141	49	51	Bactrognathid (T-I)	do.	do.
Do.; +209.8 and 0.3m below top of Banff	IR II 7-26-3E (GSC C-195701)	do.	150	27	73	Hindeodid-bactrognathid	do.	do.
Do.[3]; +25.9	HI 7-26-4G (GSC C-195703)	do.	22	69	31	Indet.	Siliceous, spicular mudstone	Deep ramp to basin

TABLE 6 (CONTINUED)

FORMATION (MEMBER) STRATIGRAPHIC LEVEL	SECTION, FIELD NO. (GEOL. SURVEY CANADA LOC. NO./ USGS COLLN. NO.)	AGE	TOTAL CONODONTS	% DET.[7]	% INDET.	BIOFACIES[8] (I, indigenous; T, transported)	MICROLITHOFACIES	DEPOSITIONAL ENVIRONMENT
Do.[3]; +16.9	NL 8-7-3O (GSC C-195705)	late Tournaisian (lower-middle *anchoralis-latus*)	165	62	38	*H. segaformis* (T-I)	Cherty, lime mudstone	do.
Do.[6]; +3.5	CP 8-1-3F (GSC C-195710)	middle Tournaisian (upper Lower *crenulata*-into *isosticha*-Upper *crenulata*)	3	67	33	Indet.	Lime mudstone	Deep ramp to basin margin
Do.; +6.1	CP 7-13-2F (GSC C-195711)	middle Tournaisian (upper Lower *crenulata*-middle *isosticha*-Upper *crenulata*)	44	64	36	Siphonodellid (T)	do.	do.
Do.; +8.5	CP 8-4-3C (GSC C-195712)	middle/late Tournaisian (uppermost *isosticha*-Upper *crenulata* to lowermost *typicus*?)	400	50	50	Siphonodellid (T-I, lag concentrate)	Glauconitic and phosphatic skeletal wackestone	do.
Do.; +10.1	CP 8-4-3J (GSC C-195713)	do.?	38	11	89	Indet.	do.	do.
Do.[3]; +19.0	LR 8-5-3T (GSC C-195717)	late Tournaisian? (Upper *typicus-anchoralis-latus*?)	59	39	61	Indet. (winnow)	Calcitized, phosphatic mudstone	do.
Do.; +20.6	LR 8-5-3(3) (GSC C-195718)	late Tournaisian (Upper *typicus-anchoralis-latus*)	59	32	68	Indet.	Calcitized, phosphatic, peloidal mudstone	do.
Do.; +87.0	LR 8-5-3AJ (GSC C-195719)	do. ?	131	43	57	Hindeodid (T-I)	Cherty, spicular carbonate	Shallow to middle ramp
Do.[3]; +4.2	R 7-17-4C (USGS 30858-PC)	middle Famennian-late Tournaisian (probably late Tournaisian)	25	28	72	Indet.	Interlaminated siliceous, spicular mudstone and skeletal wackestone	· do.
Do.[3]; +77.4	MF 7-24-4J (GSC C-195724)	middle Tournaisian (*sandbergi-isosticha*-Upper *crenulata*)	9	67	33	Indet.	Cherty lime mudstone	Deep to middle ramp
Do.[3]; +64.8	LM 8-6-5C (GSC C-195743)	early-middle Tournaisian (*duplicata* - *isosticha*-Upper *crenulata*, probably Lower *crenulata* - *isosticha*-Upper *crenulata*)	139	37	63	**Siphonodellid**-bispathodid (I-T)	Wavy laminated lime mudstone	Deep ramp
Do.[3]; +44.6	MB 8-26-3M (GSC C-195735)	early-middle Tournaisian (Lower *crenulata-isosticha*-Upper *crenulata*)	99	34	66	Siphonodellid (T-I, winnow)	Skeletal, peloidal/packstone and wackestone	Deep ramp
Do.; +150.0	MB 8-26-3P (GSC C-195736)	late Tournaisian (lower-middle *anchoralis-latus*)	260	35	65	Polygnathid-hindeodid- (T-I, winnow)	Bioclastic and peloidal packstone	Middle to deep ramp
Do.[6]; +136.5	JC 8-23-3I (GSC C-195740)	middle Tournaisian (Lower *crenulata* - *isosticha*-Upper *crenulata*)	370	68	32	Polygnathid (I)	Skeletal wackestone/packstone	Middle ramp
Do.; +160.6	JC 8-23-3J (GSC C-195741)	middle Tournaisian (late Kinderhookian)	26	27	73	Indet.	do.	do.
Do.[4]; ~+225	LS 7-29-3K & 7-12-2A (GSC C- 195729, 30)	Visean (*texanus* into Lower *Cavusgnathus*)	161	24	76	Bispathodid-hindeodid-cloghergnathid (T)	Cherty, skeletal packstone	Shallow to middle ramp
Do.; +222	LS 7-12-2B (GSC C-195731)	do.	242	15	85	Bispathodid (T)	do.	do.

[1]Sample collected at base of section.
[2]Stratigraphic position below top of Palliser Formation, in meters. Samples at -0.05 m were collected from the top of the formation.
[3]Stratigraphic position above base of Exshaw Formation, in meters.
[4]Base and top of section not exposed; stratigraphic position above base of section, in meters; lower ~125 m are shale and succeeding ~100 m are covered.
[5]Base of Banff Formation not exposed; measurement given in meters above base of lowest exposed Banff.
[6]Stratigraphic position above base of Banff Formation, in meters.
[7]Includes all specimens identifiable to morphotype including ramiform and coniform elements that are not generically assignable.
[8]Only samples containing at least 14 generically assignable elements, including all morphotypes, were used for biofacies analysis. Biofacies are designated on the basis of the dominant genus or genera. If representatives of one genus form 70% or more of the fauna, the biofacies is named for that genus. If two or three genera form 70% or more of the fauna, the biofacies is named for these genera in order of decreasing abundance; if representatives of one of these genera make up more than 50% of the fauna, its name is shown in **bold** type. Biofacies are not designated for samples in which one to three genera do not compose at least 70% of the fauna; the species association in such samples is considered the result of postmortem mixing of species representing more than one biofacies.

APPENDIX 1. LOCALITY REGISTER

Section name[1]	Location	Structural setting	Latitude N./longitude W.
Cleft Rock (CR)	Whitefish Range, Mont.	MacDonald thrust sheet imbricate	48°53.5'/114°31.1'
Mt. Hefty (MH)	Whitefish Range, Mont.	MacDonald thrust sheet imbricate	49°00.9'/114°33.8'
Inverted Ridge I (IRI)	MacDonald Range, B.C.	MacDonald thrust sheet	49°04.0'/114°40.8'
Inverted Ridge II (IRII)	MacDonald Range, B.C.	MacDonald thrust sheet	49°05.5'/114°43.0'
Howell inlier (HI)	MacDonald Range, B.C.	Lewis thrust sheet imbricate	49°15.3'/114°44.0'
North Lost Creek (NL)	Flathead Range, Alta.	Lewis thrust sheet	49°26.25'/114°35.9'
Crowsnest Pass (CP)	Flathead Range, Alta.	Lewis thrust sheet	49°37.5'/114°38.9'
Lizard Range (LR)	Lizard Range, B.C.	Hosmer thrust sheet	49°26.9'/115°07.2'
Roosville (R)	Whitefish Range, Mont.	Rocky Mountain trench	48°59.0'/115°02.0'
Wardner (W)	Lake Koocanusa, B.C.	Rocky Mountain trench	49°25.0'/115°25.2'
Mt. Frayn (MF)	B.C.	Bourgeau thrust sheet	49°51.1'/115°06.7'
Lussier syncline (LS)	B.C.	Tanglefoot block, Bull superblock	50°00.0'/115°30.0'
Mt. Buller (MB)	Kananaskis Range, Alta.	Sulfur Mountain thrust sheet	50°53.5'/115°19.7'
Limestone Mountain (LM)	Opal Range, Alta.	Rundle thrust sheet	50°51.5'/115°09.3'
Mt. Lorette (ML)	Fisher Range, Alta.	Lac des Arcs thrust sheet	50°57.4'/115°06.0'
Jura Creek (JC)	Alta.	McConnell thrust sheet	51°05.4'/115°09.6'
Mount Bourgeau (MBo)	Massive Range, Alta.	Bourgeau thrust sheet	51°08.5'/115°47.1'

[1]Location of sections shown in figure 1. All sections are in the Front Ranges except Lussier syncline (Main Ranges) and Wardner and Roosville (Rocky Mountain trench). All sections are in the southern study area except Mt. Buller, Limestone Mountain, Mt. Lorette, Jura Creek, and Mt. Bourgeau.