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THE STRUNIAN EVENT IN WESTERN CANADA WITH REFERENCE TO OSTRACODE ASSEMBLAGES

by

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(11 figures and 1 table)

ABSTRACT. - In Western Canada, during the late Devonian and early Carboniferous, a slowly subsiding stable platform was covered by an epicontinental sea with rich and varied invertebrate faunas, which were affected by transgressions and regressions. Three main paleoenvironments can be distinguished from the Southeast to the Northwest. They largely control the distribution of ostracodes. Significant changes in the paleontologic and sedimentologic record are known during the Strunian : faunal break and erosional phase are emphasized. The reconstruction of paleobiogeographic ostracode provinces suggests fundamental changes at the Devonian-Carboniferous boundary. These paleontologic, sedimentologic and paleobiogeographic features seem to be linked to a major tectonic event. (Abstracted by the editors).

RESUME. - Au Canada occidental, pendant le Dévonien tardif et le Carbonifère précoce, une plateforme stable, lentement subsidente, fut couverte par une mer épicontinentale avec une faune riche et variée d'invertébrés, et sujette à des transgressions et des régressions. Trois paléoenvironnements majeurs peuvent être reconnus du Sud-Est au Nord-Ouest. Ils contrôlent principalement la distribution des ostracodes. Des changements significatifs dans les successions paléontologiques et sédimentologiques sont connus au Strunien : interruptions de faune et phases d'érosion sont mises en évidence. La reconstruction paléobiogéographique des provinces d'ostracodes suggère des changements fondamentaux à la limite Dévonien-Carbonifère. Ces faits paléontologiques, sédimentologiques et paléobiogéographiques paraissent être associés à un événement tectonique majeur.

1. - INTRODUCTION

During the Upper Devonian and Dinantian, the Canadian Shield was an emerged area, belonging to the Old Red Continent together with Greenland and Northern Europe. Thick sequences of fossiliferous sediments settled in an epicontinental sea on this western margin of the Old Red Continent. The Famennian and Tournaisian deposits are well known from boreholes and outcrops. These have yielded rich ostracode assemblages. Important changes in these assemblages near the Devonian-Carboniferous boundary suggest a major event in the Strunian.

1.1.- GENERAL OUTLINE OF THE GEOLOGY

Western Canada can be subdivided into three geological units (Douglas & Tremblay, eds. 1970) (fig. 1) :

- The Precambrian Shield forming the western margin of the Old Red Continent.
- The Intern Platform lying on the extension of this Precambrian Shield. The terranes are mainly Paleozoic usually covered by Mesozoic and Cenozoic sediments. During the late Devonian and early Carboniferous, this slowly subsiding stable platform was covered by an epicontinental sea with rich and varied invertebrate faunas, which were affected by transgressions and regressions.
- In the Canadian part of the North American Cordillera, the Rocky Mountains consist of numerous thrust sheets overlying the Intern Platform (Dercourt, 1970; Wheeler *et al.*, 1972; Mansy, 1980).

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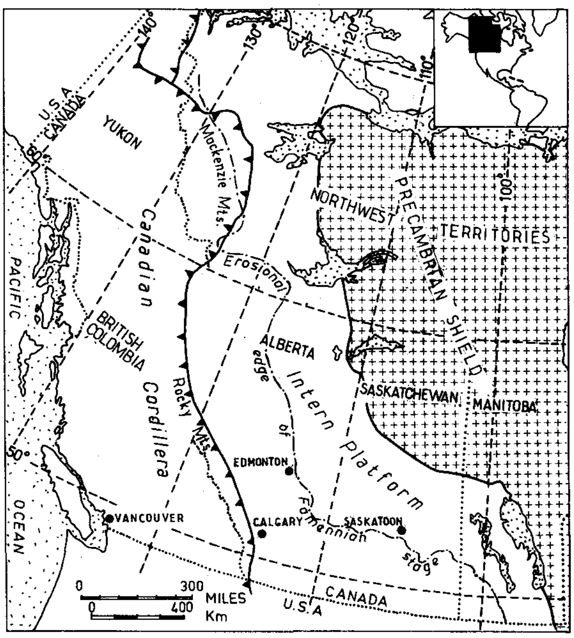

Figure 1. - Geographical position and geological framework of the area discussed. After Bassett & Stout (1968).

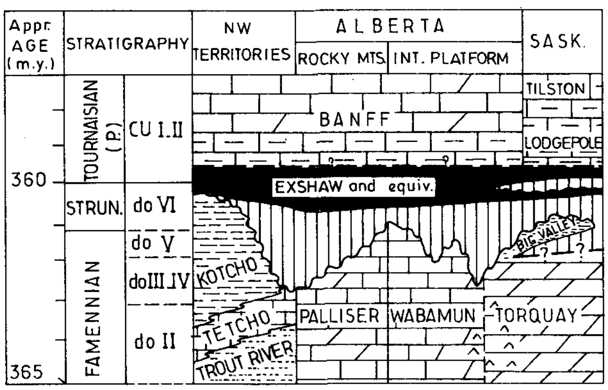

Fig. 2. - Stratigraphical correlation of Famennian, Strunian and Tournaisian rock units in the Western Canada. After Lethiers (1981).

1.2.- LITHOSTRATIGRAPHY

The stratigraphic position of the lithostratigraphic units discussed here is shown in figure 2. The Upper Famennian to Strunian is mainly represented by the green shales of the Big Valley Formation in Saskatchewan (subsurface, 30 m), by the limestones of the Wabamun Group, on the Intern Platform, in Alberta (subsurface, 240 m), by the limestones of the Palliser Formation in the Rocky Mountains (outcrops, 240 m), and by the green or grey shales of the Kotcho Formation in the Northwest Territories (subsurface, 210 m).

According to the results of palynological and conodont investigations the Devonian-Carboniferous boundary is within the carbonaceous shales of the Exshaw Formation and its equivalent, the Bakken Formation (30 m) (McQueen & Sandberg, 1970). This characteristic lithostratigraphic unit is present in the Rocky Mountains and on the Intern Platform. Laterally, it passes into the Sappington Member of the Three Forks Formation in Montana (USA). The Exshaw Formation is overlain by the dark, cherty limestones of the Banff Formation of Tournaisian (Kinderhookian) age.

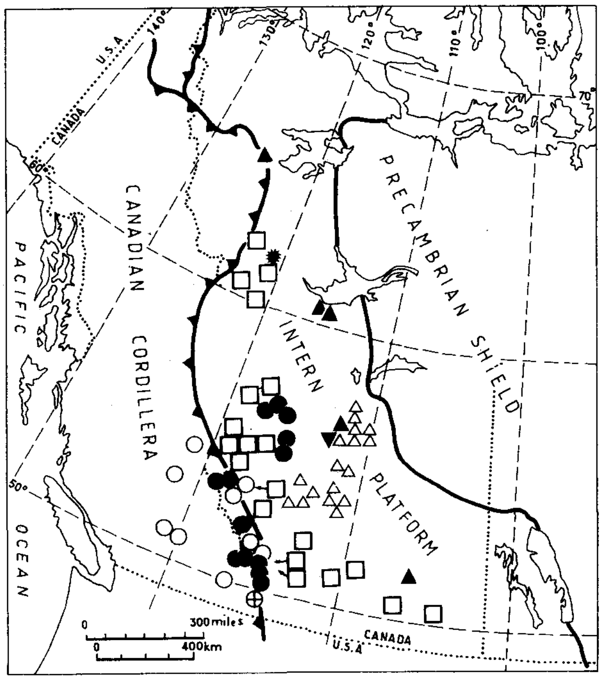

Figure 3. - The main ostracod locations in the Upper Devonian and Lower Carboniferous from Western Canada.
White circles : Crasquin (1984), Mississippian; Black circles : Green (1963), Mississippian; Crossed circle : Copeland (1960), Lowermost Mississippian; White triangles : Loranger (1954, 1963a, b), Frasnian; Black triangles : Braun (1966, 1968) Braun & Mathison (1982), Frasnian; Reverse black triangle : McGill (1963), Frasnian; Star : Kindle (1919), Frasnian; Square : Lethiers (1978, 1980, 1981), Frasnian, Famennian, Strunian.

1.3.- OSTRACODE STUDIES

Upper Devonian and Lower Carboniferous ostracode assemblages have been studied from 67 localities, of which 20 in the Cordillera and 47 on the Interior Platform. Most locations are situated in Alberta (50), 8 are in the Northwest Territories, 5 in British Columbia and 4 in Saskatchewan. Practically all the publications on this subject appeared during the past thirty years (since 1954, fig. 3).

2. - LATE DEVONIAN OSTRACODE ENVIRONMENTS

The Late Devonian paleogeography of Western Canada (fig. 4) is based on the papers by Bassett & Stout (1967), Dercourt (1970) and Nelson (1970).

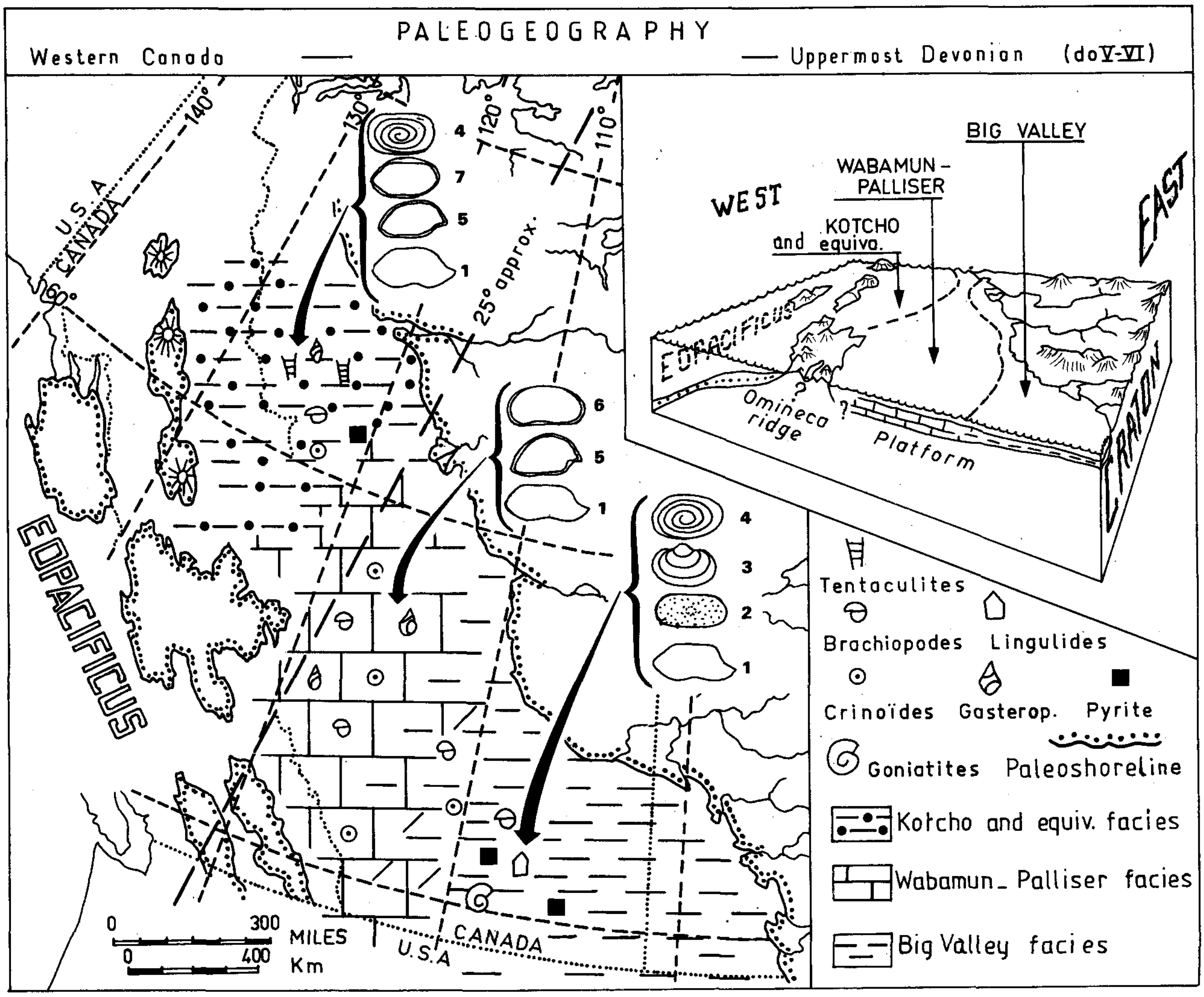

Figure 4. - Paleogeographical reconstruction showing the three main areas of sedimentation during the Uppermost Famennian time in the Western Canada. After Lethiers (1981)
Some characteristic taxa : 1. *Bairdia,* 2. *Ovatoquasillites,* 3. *Cryptophyllus,* 4. *Entomozoidae,* 5. *Acratia,* 6. *Microcheilinella* and *Healdianella,* 7. *Serenida* and *Tchizhovaella.*

Although the limit of the Eopacificus is still unprecise, the different depositional environments of the shelf are well known. Three main paleoenvironments can be distinguished from the Southeast to the Northwest (Lethiers, 1981) :

- A shallow marine, calm near-shore area more or less restricted, with argillaceous sediments and variable salinity : the Big Valley environment.
- An open marine, well-aerated carbonate shelf without reefs in Western and Northern Alberta : the Wabamun-Palliser environment.
- A probably deeper (or more quickly subsiding), sometimes restricted "basin", with argillaceous sediments : the Kotcho environment.

These paleoenvironments have largely controlled the distribution of the ostracodes (fig. 5) :

- Bairdiacea *(Bairdia, Acratia, Microcheilinella, Newsomites* and *Healdianella)* abound in carbonates of the infralittoral, open marine environment.
- Many of the Metacopina, such as *Ovatoquasillites cribraria greeni* Lethiers, 1978 preferably occur in the shales of the Big Valley environment. Maybe, their distribution was controlled by the paleoclimate. The Late Devonian paleo-equator passed through the southeastern part of the United States (Habicht, 1979).
- The Kloedenellacea adapted themselves to various environments, but these tend to be absent in the carbonates of the infralittoral to circalittoral zones of the Palliser Formation.
- The Beyrichicopina seem to have favoured more argillaceous substrata and avoided the carbonate substratum.

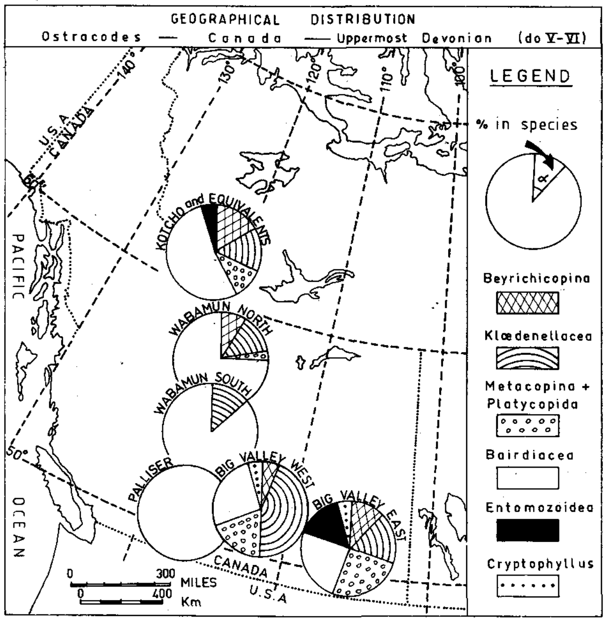

Figure 5. - Distribution of the main taxa of Ostracodes in the different facies from the Western Canada during the uppermost Famennian time. After Lethiers (1981).

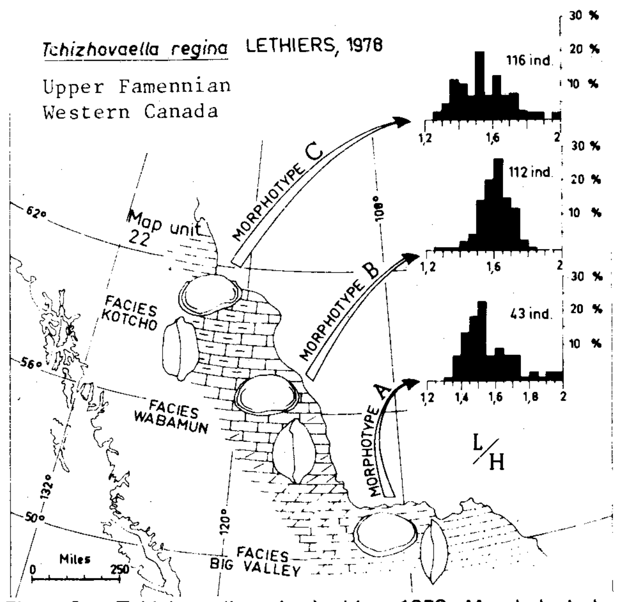

Figure 6. - *Tchizhovaella regina* Lethiers, 1978. Morphological variations in the main facies of the Uppermost Famennian, Western Canada.

FACIES	ENVIRONMENTS	ECOTYPES
BANFF (Tournaisian)	Shaly limestones from a large platform without reef.	*Bairdiacea* *Paraparchitacea* *Kloedenellacea*
EXSHAW and BAKKEN	Black shales from euxinic platform	*Shemonaella*
PALLISER-WABAMUN (Famennian)	Limestones ± dolomitic from platform without reef	*Bairdia*, *Acratia*, *Microcheilinella*, *Newsomites*, *Healdianella*, *Knoxiella*
IRETON-WATERWAYS (Frasnian)	Limestones and shales from shallow platform with reefs	*Kloedenellid*, *Acratia*, *Bairdia*, *Plagionephrodes* *Eriella*, *Cavellina*

Figure 7. - Changes of Ostracod Ecotypes during the Upper Devonian and Tournaisian time on the Western canadian platform from Alberta.

- Species of *Cryptophyllus* preferred the shallow marine, restricted facies of the Big Valley Formation.
- The distribution of the presumably pelagic Entomozoidae is not controlled by ecology but rather by selective fossilisation in restricted, argillaceous sediments.
- Some species seem to have been endemic and occur in only one of the three main environments, for example species belonging to the genera *Evlanovia, Buregia, Barychilina* and *Endolophia.*
- Species of the Bairdiacea may occur in two or three different environments.
- *Tchizhovaella regina* Lethiers 1978 is found in all three environments, but is represented by different morphotypes (fig. 6) in each facies.

Apparently the distribution of faunal assemblages and depositional environments was largely controlled by :

a - the climate (facies boundaries parallel to paleolatitudes),

b - the opening-up of the sea (water energy, oxygenation, salinity), and

c - the bathymetry.

3. - EVOLUTION OF LATE DEVONIAN AND DINANTIAN OSTRACODE ASSEMBLAGES

Several ostracode ecozones can be distinguished in the Upper Devonian and Dinantian strata on the Western Canadian Platform. These illustrate the changes in the paleogeographic conditions (fig. 7).

During the Frasnian, the sediments were deposited in a great variety of environments ranging from more or less restricted to open marine littoral, through biostromal to peribiohermal (Loranger, 1965). The ostracode assemblages are rich and diversified (Braun, 1967) and include the following families : Aechminellidae, Kirkbyellidae, Graviidae, Kloedenellidae, Geisinidae, Cavellinidae, Quasillitidae, Ropolonellidae, Bairdiocyprididae, Pachydomellidae, Acratiidae and Bairdiidae.

The Famennian and Strunian ostracode assemblages are less diversified than the Frasnian ones (Lethiers, 1978, 1981). The families Kirkbyellidae and Ropolonellidae and the genus *Eriella* are not represented in the Western Canadian faunas. Amphissitidae are rare, but Serenididae abound. The (non-reefoid) carbonates of the Wabamun-Palliser environment are characterized by Bairdiidae, Acratiidae, Bairdiocyprididae and a few Kloedenellacea.

The argillaceous and cherty, dark-coloured lime-

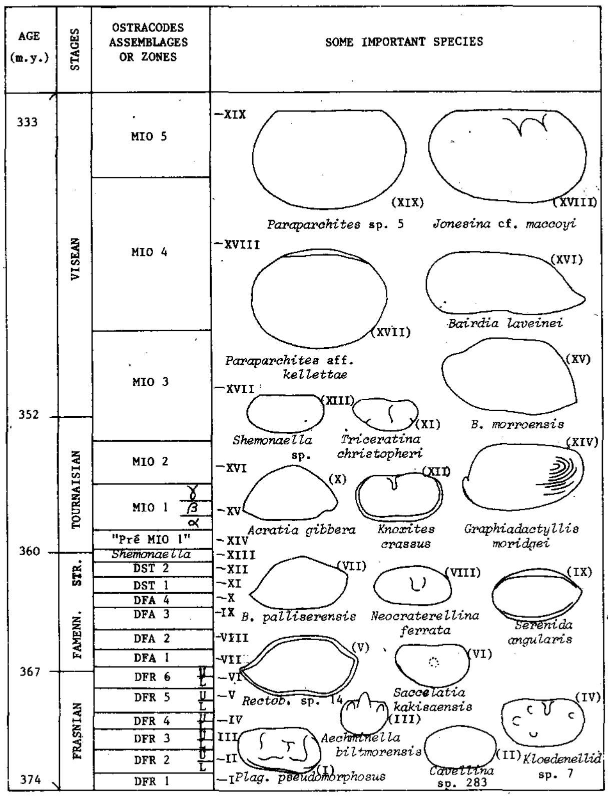

Figure 8. - General zonation with ostracod species in the Upper Devonian and Lower Carboniferous from Western Canada after Braun (1968), Lethiers (1981) and Crasquin (1984). Age (in m.y.) after Palmer (1983).

stones of the Banff Formation (Tournaisian) have yielded completely different ostracode assemblages (Green, 1963; Crasquin, 1984a). About 80 % of the species belong to three superfamilies : the Bairdiacea *(Bairdia, Bairdiacypris, Bairdiocypris, Silenites, Acratia, Microcheilinella)*, the Paraparchitacea *(Shishaella, Shivaella, Shemonaella, Paraparchites, Samarella)* and the Kloedenellacea *(Beyrichiopsis, Knoxites, Knoxina)*. These assemblages belong to an ecozone with mondial distribution (Crasquin, 1984b) which characterizes carbonate shelf environments, ranging from intertidal to infralittoral, in presumably warm climatic zones.

A general zonation, based on benthic ostracode assemblages, for the Frasnian to Viséan deposits of Western Canada is shown in figure 8. The ostracode contents of the *Shemonaella* sp. zone (Lethiers *in* Coquel *et al.*, 1976) needs to be specified. Also the "Pre-MIO1" zone (corresponding to the assemblages described by Copeland in 1960 from the Mississippian of the Rocky Mountains) needs a formal definition.

A calculation of the average duration in millions of years of the various zones and subzones (table 1) shows remarkable differences. Of course, this duration of zones and subzones depends on the vertical distribution of species. On the platform, the appearance and extinction of benthic ostracode species in linked to transgressions and regressions. This link has been recognized independently by Lethiers (1983a) for the Devonian, and by Van Harten & Van Hinte (1984) for the Post-Paleozoic.

Table 1. - Calculated average duration of ostracode zones and subzones for the Middle Devonian to Viséan in Western Canada (data for Middle Devonian from Braun, 1978). Note the contrast between the relatively short length of the Devonian and Tournaisian zones and subzones (corresponding to the large number of sedimentary cycles), and the long duration of the Viséan zones and subzones (reflecting a period of increased stability).

Viséan	:	7	m.y.
Tournaisian	:	1.50	m.y.
Famennian/Strunian	:	1	m.y.
Frasnian	:	0.65	m.y.
Middle Devonian	:	1.40	m.y.

4. - THE STRUNIAN EVENT

Significant changes in the paleontologic and sedimentologic record are associated with a major tectonic event during the Strunian in Western Canada.

4.1. - FAUNAL BREAK

Numerous ostracode species disappear at the end of the Famennian and during the Lower Strunian in Western Canada. Only five of the 148 species described thus far from the Famennian and Strunian of Western Canada range into the Dinantian. However, in several cases these five species are represented by different subspecies. For example, the subspecies *Cribroconcha triquetra prima* Lethiers 1978 and *Ovatoquasillites cribraria greeni* Lethiers 1978 from the Late Famennian to Lower Strunian (Big Valley Formation) are replaced in the Dinantian strata by, respectively, *Cribroconcha triquetra triquetra* Green 1963 (Middle Tournaisian to Lower Viséan) and *Ovatoquasillites cribraria cribraria* (Green 1963) (Lower to Middle Tournaisian). The Tournaisian (Banff Formation) is characterized by the mass appearance of about 200 ostracode species (Crasquin, 1984a). The systematic affinities of many of these suggest an allopatric origin on the United States Platform, in Eastern Siberia and in Western Europe.

A comparable, but less dramatic faunal break is known at the Frasnian-Famennian boundary (Braun & Lethiers, 1982). However, the changes in the ostracode assemblages are more gradual at this level. Many species cross the boundary and there is no major drecrease in the ostracode biomass, this in contrast to other groups of organisms (cf. McLaren, 1985).

4.2. - EROSIONAL PHASE DURING THE STRUNIAN

There is ample biostratigraphic and sedimentologic evidence that the top of the Upper Devonian (Upper Famennian to Lower Strunian) deposits in Western Canada (Big Valley, Wabamun, Palliser and Kotcho) has been affected by differential erosion (Christopher, 1961; McQueen & Sandberg, 1970). The diachronic character of the eroded top of these strata has been emphazised by Lethiers (1978, 1981). The Big Valley/ Wabamun carbonates are unconformably overlain by the black shales of the Bakken-Exshaw Formations. The same phenomenon is known in the Rocky Mountains of British Columbia (Geldsetzer, 1982). Some eustatic variations can be detected toward mid-Famennian (Lethiers, 1983b, fig. 1) but without this importance.

4.3. - BAKKEN-EXSHAW BLACK SHALES

In between the predominantly carbonates of the Upper Devonian Wabamun Group and the Tournaisian Banff Formation, the black shales of the Exshaw Formation occur (fig. 2). These are found both on the Intern Shelf and in the Rocky Mountains of Alberta. Towards the East and South these laterally pass into the Bakken Formation of Saskatchewan and the Sappington Member of the Three Forks Formation of the Western United States. These widely distributed black shales and siltstones exhibit a fairly uniform lithology and yield Tasmanacea, spores and conodonts (Coquel *et al.*, 1976), indicating that the Devonian-Carboniferous boundary occurs within these deposits. The lower unit of the Bakken-Exshaw Formations often consists of more or less pyritic, carbonaceous black shales with a relatively high radioactivity (Christopher, 1961). Presumably, these have been deposited in a rather restricted marine environment, poorly aerated, probably shallow and with a low water energy. This environment was only inhabited by a few ostracode species belonging to the genus *Shemonaella.*

4.4. - WORLDWIDE CHANGES IN THE PALEOBIOGEOGRAPHY

Paleobiogeographic ostracode provinces and their mutual relationships have been reconstructed for the Upper Famennian (Lethiers, 1983b) and the Dinantian (Crasquin, 1984a). These suggest fundamental changes at the Devonian-Carboniferous boundary (fig. 9). During the Upper Famennian, the ostracode paleobiogeography is characterized by the connections between Western Canada and the USSR (Russian Platform, Kouzbass, Omolon area : *Serenida* province) and by the Paleotethys realm (Western Europe and Northern Gondwana : *Hypsela-Rectonaria* province). During the Dinantian, these connections disappear except between Western Canada and Eastern Siberia (Kolyma area). But new connections seem to develop between North America and Western Europe (Jeziorowska, 1981; Crasquin, 1984a), and between Northern Africa, the Russian Platform and Western Siberia (Kouzbass). These changes were induced by climatic modifications, widespread Dinantian transgressions, orogenic phases (producing a new pattern of geographic barriers), and by a change in the marine currents.

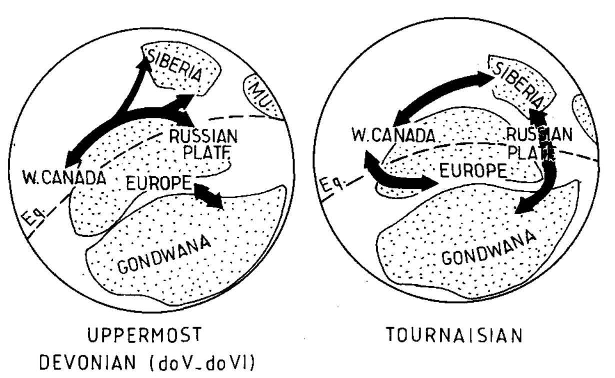

Figure 9. - Ostracod faunal relations of paleobiogeographic areas. Arrows show the most important relations around the schematic drawings of cratonic masses.

A similar change in the paleobiogeographic provinces has not been observed at the Frasnian-Famennian boundary (Lethiers, 1983b).

4.5. - UPPERMOST DEVONIAN ANTLER OROGENY (Fig. 10-11).

The above mentioned paleontologic, sedimentologic and paleobiogeographic features seem to be linked to a major tectonic event in the "Middle" Strunian of Western Canada. The changes in the faunal relationships with other regions might be explained by the establishment of a marine communication between Western Canada and Europe after the Acadian Range erosion during the Upper Devonian, and by the evolution of the "Uralian Channel". The Late Famennian to Early Strunian erosion and the subsequent restricted marine Bakken-Exshaw sedimentary environment may be correlated with the Antler Orogeny (Nielson & Stewart, 1980) affecting the internal zones of the North American Cordillera.

The Antler Orogeny and its Canadian equivalent, the Cariboo Orogeny, are characterized in Western Canada by the Barkerville and Kootenay "Transitional facies" (Mansy, 1985), which outcrop on the western edge of the carbonate platform and its contiguous shale basin.

To the West of the Shuwap Complex, the orogeny is marked by Late Devonian deformations and granitoidic intrusions (- 372 m.y.; Okulitch *et al.*, 1975). The base of the Milford Group in the Kootenay Arc is conglomeratic. The Milford Group overlies the warped Lardeau Group (Wheeler, 1965). The clasts in the basal conglomerate of the Milford Group have been affected by two deformation phases and by a metamorphic phase (Fyles & Read, 1981; Price, 1981). Magmatic activity of comparable age (- 360 m.y.) has also been detected to the West of the Swannel Range in Northern British Columbia (Mansy & Dodds, 1975; Gabrielse *et al.*, 1982). Also the Yukon Crystalline Complex

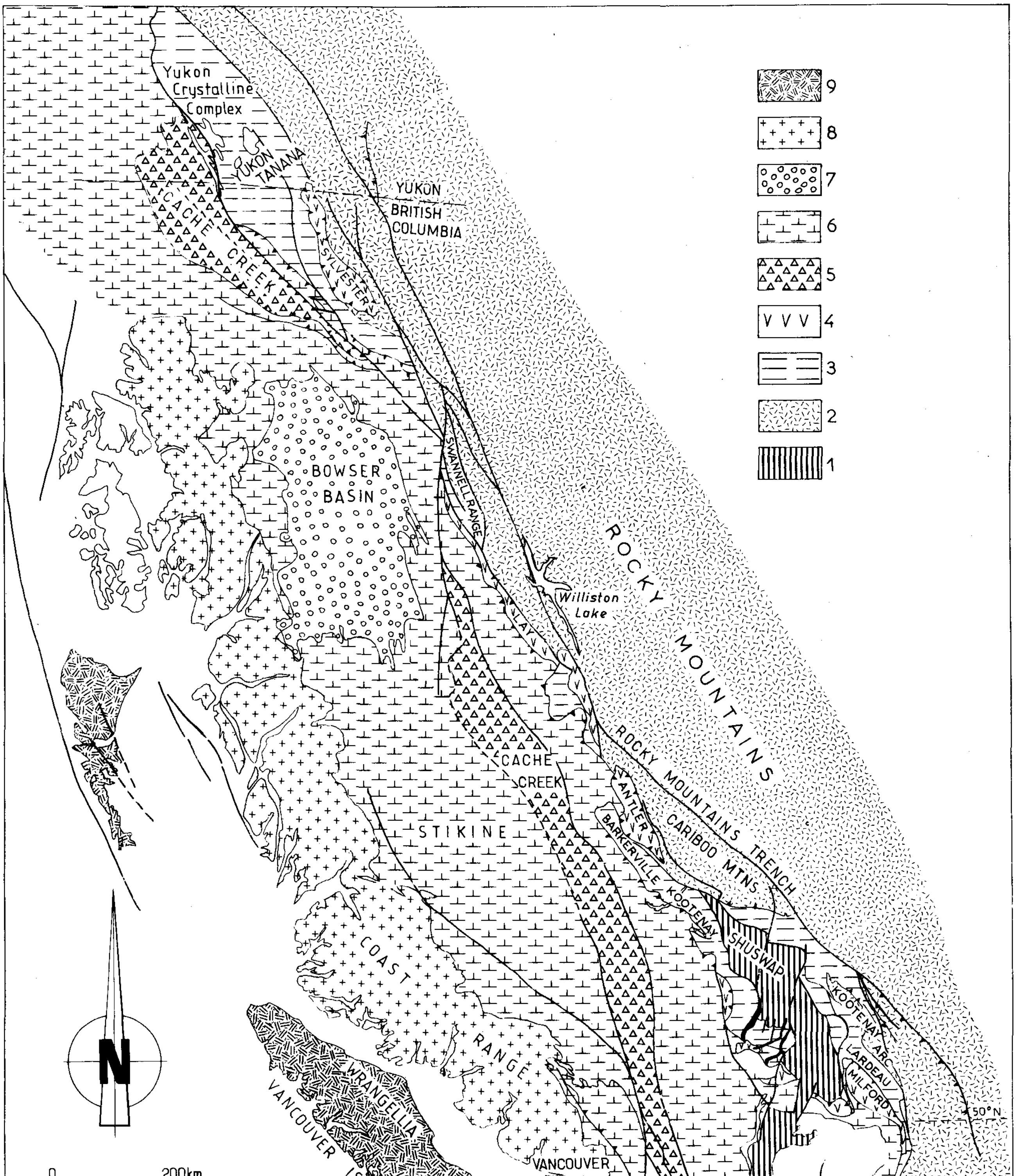

Figure 10. - Location map of the internal zones in Western Canada.
1. Metamorphic core complex; 2. Miogeoclinal facies; 3. Transitional facies; 4. Upper Paleozoic oceanic facies; 5. Cache Creek Group; 6. Stikine block; 7. Molassic basin; 8. Granit; 9. Wrangellia.

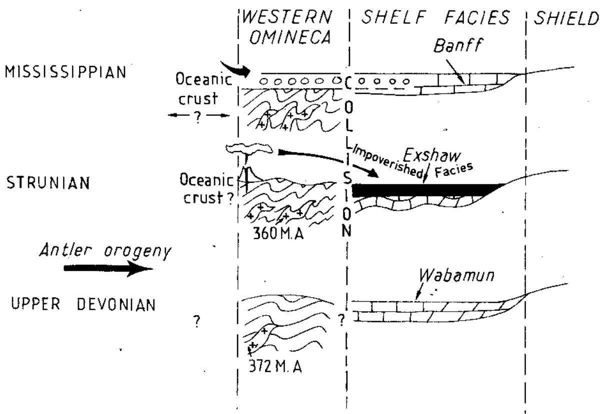

Figure 11. - Tectonic diagrams of Western Canada for explaining the paleobiogeographic change at the Devonian-Carboniferous boundary.

with quartzitic monzonites in Yukon (- 375 m.y.; Tempelman-Kluit, 1980) is an equivalent of the "transitional facies". The same holds for the Yukon Tanana Unit terranes with intrusions (- 345 m.y.; Aleinikoff *et al.*, 1981) of Alaska.

Thus, a polydeformed detritic zone with granitic intrusions ranging between - 375 and - 345 m.y. can be traced from Alaska to Nevada. This parautochthonous zone includes thrust sheets of oceanic material (Sylvester and Milford Groups). The tectonisation of the western border of North America was partly matched by a widespread transgression, characterized by the restricted shallow-marine Bakken-Exshaw environment. The sometimes phosphatic, uraniferous black shales of these deposits include sanidine and montmorillonite derived from volcanic ashes coming from the West.

Throughout the Western Canadian Platform, the strata deformed by the uppermost Devonian Antler Orogeny are covered by a Mississippian conglomerate with abundant clasts of radiolarian-bearing cherts (Klepacki *et al.*, 1985). Apparently, the open-marine environment with optimal conditions for rich and diverse life communities became reestablished from the Early Dinantian onwards. Presumably, the Antler tectonic event has controlled the faunal break mentioned above. This break has been enhanced by the restricted marine environment during the Bakken-Exshaw deposition.

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