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Cambrian and Upper Devonian Carbonate Lithologies of the Whitefish-MacDonald Range, Northwest Montana and Southeast British Columbia, A Preliminary Report

Abstract

This study describes undifferentiated Cambrian and Upper Devonian carbonate rocks in the northern Whitefish Range of northwestern Montana and the contiguous MacDonald Range of southeastern British Columbia. An 804 m thick section on Inverted Ridge, British Columbia is described in this report.

Cambrian lithologies are dominated by bioturbated, dolomite and lime mudstones and are interpreted as having been deposited in a mostly subtidal marine environment. Upper Devonian lithologies contain bioturbated, dolomite and lime mudstones, algal and stromatoporoid dolomitic and lime bindstones and crinoid-intraclast, dolomitic and lime wackestones. The Devonian rocks are interpreted as having been deposited in a subtidal to intertidal, occasionally supratidal marine environment. The Cambrian-Devonian contact is placed at the base of a distinct sandstone unit characteristic of Devonian strata in the southern Canadian Cordillera.

Lithologic data obtained from this study will be useful in the continuing exploration for natural gas and oil in the Rocky Mountain Fold and Thrust belt. Paleoenvironmental interpretations will fill a large void on regional paleogeographic maps. Finally, conodont age dating of the Devonian rocks of this study has accurately placed their time of deposition as during the latest Frasnian to Middle Famennian ages of the Late Devonian Epoch.

Scope of Investigation

Thrust-faulted blocks of undifferentiated Cambrian and Upper Devonian carbonate rocks are exposed in the northern Whitefish Range, Lincoln and Flathead counties northwestern Montana and the contiguous MacDonald Range of southeastern British Columbia (Figure 1). In adjacent northwest and central Montana (Missoula-Philipsburg area), equivalent rocks include the Cambrian Hasmark Formation, the Jefferson Formation and the Devonian portion of the Three Forks Formation (Figure 2). Lower Paleozoic units defined by these lithologies have been mapped and stratigraphic sections measured (Price 1962; Norris and Price 1966; Mudge 1977, 1982; Whipple, pers. comm. 1988), but detailed sedimentologic and biostratigraphic data have not been published. The purpose of this article is to provide a detailed description of the previously undifferentiated carbonate rocks exposed in the Whitefish-MacDonald Range.

Location of the Study Area

The Whitefish-MacDonald Range is located within the Rocky Mountain fold-and-thrust belt in Lincoln and Flathead counties, northwestern Montana and southeastern British Columbia, respectively. The range is bounded on the north by a line parallel to and 24 km north of the International Boundary, on the south by Lat. 48 degrees, 30 minutes north, on the east by Glacier Park and the North Fork of the Flathead River, and on the west by the drainage between the Whitefish and Salish ranges. The section of rock measured in this study is located on Inverted Ridge in southwestern British Columbia, 24 km north of the International Boundary.

Methods of Study

Field work was conducted during July and August, 1987 and 1988, and October, 1989. The section was measured using a Jacob's staff, Brunton compass, and steel tape. Information gathered in the field included descriptions of lithology, bedding thickness, megafossil type, primary sedimentary features, and topographic expression. Oriented samples were collected at six meter intervals and at major lithologic changes. Samples were examined using acetate peels, polished slabs, and petrographic thin sections. Lithologic descriptions utilize the carbonate classification scheme of Dunham (1962), modified by Embry and Klovan (1971).

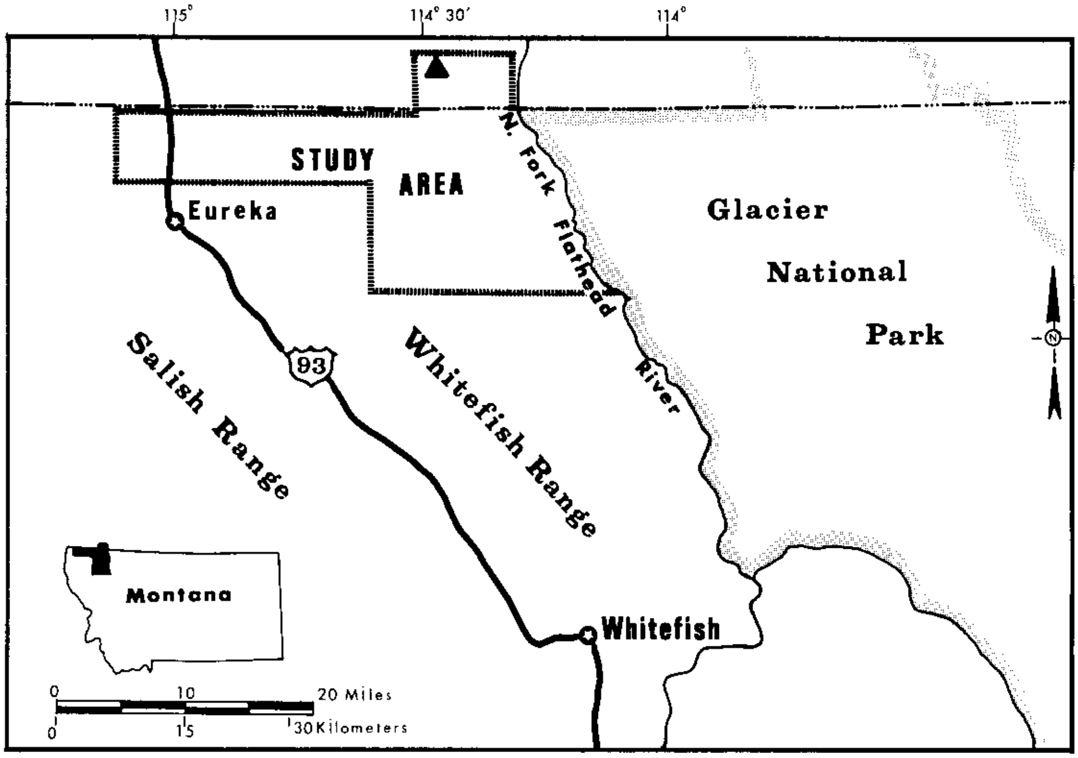


Figure 1. Location map of the study area. The position of the stratigraphic section at Inverted Ridge is indicated by the darkened triangle.

The Cambrian-Devonian Unconformity

In much of Montana Devonian rocks rest unconformably on Cambrian rocks. In southeastern British Columbia, at Inverted Ridge, Upper Cambrian, Ordovician, Silurian, and all but Upper Devonian rocks are missing. In this study the Cambrian-Devonian unconformity is placed at the base of the distinctive six-meter thick calcareous quartz arenite (Unit 2) 242 m above the base of the Cambrian carbonate interval. This interval is noted on Figure 3, the Inverted Ridge Graphic Section.

The base of the quartz arenite was chosen for several reasons. First, Late Devonian conodonts are present 70 m above the quartz arenite without a distinctive lithology change or unconformity observed between the sandstone and typical Devonian lithologies higher in the section. Second, several authors (Price 1962, Norris and Price 1966) have described a similar thin sandy unit at the Cambrian-Devonian boundary at adjacent sections in Canada.

Inverted Ridge Section, British Columbia

In the MacDonald Range, at Inverted Ridge, the Cambrian and Devonian carbonate section is recognized as a series of brown and gray steep slopes and cliffs. The base of the section conformably overlies the well exposed characteristic green shale and thin limestone interbeds of the Gordon Shale which, in turn, overly the Flathead Sandstone. The contact between the first carbonate unit and the underlying Gordon Shale is conformable over several meters. The boundary is placed where the thin limestone beds exceed 50 percent of the outcrop.

The 804 m thick measured section at Inverted Ridge is divided into 13 stratigraphic units based on lithology. Each unit is briefly described. The description is followed by an environmental interpretation. Sample positions and assigned lithologic units are numbered and indicated on both the written and graphic logs.

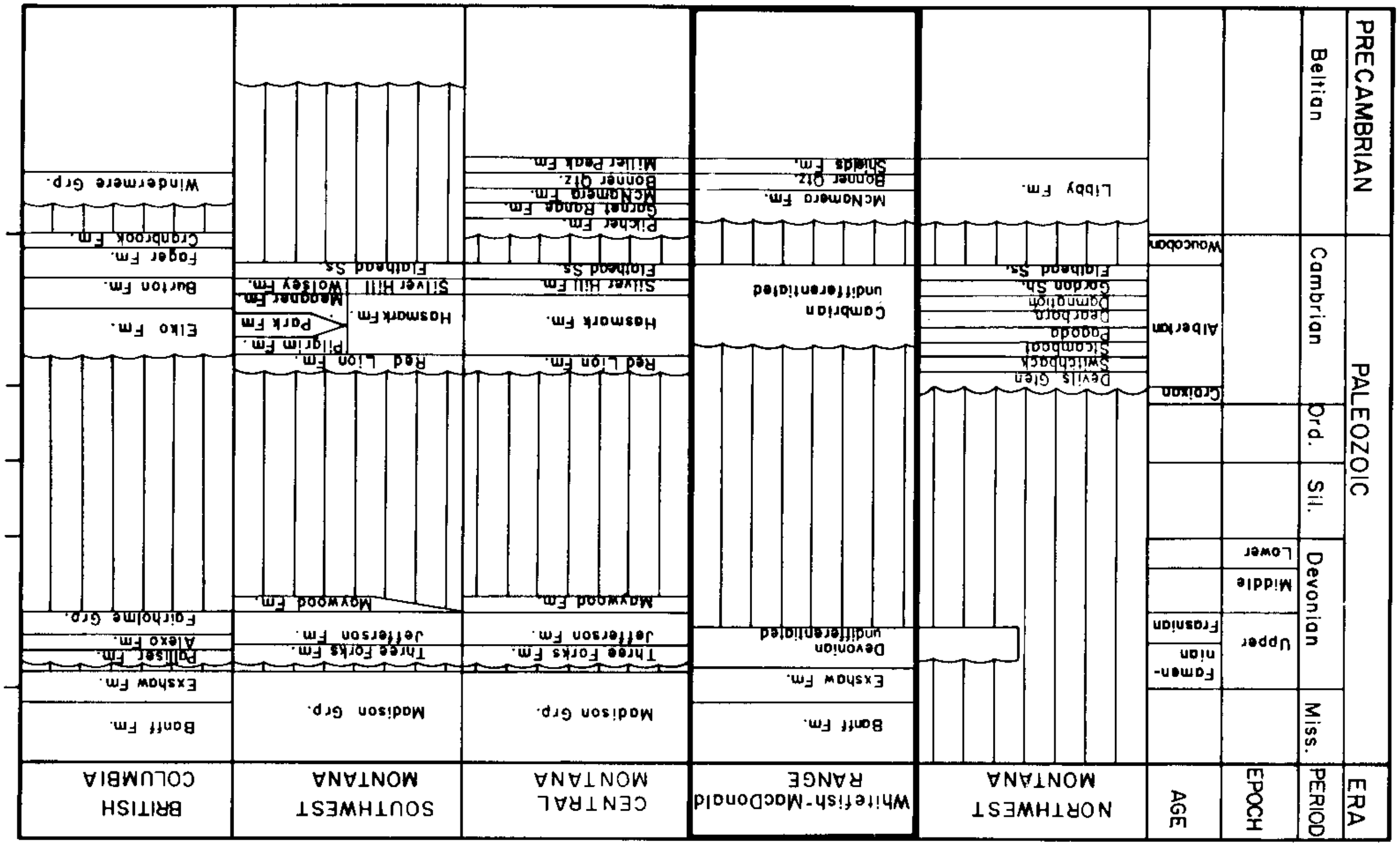


Figure 2. Regional stratigraphic correlation chart for Montana and southeastern British Columbia. The stratigraphic nomenclature for the Whitefish Range is highlighted by a thickened line (from Balster 1980).

Stratigraphic Sequence

Unit 1: Bioturbated Dolomite Mudstone (samples 1 to 26)

Description. The dominant lithology within the Cambrian interval of the Inverted Ridge section is a mottled, dolomitized mudstone that lacks preserved fauna. The unit is 221 m thick, mostly black on a fresh surface, and calcareous in the first 32 m. The unit is thin bedded with very thin shaly interbeds. Porosity is poor, vugs are few, and geopetal infilling of horizontal burrows is common. Fossils are absent except from the base to 22 m where disarticulated, abraded, unoriented trilobite and linguloid brachiopod fragments are common. At 170 m and 190 m above the base cryptalgal laminations are present.

Environmental Interpretation. The mottled mudstone indicates infaunal burrowing of a muddy substrate and a general lack of preserved calcareous fauna implies a low oxygen or dysaerobic zone as might be encountered on an open marine shelf, below wave base, at a depth of between 50 and 150 m (Byers 1977). Algal laminations 175 m above the base of the unit suggest a rapid shallowing of the depositional environment.

Unit 2: Medium Grained Calcareous Quartz Arenite (sample 27).

Description. The unit is six meters thick, pale orange on a fresh surface, thinly laminated to thin bedded, and porous. It forms steep ledges and has one centimeter interbeds of light green shale throughout. Two to five centimeter thick low angle tabular cross-beds of very even and regular thickness are present. Fossils were not observed.

Environmental Interpretation. The low angle of slope, long, lateral extent in outcrop, and the very even and regular thickness of the cross-beds suggest a beach environment (McKee and Sterrett 1961, Reineck and Singh 1977). Periodic pulses of terrigenous muds from an adjacent tidal flat environment may have produced the clay interbeds.

Unit 3: Bioturbated Dolomite Mudstone (samples 28 and 29)

Description. The unit is 18 m thick, black on a fresh surface, mostly thin bedded, forms prominent ledges, and is porous in the middle six meters. Shelly fauna are not present, but flat-lying algal laminations appear in the upper six meters. The unit is extensively mottled in the lower 12 m.

Environmental Interpretation. Similar to unit 1, the mottled texture indicates infaunal burrowing. The absence of calcareous fossils in a mottled sediment implies a low oxygen zone, possibly on an open marine shelf where calcareous fossils were not preserved, but where more low-oxygen-tolerant soft-bodied infauna could survive. The flat lying algal laminations near the top of the unit suggest a shallowing of the environment, possibly into the intertidal zone.

Unit 4: Solution Breccia (sample 30)

Description. The unit is six meters thick, pale yellow on a fresh surface, and forms a prominent ledge. Angular clasts of light gray dolomitic mudstone to 15 mm in diameter are suspended in a matrix of pale yellow intraclast lime grainstone. The matrix is porous, especially adjacent to the dolomite clasts.

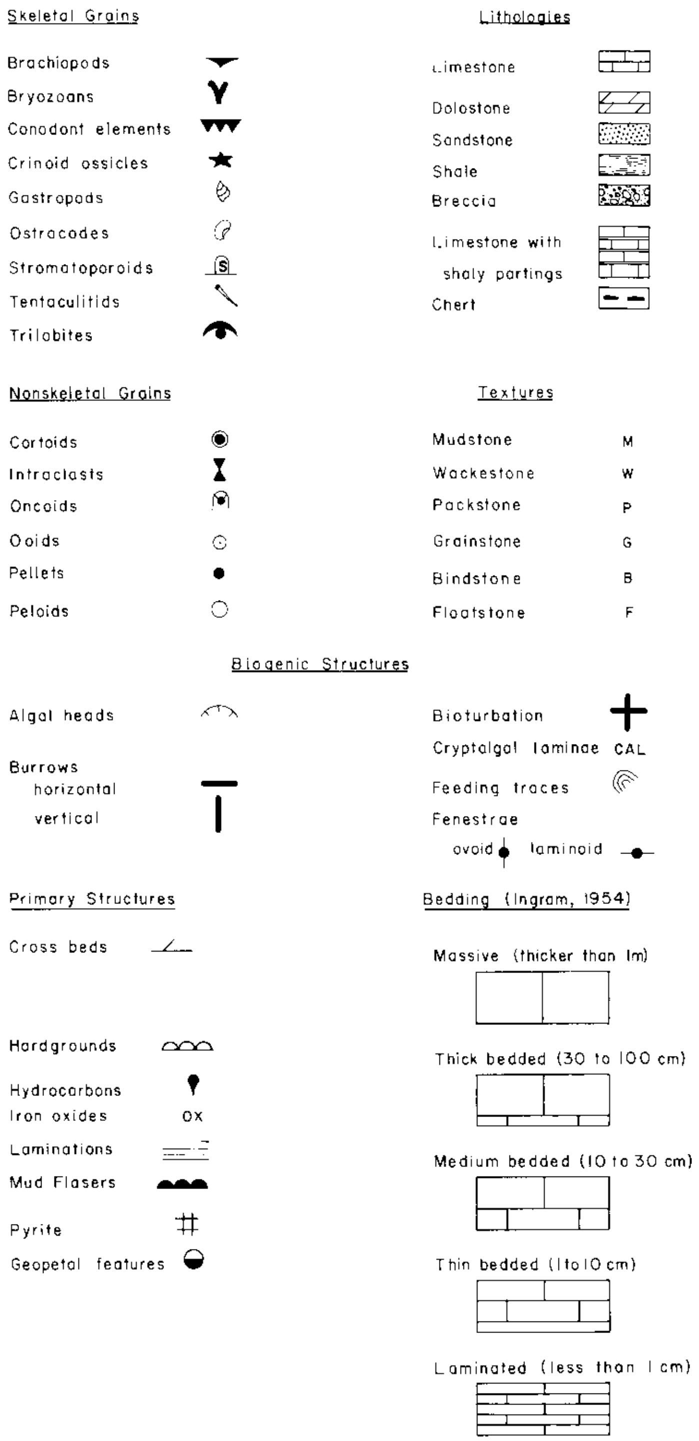
Environmental Interpretation. Unit 4 is a solution breccia, a type of collapse breccia formed as soluble minerals (carbonates, gypsum, or evaporites) are removed by solution of circulating ground water. The overlying rock fragments collapsed into the irregular solution cavities. The soluble minerals are commonly those deposited in a supratidal setting similar to Unit 5, or on a salt flat or playa. The presence of a solution breccia often implies an environment of prolonged subaerial exposure (Esteban and Klappa 1983). Features suggestive of subaerial exposure such as caliche, oxide concentrations, or paleosols were not observed.

Unit 5: Algal Lime Bindstone (samples 32 to 35)

Description. The unit is 24 m thick, black on a fresh surface, thin bedded, and forms thick ledges. Shelly fauna were not observed, however a clotted algal fabric, algal filaments, and intraclasts are common throughout the unit.

Environmental Interpretation. Monty (1976) observed that a non-layered, clotted, algal fabric is diagnostic of a supratidal environment. The presence of abundant intraclasts and an absence of preserved shelly fauna also suggest a supratidal environment.

SYMBOLS


Skeletal Grains
Brachiopods
Bryozoans
Conodont elements
Crinoid ossicles
Gastropods
Ostracodes
Stromatoporoids
S
Tentaculitids
Trilobites
Lithologies
Limestone
Dolostone
Sandstone
Shale
Breccia
Limestone with shaly partings
Chert
Nonskeletal Grains
Cortoids
Intraclasts
Oncoids
Ooids
Pellets
Peloids
Textures
Mudstone M
Wackestone W
Packstone P
Grainstone G
Bindstone B
Floatstone F
Biogenic Structures
Algal heads
Burrows
horizontal
vertical
Bioturbation
Cryptalgal laminae CAL
Feeding traces
Fenestrae
ovoid
laminoid
Primary Structures
Cross beds
Hardgrounds
Hydrocarbons
Iron oxides OX
Laminations
Mud Flasers
Pyrite
Geopetal features
Bedding (Ingram, 1954)
Massive (thicker than 1m)
Thick bedded (30 to 100 cm)
Medium bedded (10 to 30 cm)
Thin bedded (1 to 10 cm)
Laminated (less than 1 cm)

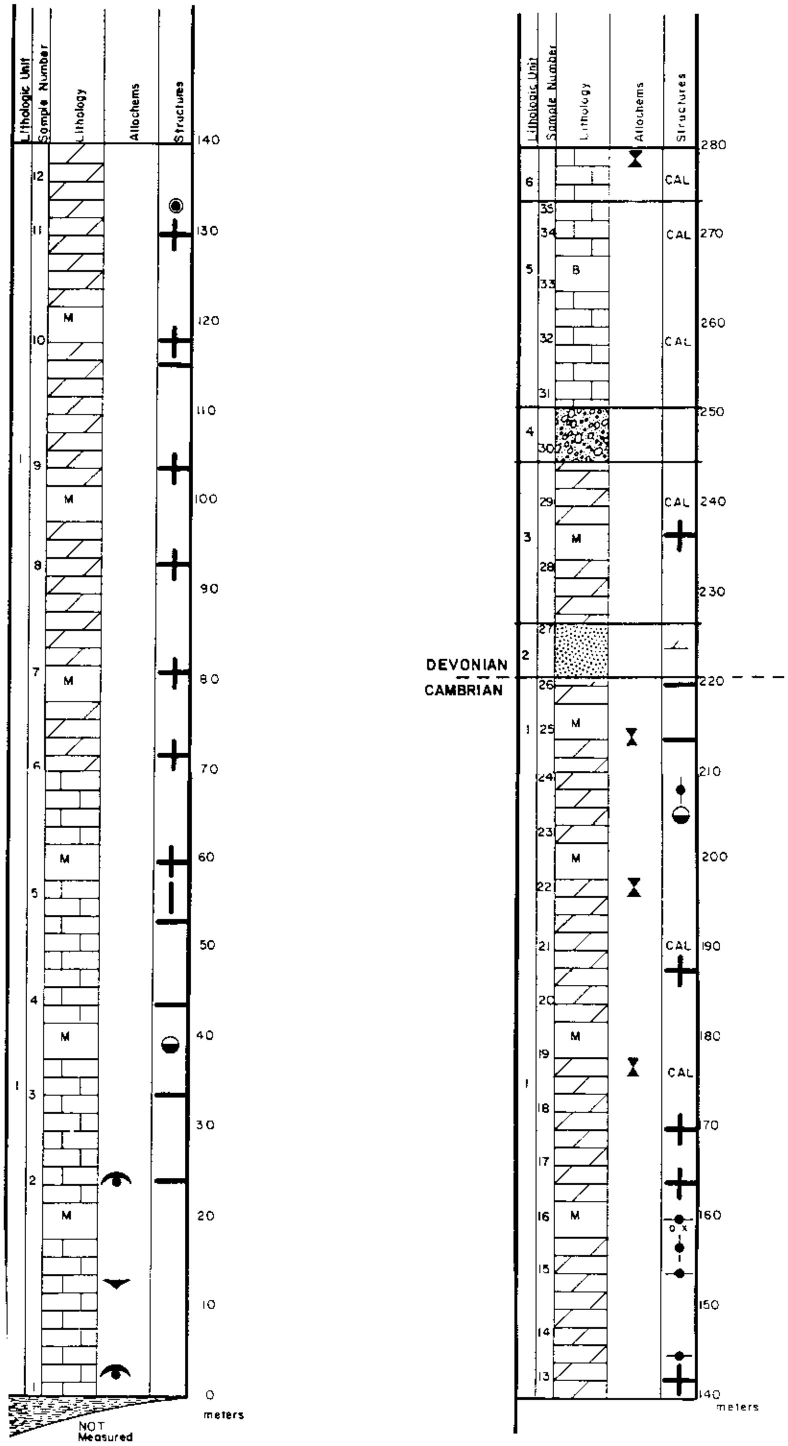


Figure 3. Graphic section at Inverted Ridge, southeastern British Columbia. Inverted Ridge has the most complete stratigraphic section of Cambrian and Upper Devonian strata in the Whitefish-MacDonald Range.

(Figure 3 continued, next page)

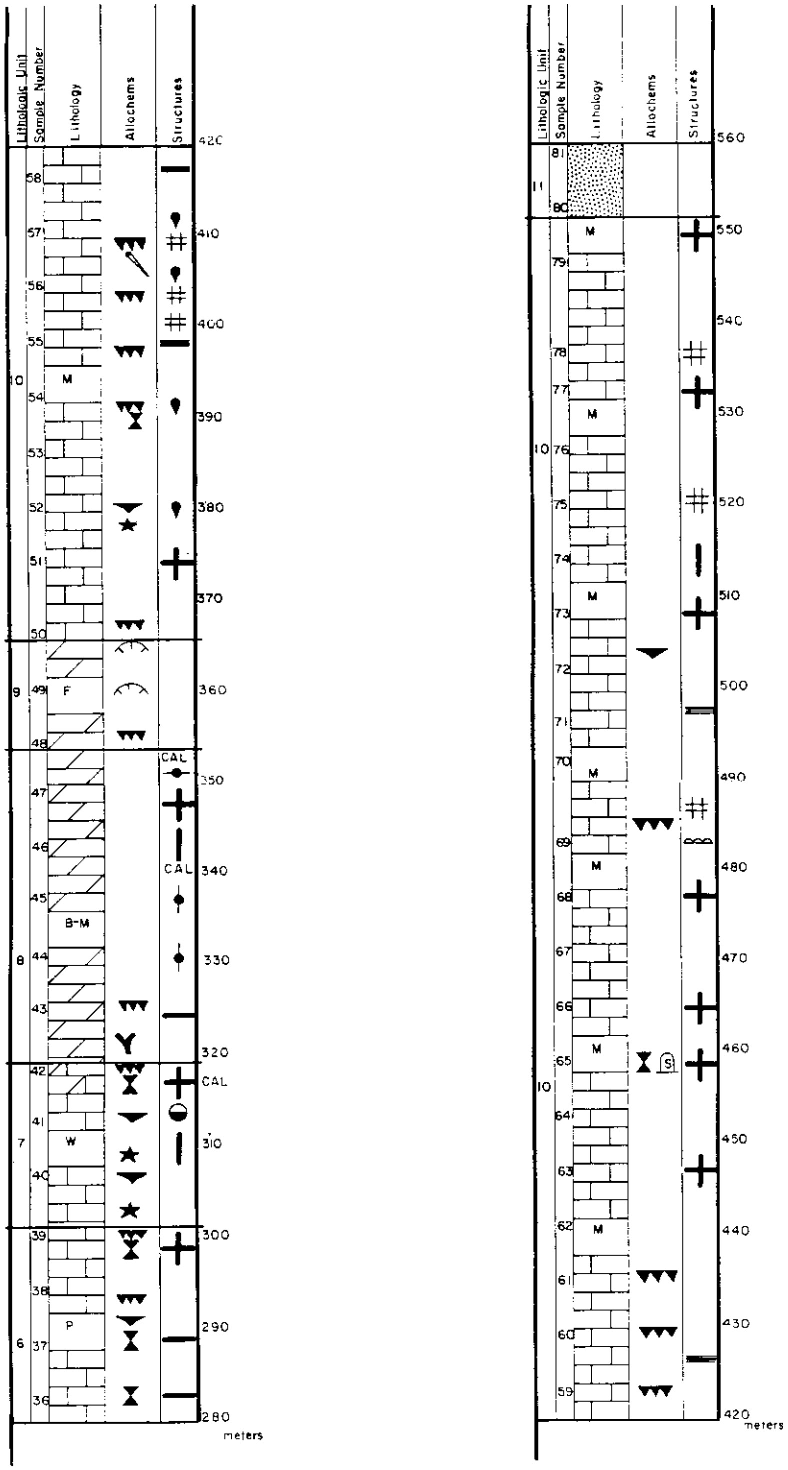


Figure 3. Graphic section at Inverted Ridge, southeastern British Columbia, continued.
(Figure 3 continued, next page)

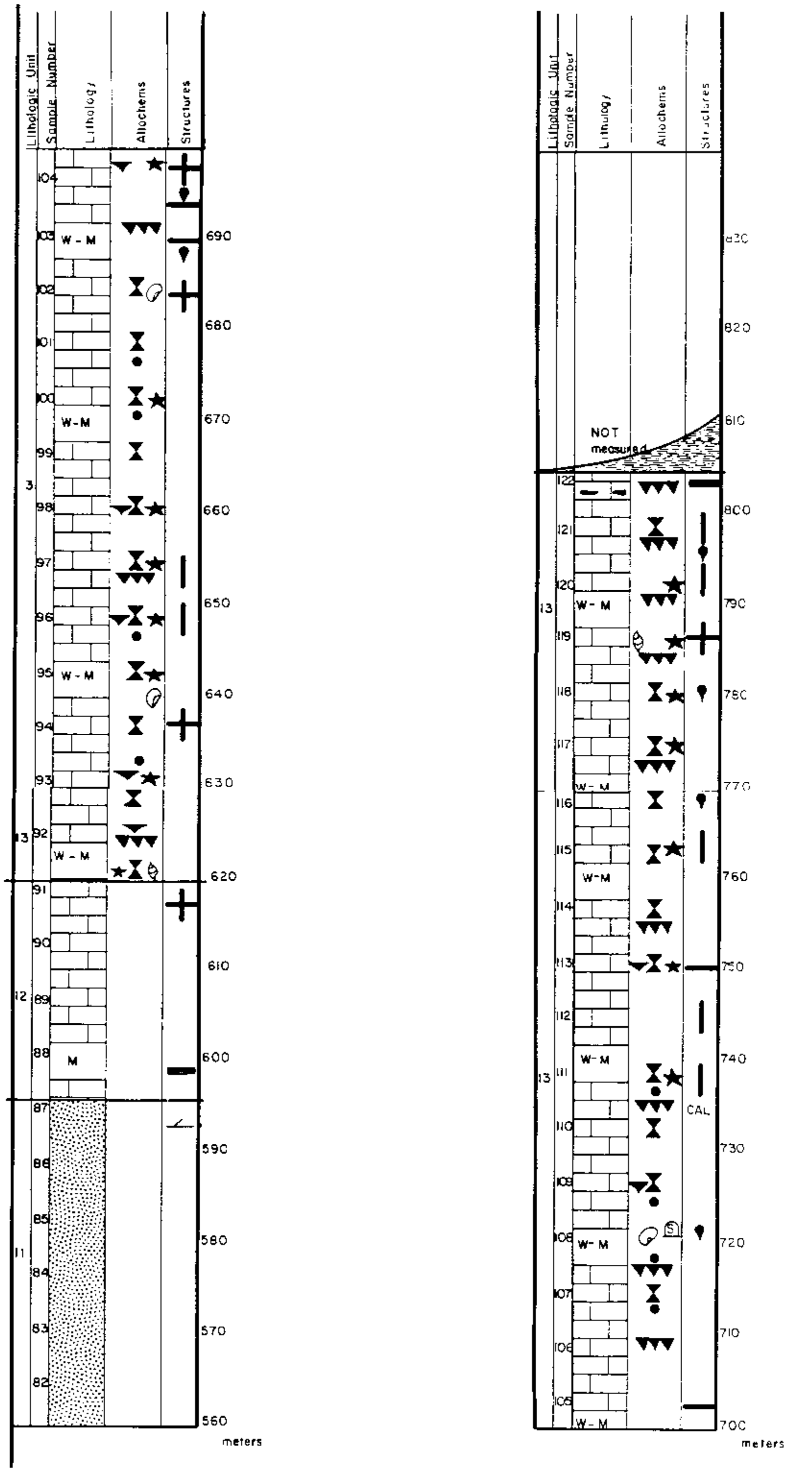


Figure 3. Graphic section at Inverted Ridge, southeastern British Columbia, continued.

Unit 6: Intraclast Lime Packstone (samples 36 to 39)

Description. The unit is 24 m thick, black on a fresh surface, thin bedded, and forms cliffs. Vugs and stylolites are present but uncommon. The unit is horizontally burrowed for the first 18 m and mottled from 18 to 24 m. Micritic intraclasts are common to abundant and frequently compacted. Rare, abraded, disarticulated crinoid ossicles, ostracodes, brachiopods, and Devonian conodont elements (*Polygnathus*) are present in the first 12 m. Flat lying, continuous algal laminations and a clotted or thrombolitic (Monty 1976) algal fabric are present in the upper six meters.

Environmental Interpretation. The intraclasts, whose formation requires some wave or current energy, and the disarticulated fauna, indicate an energetic environment. The presence of ostracodes associated with algal features, indicates a restricted intertidal to supratidal environment, possibly a cutoff lagoon or coastal pond (Flugel 1982).

Unit 7: Crinoid Brachiopod Lime Wackestone (samples 40 to 42).

Description. The unit is 18 m thick, black to dark gray on a fresh surface, thin bedded, and forms steep ledges. The unit is mottled from 12 to 18 m above the base. Intraclasts are common throughout. The unit is dolomitic at about 15 m from the base. Scattered, abraded brachiopod valves and crinoid ossicles are common throughout the unit, often concentrated in vertical burrows. Horizontal, laterally continuous algal laminations are common at 12 to 18 m. Devonian conodont elements (*Polygnathus*) are present 16 m above the base of the unit.

Environmental Interpretation. Flat lying algal laminations, the presence of burrows, calcareous fossils, and infaunal mixing of the sediments indicate an intertidal environment.

Unit 8: Cryptalgal Dolomite Bindstone-Mudstone (samples 43 to 48)

Description. The unit is 34 m thick, dark gray to brown black on a fresh surface, medium bedded, and forms cliffs. The unit has white calcite infilled laminoid and ovoid fenestrae in a clotted cryptalgal fabric. It is bioturbated, has vertical burrows to 1 cm in diameter, and contains fragmented brachiopod valves, some conodont fragments, and bryozoans throughout.

Environmental Interpretation. The clotted cryptalgal fabric indicates an upper intertidal to supratidal environment. An intertidal environment is favored, as the presence of burrows and bioturbation argue against a supratidal environment where infauna are uncommon.

Unit 9: Stromatolitic Dolomite Floatstone (samples 49 and 50)

Description. The unit is 12 m thick, gray to black on a fresh surface, medium bedded, and forms cliffs. The unit consists of isolated domal algal heads to 21 cm in diameter, out of growth position and isolated in a matrix of black dolomite mudstone. Hydrocarbon residues are common along stylolitic boundaries within the algal heads. Devonian conodont elements (*Polygnathus*) are present but rare in the mudstone.

Environmental Interpretation. Logan and others (1964), Ginsburg (1975), and James (1977) described algal structures and suggest that large algal domes represent intertidal to subtidal environments with vigorous circulation. The surrounding black mudstone indicates a much lower energy environment, below wave base, possibly a foreslope environment or lagoon. The algal heads may have been dislodged during a storm and transported to a lower energy, muddy environment by a submarine slump or turbidity current.

Unit 10: Bioturbated Lime Mudstone (samples 51 to 79)

Description. The unit is 188 m thick, black on a fresh surface, thin bedded, and a steep ledge and cliff former. The unit is intermittently burrowed and finely laminated, with uncommon mud intraclasts and rare mud flasers. Hydrocarbon residues are present from 12 to 30 m above the base of the section. Late Devonian conodont elements (*Palmatolepis*) are present throughout the unit.

Environmental Interpretation. Based on Byer's model (1977), the burrowed texture indicates a well oxygenated sediment-water layer about 50 m deep, possibly an open marine shelf, below normal wave base.

Unit 11: Medium Grained, Calcareous Quartz Siltstone (samples 80 to 87)

Description. The unit is 43 m thick, orange on a fresh surface, thin bedded, and forms very gentle slopes. The quartz grains are well rounded, well sorted, and thinly laminated. One centimeter planar cross-bed sets are present 40 m from the base of the unit. The unit has intergranular porosity. No fossils were observed.

Environmental Interpretation. The unit appears to consist of recycled grains of silt eroded from a pre-existing mature siltstone. The centimeter-thick planar cross-bed sets slope very gently, suggesting beach deposition (Reineck and Singh, 1977).

Unit 12: Laminated Lime Mudstone (samples 88 to 91)

Description. The unit is 25 m thick, light gray on a fresh surface, thin bedded, and forms ledges. Planar laminations occur from the base of the unit becomes mottled and has a distinct clotted algal texture.

Environmental Interpretation. The absence of shelly fauna throughout the unit, and only minor bioturbation within the upper portion, indicate a restricted environment, possibly within a dysaerobic zone, as within a cutoff lagoon or restricted bay, where only more resistant infauna could survive (Byers, 1977).

Unit 13: Intraclast Lime Wackestone-Mudstone (samples 92 to 122).

Description. The unit is 185 m thick, black on a fresh surface, medium bedded to massive and forms cliffs. Intraclasts are the dominant grain constituent. The unit has vertical and horizontal burrows, commonly infilled with intraclasts to two centimeters in diameter. Algal laminations and laminar encrusting stromatoporoids are present but not common. Abraded brachiopods and crinoid ossicles are abundant. Gastropods, ostracodes, oncoids, ramose bryozoans, pellets and Late Devonian conodont elements (*Palmatolepis*) are common.

Environmental Interpretation. The presence of abundant shelly fauna, oncoids, and minor algal laminations suggest a well oxygenated environment, possibly landward of a resistant stromatoporoid buildup.

Conclusions

1. This study confirms that Ordovician through Middle Devonian strata are not present in this stratigraphic section; however, Upper Devonian strata are present. Based on conodont studies and lithologic interpretations, an unconformity between Cambrian and Upper Devonian strata is recognized at the base of Unit 2.

2. Within the study area, Cambrian lithologies are dominated by bioturbated dolomitic and lime mudstone. Strongly bioturbated dolomitic wackestone and dolomitic to lime bindstone are minor. These lithologies are interpreted as having been deposited as low energy carbonates in a subtidal marine environment, below storm wave base, commonly within a dysaerobic (low oxygen) zone.

3. Devonian lithologies are composed of bioturbated dolomite and lime mudstone, algal and stromatoporoid dolomite and lime bindstone, and crinoid-intraclast dolomite and lime wackestone.

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