

The Burgess Shale: Not in the Shadow of the Cathedral Escarpment

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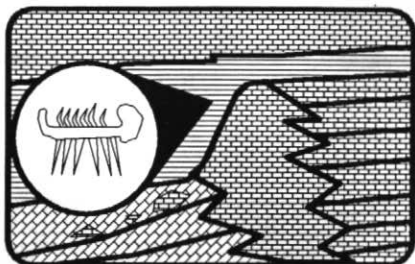
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Articles



The Burgess Shale: Not in the Shadow of the Cathedral Escarpment

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Introduction

A few kilometres north of the town of Field in Yoho National Park, eastern British Columbia, high on the ridge between Mount Field and Wapta Mountain, a small quarry has been cut into gently dipping mid-Cambrian shales. This unassuming quarry is the source for arguably the most significant assemblage of fossils ever described — the Burgess Shale fauna. In addition to being superbly preserved and biologically unmatched, this diverse assemblage constitutes the best evidence possible of the magnitude, trajectory and nature of the great metazoan radiations that occurred near the base of the Phanerozoic.

Excavation of two metres of strata by workers employed by C.D. Walcott, Secretary to the Smithsonian Institution, between 1910 and 1917 (Walcott, 1911) and by a Geological Survey of Canada party led by J.D. Aitken in the late 1960s (Aitken and Fritz, 1968) resulted in the accumulation of extraordinarily large and diverse collections of exquisitely preserved algae, sponges, brachiopods, cnidarians, molluscs, worms, arthropods, echinoderms, chordates and various unclassified animals; many showing the detailed soft-part preservation that has become the cachet of the Burgess Shale (Figure 1).

This remarkable biota was first documented by Walcott in a series of papers published between 1911 and 1924. H.B. Whittington of Harvard University (now at Cambridge University) took charge of a new investigation of these fossils in 1966 and, since 1971, he and his colleagues D.E.G. Briggs, S. Conway Morris, D.L. Bruton, and C.P. Hughes have published some 50 papers and monographs on the systematics, preservation, ecology and evolutionary significance of virtually all of the faunal groups represented in the Burgess Shale (see Conway Morris and Whittington, 1979; Conway Morris *et al.*, 1982; Whittington, 1985). Through their efforts in both the scientific and the popular press, this one-half billion-year-old soft-bodied *Fossil-Lagerstätten* (literally, "bedded fossil treasure") has now become exceptionally well known.

The weird and wonderful animals that emerged during the restudy of the Burgess assemblage have been exhibited on a stage that is both dramatic and, for early Paleozoic Laurentia, exceptional — at the base of a 200 metre vertical wall of reef carbonate. This wall, the Cathedral Escarpment, appears, in every graphic reconstruction of the Burgess Shale environment (Conway Morris and Whittington, 1979, 1985): it is the basis for a new diorama of the Burgess Shale at the United States National Museum of Natural

History (Whittington, 1985; Boardman *et al.*, 1987); it has been incorporated as a backdrop to a compelling painting showing a worm's-eye view of bizarre Burgess animals (John Gurche, *in Reader*, 1986); and it has become an essential component of various ecologic and taphonomic models of the Burgess Shale fauna (Whittington, 1985; Conway Morris, 1986) and sedimentologic models of adjacent strata (Piper, 1972; McIlreath, 1977; Aitken and McIlreath, 1984).

The existence of the Cathedral Escarpment as a Cambrian submarine scarp and reef front has never been questioned and, now, it is virtually impossible for anyone to attempt to visualize the living Burgess Shale animals without seeing its vertical face looming in the background. Moreover, the escarpment has been used to explain the local occurrence and preservation of the Burgess Shale fauna. Conway Morris and Whittington (1985, p. 2) stated that "... in some way the reef escarpment controlled the distribution of the faunas that lived on and in the muds of the adjacent deep water". Aitken and McIlreath (1984, p. 19) suggested that the Burgess Shale biota flourished in the nutrient-rich water that upwelled at the reef front. Boardman *et al.* (1987, frontispiece) made the extraordinary claim that the small and delicate species of the Burgess biota were buried by the slumping reef face.

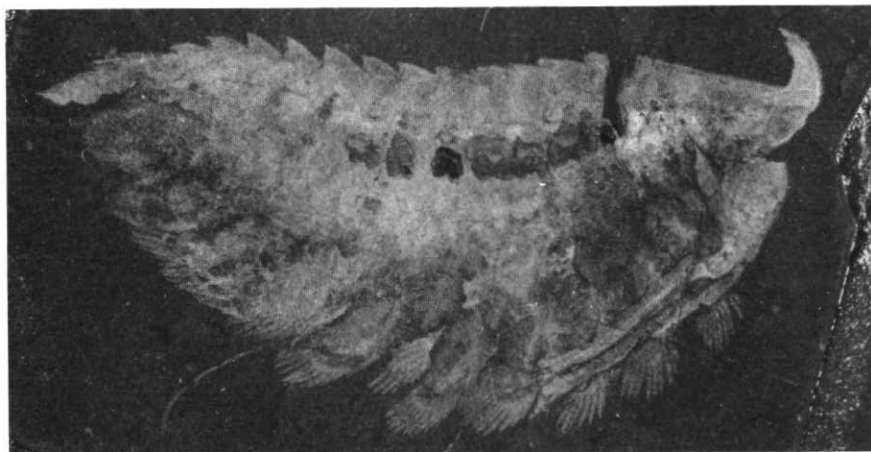


Figure 1 The Burgess Shale affords an unequalled glimpse of mid-Cambrian life. The arthropod *Leanchoilata superlata* Walcott, shown here in side view, has an upturned snout on its head and 13 pairs of biramous appendages. It probably swam close to the bottom where it used its long anterior appendages (here folded under the trunk) to search for food (photograph by H.B. Whittington, 1.5 ×).

The feature called the Cathedral Escarpment certainly seems to be real. It has been identified on a number of mountain sides in the area around the town of Field. On Mount Stephen (McIlreath, 1977, fig. 3), Mount Field (Aitken and McIlreath, 1984, fig. 2) and adjacent to the Burgess Shale quarry (Whittington, 1971, fig. 1), it appears as a steeply inclined plane separating gently dipping eastern carbonates from gently dipping western shales. And it has been mapped for more than 50 km across Yoho National Park (Aitken and McIlreath, 1984).

The evidence that led to the definition of the Cathedral Escarpment as a 200 m high submarine scarp did not come, as one might expect, from paleoenvironmental analysis of lithofacies or from study of paleobathymetric indicators such as sedimentary structures, trace fossils, or fossil communities, or even from consideration of depositional models. No, this is a Cambrian bathymetric feature that has been defined by trilobite biostratigraphy. The biostratigraphic evidence has now stood unchallenged and untested for 20 years. Here, in the first critical appraisal, the escarpment model is replaced by a ramp model — one that has considerable implications for the environment and mode of formation of the Burgess Shale.

Geologic Setting

In the area around Field in Yoho National Park, the mid-Cambrian succession consists of a carbonate platform, now largely dolomitized, assigned to the Cathedral Formation which is flanked to the west by a shale basin filled with siliceous, silty and calcareous mudstones and minor limestones of the Stephen Formation (Figure 2). A major limestone unit in the lower Stephen adjacent to the platform was named the Boundary Limestone. The Burgess Shale Quarry is located about one-third the way up in the Stephen in

the easternmost part of the shale basin, and about 20 m from the vertical contact with the Cathedral carbonates (Aitken and McIlreath, 1981, fig. 13). A thin Stephen Formation overlies the Cathedral on the platform and is, in turn, overlain by dolostones and limestones of the Eldon Formation (see also Rasetti, 1951; Fritz, 1971; McIlreath, 1977).

Trilobite Zones in the Cathedral and Stephen Formations

The distribution and systematics of mid-Cambrian trilobites in the Cathedral and Stephen formations of Yoho National Park were dealt with in considerable detail by Rasetti (1951) who allocated collections from different localities to two zones: a *Glossopleura* Zone comprising three faunules in the Cathedral and lower Stephen and an overlying *Bathyriscus-Elrathina* Zone consisting, in the Stephen, of four faunules.

Fritz (1971) documented the distribution of the same zones in the same formations, but unlike Rasetti's, his study was based on numerous trilobite collections accurately located at many levels within stratigraphic sections measured along the trace of the Cathedral margin. Rasetti's zonal names were retained, but the three faunules of the *Glossopleura* Zone were dropped and the name and definition of some of the faunules of the *Bathyriscus-Elrathina* Zone were revised. Fritz showed that the *Glossopleura* Zone is present in the upper beds of the Cathedral carbonates on the platform as well as in the lower Boundary Limestone in the basin. The upper Boundary Limestone and the rest of the Stephen Formation in basinal sections were assigned to four faunules of the *Bathyriscus-Elrathina* Zone; the fourth faunule also being present in the thinner Stephen overlying the Cathedral on the platform (Figure 3).

Fritz demonstrated that the Stephen For-

mation is continuously, if sparsely, fossiliferous for its entire thickness. Neither he nor Rasetti recovered diagnostic fossils from the dolostones which comprise the bulk of the Cathedral Formation in this area.

Biostratigraphic Models

Correlation of strata with fossils is rarely a matter of simply drawing lines of correlation between the same biostratigraphic units in different sections. Assumptions made about the nature of the units will inevitably influence which strata are correlated. More often than not, the assumptions are left unstated and the resulting correlations tend to be treated as biostratigraphic fact, when actually they are contingent on the validity of a particular biostratigraphic model.

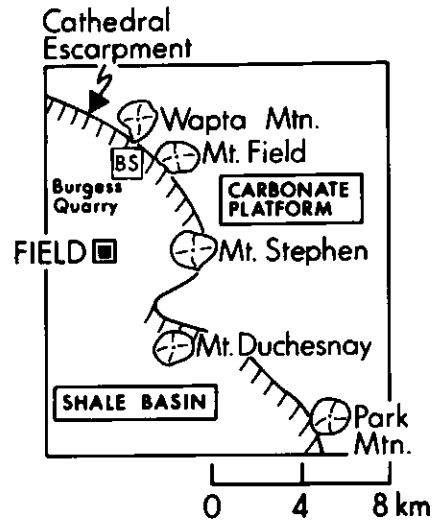


Figure 2 The mid-Cambrian feature called the Cathedral Escarpment can be mapped readily on mountainsides in the vicinity of Field in eastern British Columbia. In this and in following figures, location of Burgess Shale Quarry is shown as (BS).

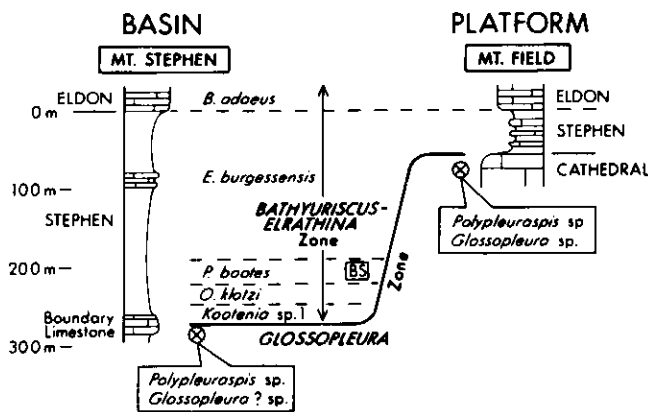


Figure 3 The distribution of trilobite zones and faunules in a measured section from the shale basin at Mt. Stephen and one from the carbonate platform at Mt. Field (sections and biostratigraphic data from Fritz, 1971). In addition to the two taxa shown, the *Glossopleura* Zone in the Boundary Limestone also includes *Oryctocephalus cf. reynoldsi*.

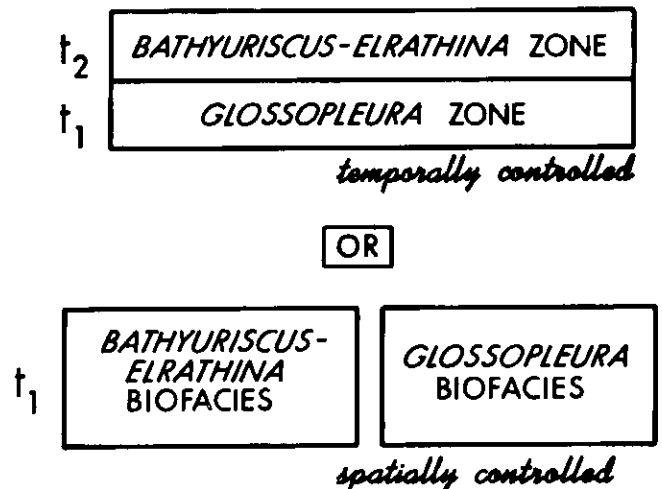


Figure 4 Two possible ways to explain the distribution of trilobites of the *Glossopleura* and *Bathyriscus-Elrathina* zones in the vicinity of the Cathedral margin. See text for discussion.

With reference to the *Glossopleura* and *Bathyriscus-Eirathina* zones in the vicinity of the Cathedral margin, two possibilities emerge. First, the distribution of the trilobite genera that comprise these zones is controlled solely by time factors (Figure 4 upper). Or second, these zones represent contemporaneous biofacies whose distribution is controlled by environmental factors (Figure 4

lower). These two possibilities are best explored in the context of separate biostratigraphic models: an *Index Model* which is based on index fossil biostratigraphy and *Dual Model* which draws on dual biostratigraphy as outlined recently by Ludvigsen *et al.* (1986). Below, the two models are applied to Fritz' (1971) comprehensive biostratigraphic data of mid-Cambrian trilobites in the vicinity

of the Burgess Shale quarry, and compared and contrasted in a series of simple (possibly simplistic) stratigraphic diagrams.

Index Model. The Cathedral Escarpment owes its existence to Fritz' (1971) implicit use of this biostratigraphic model to explain the distribution of trilobite faunas in the Cathedral, Stephen and Eldon formations. This model is rooted in a particular zonation of Cambrian strata — one that has been promoted by Rasetti (1951), Lochman-Balk and Wilson (1958) and Fritz (1970), among many others, as a standard for Laurentia. This zonation comprises a single sequence of assemblage zones of trilobite genera. Each zone being a unique and infallible indicator to a certain time interval and each zonal boundary being isochronous. The index genera are apparently immune to environmental influences because the zones are claimed to be applicable to all coarse clastics, fine clastics and carbonates of Cambrian Laurentia (Figure 5). It follows that the absence of a zone can be explained only by erosion or non-deposition of strata or by obliteration of fossils.

A correlation chart of Fritz' (1971) mid-Cambrian stratigraphic sections in Yoho National Park (Figure 6) shows that the lower Boundary Limestone in the basin and the upper Cathedral on the platform are coeval because both contain *Glossopleura* and *Polyleuraspis*; these genera being indicative of the *Glossopleura* Zone. The upper Stephen in the basin and the thin Stephen on the platform are also correlated

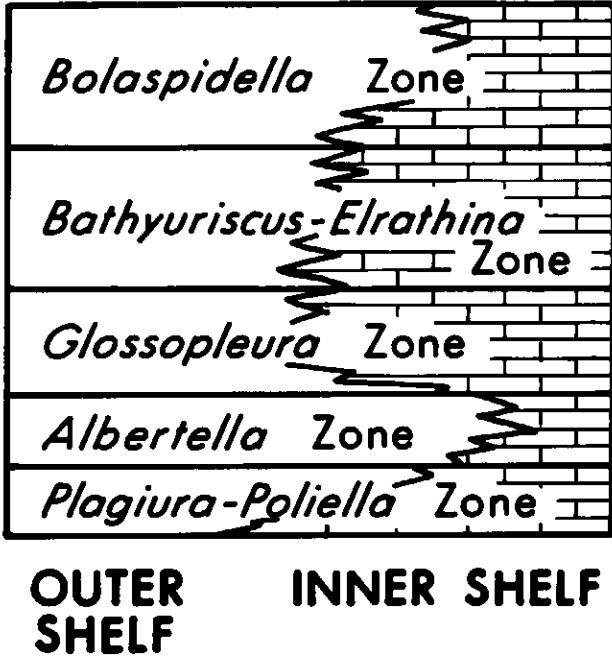


Figure 5 The Index Model is based on this mid-Cambrian trilobite zonation of generic assemblage zones whose distribution in different lithofacies is controlled solely by time. (From Lochman-Balk and Wilson, 1958).

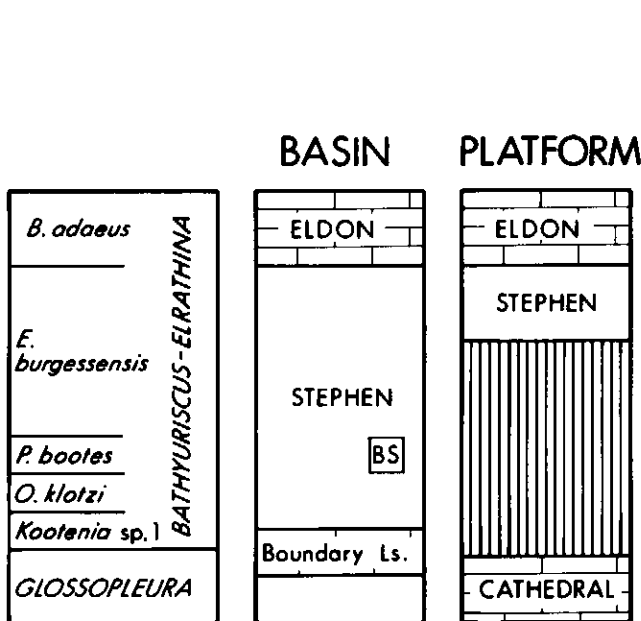


Figure 6 A correlation chart of the Stephen, Cathedral and Eldon formations in the shale basin and on the carbonate platform according to the Index Model.

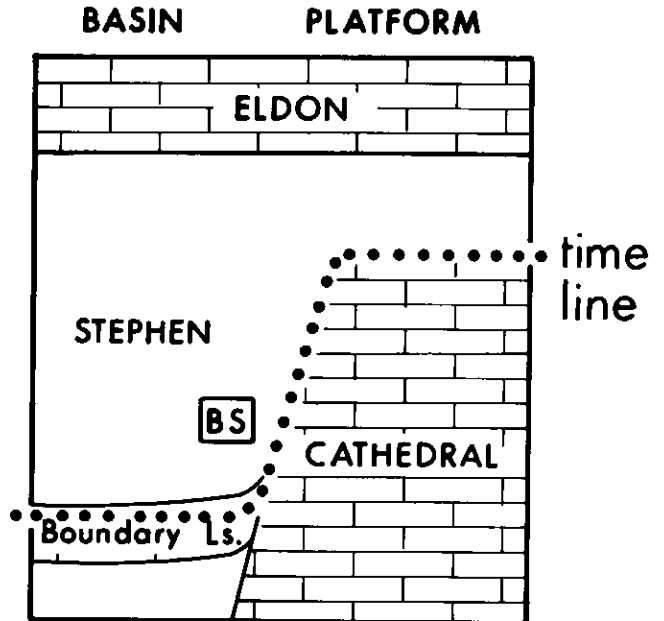


Figure 7 A stepped time line (the top of *Glossopleura* Zone) defines the Cathedral Escarpment on a stratigraphic cross-section according to the Index Model.

because they share the *Ehmaniella burgessensis* faunule of the *Bathyriscus-Elrathina* Zone. A major hiatus on the platform is indicated by the absence of the lower three faunules of the *Bathyriscus-Elrathina* Zone.

On a stratigraphic cross-section (Figure 7), the profile of the Cathedral Escarpment now becomes defined by a time line (the top of the *Glossopleura* Zone) which extends from the Boundary Limestone in the basin vertically up to the top of the Cathedral on the platform. It follows that the shallow water carbonate sediment that comprises the Boundary Limestone was deposited as a debris apron at the base of the vertical Cathedral Escarpment in water depths of about 200 m (or even much deeper, see McIlreath, 1977, p. 117). And, further, that when the lower Stephen shales (including the Burgess Shale) were being deposited in

the basin, no carbonates were accumulating on the dead platform which eventually was buried by shales carrying the *Ehmaniella burgessensis* faunule.

Do occurrences of trilobite genera constitute the basis for detailed time correlations across a major facies change? According to the Index Model, the answer is yes. And the Cambrian bathymetric feature named the Cathedral Escarpment has been defined on just that premise.

Dual Model. Because sedimentary facies are influenced by factors such as water depth, current activity, sediment grain size, temperature and light penetration — all of which are known to influence the distribution of extant biotas — study of facies must be an integral part of biostratigraphy which deals with the distribution of extinct biotas. Dual biostratigraphy (Ludvigsen et al., 1986)

emphasizes the influence of facies and provides both a methodology and a nomenclature to identify the spatial and temporal controls on the distribution of fossils in strata. This is best done with separate biostratigraphic units — biofacies (spatial units defined by specimen *abundance* of genera of higher taxa) and zones (temporal units defined by *presence* of species).

Dual biostratigraphy, in its entirety, cannot be applied to the faunas of the Cathedral and Stephen formations because abundance data are lacking for all but a few collections, but sufficient evidence exists to show that both the *Glossopleura* and *Bathyriscus-Elrathina* zones properly represent lithofacies-specific biofacies and that their common boundary is strongly diachronous.

In the well-studied Cambrian succession of the Great Basin of Nevada and Utah,

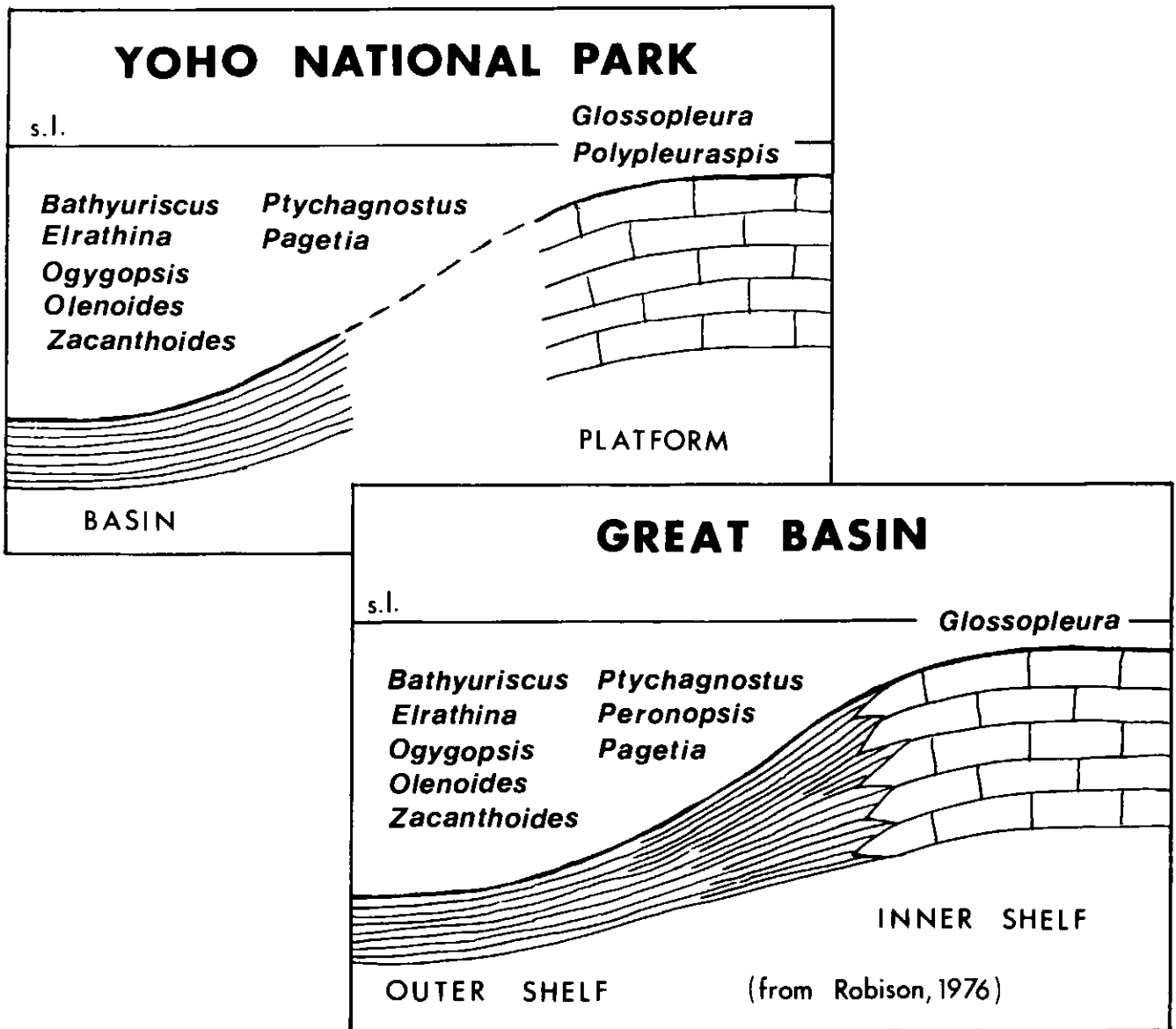


Figure 8 Facies distribution of common trilobite genera is practically identical in the mid-Cambrian of Yoho National Park in British Columbia and the Great Basin of Nevada and Utah (data for the Great Basin from Robison, 1976).

faunas above the *Albertella* Zone fall into two distinct groups: a *Glossopleura* Zone comprising low-diversity assemblages in shallow water limestones followed by a *Bathyriscus-Elrathina* Zone composed of high diversity assemblages that occur largely in deeper quiet water shales, mudstones and limestones. The name bearers of these zones do not indicate separate time intervals. Robison (1976) demonstrated that the stratigraphic ranges of *Bathyriscus* and *Elrathina* overlap completely with that of *Glossopleura*. And further, Briggs and Robison (1984, p. 4) suggested that the boundary between these two zones may have greater ecological than temporal significance. It is clear that their distribution in the Great Basin is governed by environmental factors (Figure 8). The first assemblage belongs to an inner shelf biofacies and the second to various outer shelf biofacies (Robinson, 1976, p. 100, 102; Palmer and Halley, 1979, p. 60).

In the vicinity of the Burgess Shale quarry, similar trilobite associations or biofacies showing the same dominance and diversity patterns as in the Great Basin occur in an identical lithofacies pair (Figure 8): A *Glossopleura* assemblage in shallow water limestones and a number of high diversity assemblages with *Bathyriscus*, *Zacanthoides*, *Elrathina* and others in off-shore shales and mudstones (including a *zacanthoidid-Pagetia* Biofacies and a *Bathyriscus* Biofacies; see Young and Ludvigsen, in press).

In both the Great Basin and in Yoho National Park, a major transgression superposed high diversity off-shore biofacies on low diversity shallow water biofacies at various times during the mid-Cambrian.

Because the biofacies belts are distinct compositionally, each requires a separate zonal sequence to represent adequately the temporal dimension. Robison (1976) suggested that, in the Great Basin, the *Bathyriscus-Elrathina* Zone should be abandoned and, in part, replaced by an *Oryctocephalus* Zone for outer shelf shales and limestones only, and also that the *Glossopleura* Zone be restricted to inner shelf carbonates. These units now provide a reasonable framework for interpreting the relationship of mid-Cambrian strata across the Cathedral margin in the context of the Dual Model (Figure 9).

A correlation chart of Fritz' (1971) basin and platform sections according to this model (Figure 10: correlations modified slightly from Robison, 1976, fig. 5) shows temporal alignment of the Cathedral carbonates and most of the Stephen shales even though the zones are entirely distinct. Furthermore, the absence of, for example, an outer shelf zone from an inner shelf sequence is fully expected in this model; it does not become evidence for a major hiatus.

On a stratigraphic cross-section (Figure 11), the Boundary Limestone now appears as a carbonate tongue deposited at a depth not much greater than the main mass of the Cathedral Formation. The steep contact of the Cathedral with the Stephen becomes a simple, albeit abrupt, facies change; suggesting that the Burgess Shale was deposited on a ramp, close to a belt of active carbonate accumulation and only somewhat deeper.

According to the Dual Model, the Burgess Shale was deposited on a gently inclined ramp, not at the base of a high escarpment. **Conclusion.** The two opinions about the nature of the Cathedral margin in Yoho National Park and, consequently the environmental setting of the Burgess Shale biota,

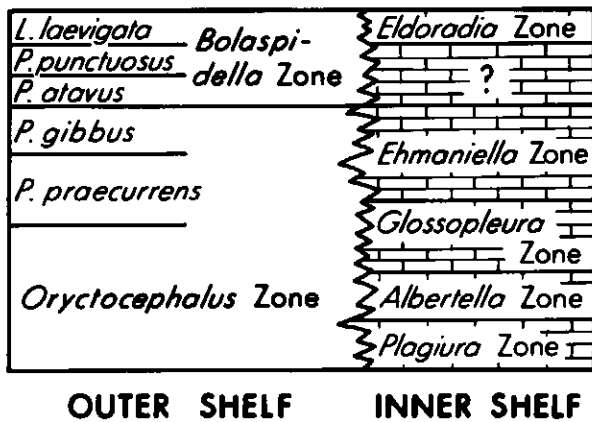


Figure 9 According to the Dual Model the distribution of fossils is controlled by both time and environment. Robison's (1976) separate lithofacies-specific zonations of mid-Cambrian rocks of Nevada and Utah accommodate such distributions.

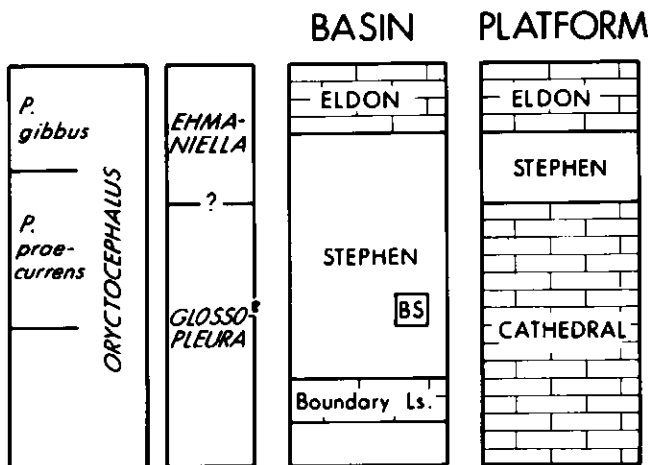


Figure 10 A correlation chart of the Stephen, Cathedral and Eldon formations in the shale basin and on the carbonate platform according to the Dual Model.

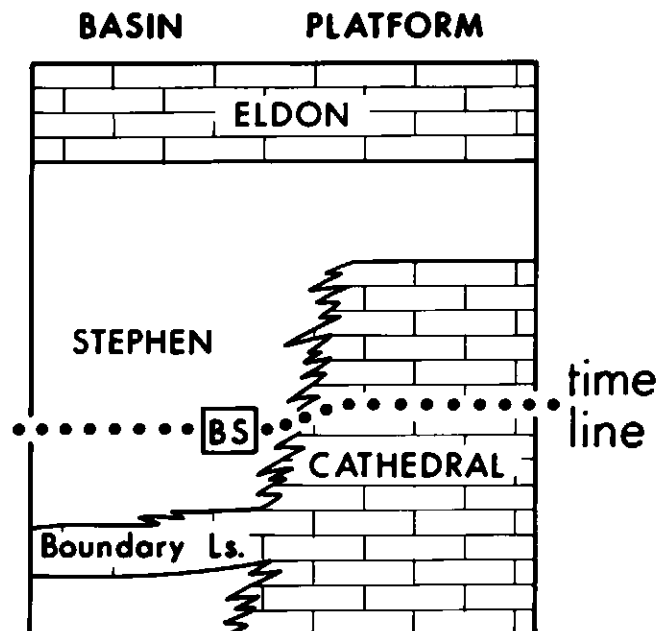
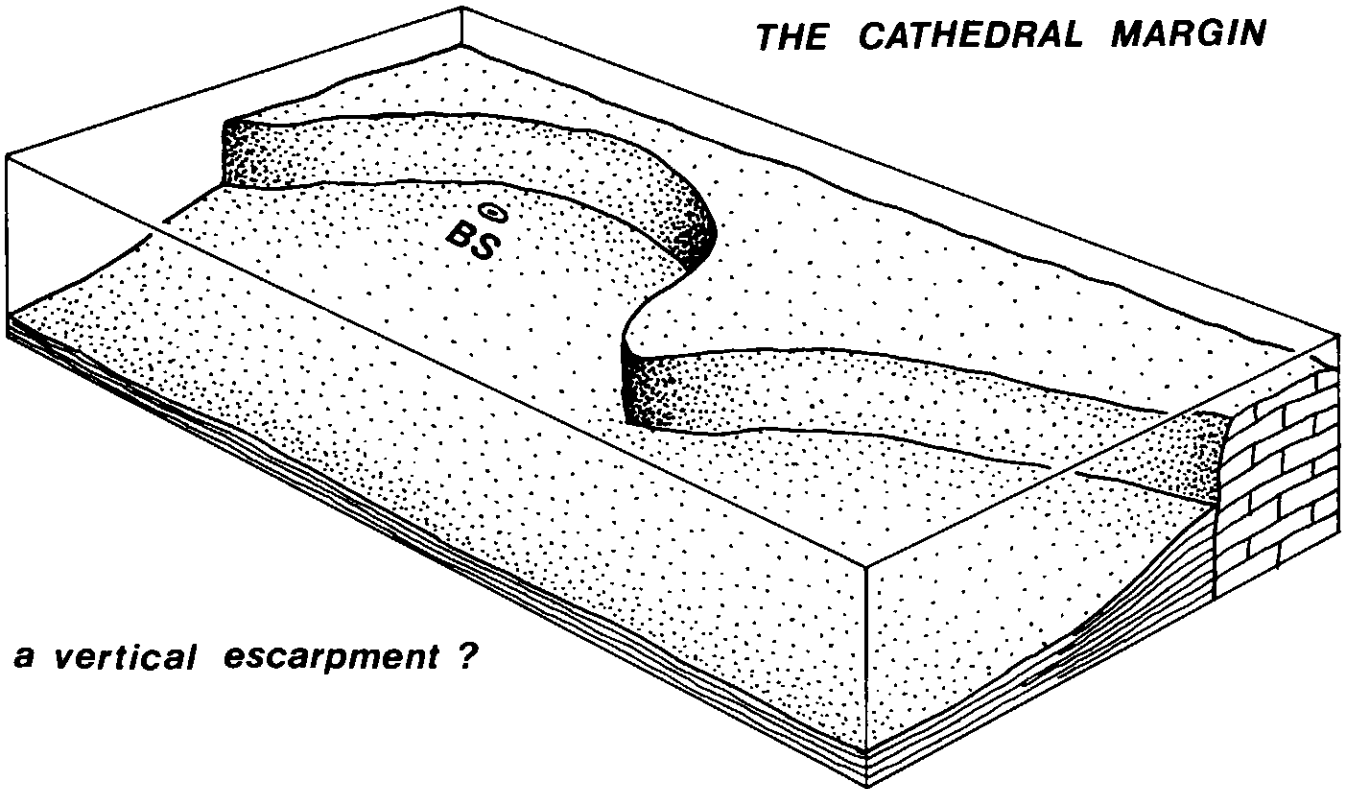
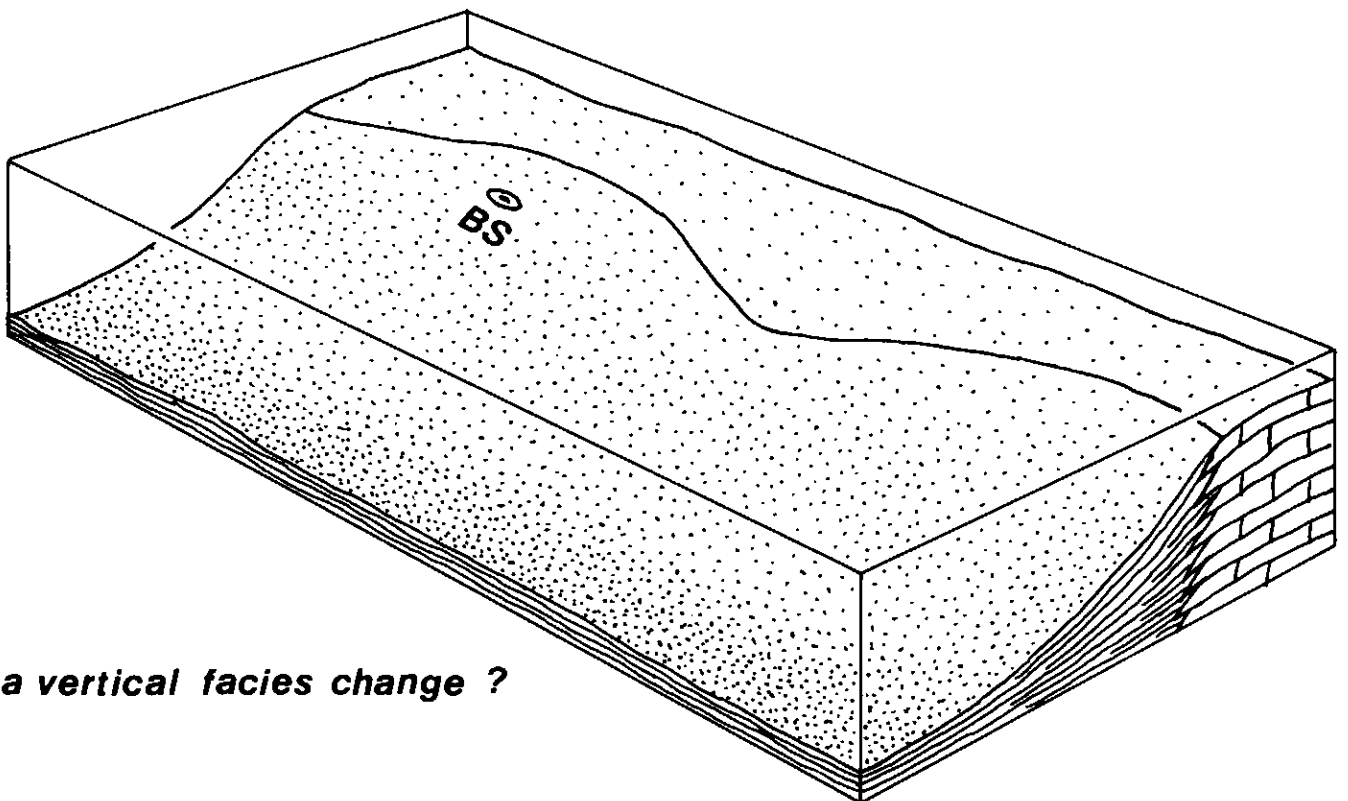


Figure 11 A time line will extend from basinal shales to platform carbonates on a stratigraphic cross-section according to the Dual Model.

THE CATHEDRAL MARGIN



a vertical escarpment ?



a vertical facies change ?

Figure 12 Block diagrams showing two different opinions about the nature of the Cathedral margin in Yoho National Park. The Index Model leads to the notion of the Cathedral margin as a vertical submarine escarpment (modified from Conway Morris and Whittington, 1985, fig. 2). The Dual Model suggests that the Cathedral-Stephen contact is a shale-carbonate facies change on a ramp.

emerge from competing models of trilobite biostratigraphy (Figure 12). The Index Model supports the notion of the Cathedral margin as a vertical escarpment, but this model requires resurrection of an obsolete facies-independent zonation of trilobites that has already been abandoned by most Cambrian biostratigraphers for theoretical as well as empirical reasons (Robison, 1976). By contrast, the Dual Model proposes that the Cathedral margin was nothing more than the juncture of two facies belts on a ramp. This model emphasizes the profound influence of facies in controlling the distribution of trilobites in strata and uses facies-specific zones to resolve diachroneity of biofacies (Ludvigsen *et al.*, 1986).

Sedimentologic Evidence for an Escarpment

As has been shown above, the biostratigraphic evidence for the Cathedral Escarpment is less than convincing. However, if such a substantial bathymetric feature *did* exist, surely the sedimentologic evidence must be unequivocal.

A vertical submarine cliff standing hundreds of metres above a muddy bottom for a few million years will inevitably leave a characteristic debris apron of angular blocks at its base (see the carbonate slope facies of McIlreath and James, 1984). If such a facies is searched for along the Cathedral margin in Yoho National Park, the evidence is clear — not a single carbonate block, let alone a sizeable debris apron, has ever been documented from the Stephen shales in front of the putative escarpment. On this basis alone, the notion of the Cathedral Escarpment as a vertical bathymetric feature can be considered to be falsified (Beales *et al.*, 1986). Limestone breccias from mid-Cambrian strata in Yoho National Park have been illustrated a number of times (Rasetti, 1951, plate. 6; McIlreath and James, 1984, figs. 2, 4), but these examples are all from the Cathedral Formation hundreds of metres below the Stephen Formation (see Aitken and McIlreath, 1984, fig. 3) and they have no bearing on either the Cathedral Escarpment or the depositional environment of the Burgess Shale.

An escarpment was also an essential component of McIlreath's (1977, fig. 8) elaborate depositional model of the Boundary Limestone as a deep-water deposit of shelf-derived sediment that bypassed a dead carbonate margin to accumulate at the base of a submarine cliff. The alternate, and certainly more parsimonious, explanation that these grainstones and packstones are of shallow water aspect *because* they were deposited in shallow water as a tongue of the Cathedral carbonates was not considered.

The sedimentologic evidence that supports the Cathedral Escarpment can be itemized succinctly. None exists!

The Burgess Shale: Turbidite or Tempestite?

Piper (1972) interpreted the thin-graded beds of calcareous siltstone and mudstone that comprise the fossiliferous layers of the Burgess Shale as turbidites and, because they contain fecal pellets and bioclastic debris, he suggested that the turbidity currents swept off the top of the Cathedral platform through gaps in the escarpment front to form coalescing deep-sea fans. However, because such gaps could not be located, McIlreath (in Whittington, 1980, p. 132; see also Aitken, 1971, p. 568) claimed that the Burgess sediments were transported in from the north, parallel to an unbreached vertical escarpment front.

With the carbonate platform effectively disallowed as a source of either Burgess sediment or Burgess animals, the entire sequence of slumping of mud and animals, transportation of the turbidity current, and final deposition as a graded bed (Whittington, 1980, fig. 2) has to take place within a narrow muddy belt in front of and parallel to the Cathedral Escarpment. Moreover, each turbidity current has to originate from a dysaerobic area, travel across the base of the photic zone to dump its load in an anoxic area according to Conway Morris' (1986, fig. 1) taphonomic model. Because the Burgess Shale quarry is located a mere 20 m from the escarpment, such a sequence of events is difficult to envisage without requiring the turbidity currents to flow upslope across an environmental mosaic developed within what appears to be a uniform lithofacies.

The Cathedral Escarpment has provided a dramatic setting for the living Burgess Shale fauna but, with regard to the development of realistic depositional models for the Burgess Shale, it has been more of a hindrance than an aid. I suggest that the sedimentary features of the Burgess Shale and the taphonomic aspects of the biota are more consistent with deposition on a storm-influenced ramp — a setting supported by the evidence of trilobite biostratigraphy presented earlier.

By identifying the Burgess Shale graded units as turbidites, Piper (1972) attributed their deposition to the waning energy conditions associated with the passage of a turbid density current. But other processes can also produce waning flows; notably, storm beds or tempestites whose formation and distribution on modern and ancient shelves and ramps have received considerable attention recently (Kreisa, 1981; Einsele and Seilacher, 1982; Aigner, 1985).

Each of the fifty or so laminated units that comprise the fossiliferous parts of the Burgess Shale is a few centimetres thick and each typically consists of a lower sharp-based calcareous siltstone with irregular mudstone laminae, a middle laminated mudstone, and an upper non-laminated mudstone (Conway Morris, 1986; Piper, 1972,

p. 173). Aigner (1984, p. 137, fig. 3 G,H) described closely comparable textures in laminated calcisiltites from the Middle Triassic of the central parts of the South German Basin and interpreted the strata as distal tempestites. Brett *et al.* (1986, p. 140, figs. 9, 14) interpreted an identical facies from the deeper parts of the Middle Devonian Hamilton Group of western New York as medial to distal tempestites. Particularly striking is the similarity of Piper's (1972, fig. 2) typical graded bed of the Burgess Shale of Kreisa's (1981, fig. 3) idealized storm sequence from the Ordovician Martinsburg Formation of Virginia. The textures of the laminated units of the Burgess Shale are fully consistent with their being distal tempestites.

The taphonomy of Burgess Shale fossils has been interpreted exclusively in terms of turbidite deposition. The detailed work by Whittington (1971, p. 1197) on the arthropod *Marrella* established that these delicate benthic animals were alive when entombed and, because the carcasses were buried with legs and gill branches in natural positions and with delicate structures such as antennae intact, the turbidity current must have been *slow moving, non-turbulent and of brief duration*. In other words, if the turbidite taphonomic model is to account for the superb preservation of *Marrella*, the most common Burgess fossil, then the key aspects of a turbidity current, those that permit the current to carry a sediment load, have to be reduced to a minimum. But, instead of compromising the nature of turbidity currents in order to force a turbidite model on the Burgess Shale, perhaps another model should be applied.

A simple tempestite model for the Burgess Shale can incorporate the bulk of the textural and taphonomic aspects of the fossiliferous layers. A severe storm on an ocean-facing muddy ramp results in storm rollers impinging the bottom to a considerable depth and causes sediment and live and dead animals to be thrown into suspension for a brief time. Waning energy as the storm passes allows rapid deposition of graded silts and muds. According to the proximal-distal tempestite spectra discussed by Kreisa (1981, p. 840) and Brett *et al.* (1986, fig. 14), the Burgess Shale would have been deposited on a ramp immediately below storm wave base at the shallow end of the distal facies; and in water depths of perhaps 50 m judging by recent storm beds in the North Sea (Aigner and Reineck, 1982)). Such a setting has also been suggested for the slightly younger Wheeler Formation in Utah (Briggs and Robison, 1984, p. 4) — a formation that includes many of the non-mineralized Burgess faunal elements in addition to a shelly fauna that does not differ statistically from that of the Burgess Shale (Conway Morris and Robison, 1982, p. 171).

The faunal differentiation expressed in

single graded bed from the Burgess Shale (Piper, 1972, fig. 2) suggests the influence of taphonomic controls. Only mineralized shells are found in the lower siltstone unit, mixed mineralized and non-mineralized shells in the laminated siltstone, and only non-mineralized shells in the upper non-laminated siltstone. Analogous taphonomic sorting has been documented in Upper Cambrian tempestites by Westrop (1986), but in that study the sorting of trilobite elements was attributed to size; in the Burgess Shale, it appears to be controlled by density of vacant shells and of living animals.

The turbidite and tempestite models clearly differ by the inferred role of transportation. Piper's (1972) turbidite model for the Burgess Shale required both sediment and fossils to be allochthonous. According to the tempestite model, however, the Burgess Shale fossils represent a taphonomically sorted, but essentially autochthonous, fauna; obviating various attempts to establish physical and biological differences between a "pre-slide" and a "post-slide" environment and to estimate the distance the fauna was transported (Whittington, 1985, p. 33-38; Conway Morris, 1986, p. 427-431, fig. 1).

The graded couplets of the Burgess Shale appear to be distal storm beds that were deposited *in situ* on a muddy ocean-facing ramp and in moderately shallow water.

Conclusion

In a bold departure from conventional biostratigraphic practice, which largely addresses regional correlation of strata, Fritz (1971) used the distribution of mid-Cambrian trilobite zones in the Field area of Yoho National Park to define a local depositional feature which he named the Cathedral Escarpment.

For close to twenty years this escarpment has provided a dramatic environmental context for the incomparable Burgess Shale fauna. The combination of the outlandish invertebrate players acting on this unusual Cambrian stage has proven irresistible to many university teachers (myself included) who exploited this theme yearly for lectures on Cambrian historical geology, stratigraphy and paleontology, as well as to uncoupled undergraduate students who regularly selected "The environment of the Burgess Shale" as a topic for term papers. It is an exciting setting; one that fires the imagination of amateur and professional alike and one that can be used for playing out imaginative and ingenious sedimentologic, stratigraphic and paleontologic scenarios. It suffers from only one slight defect: There is now no convincing evidence that this escarpment ever existed.

The sole evidence for a 200 m high escarpment towering above the Burgess Shale — a stepped time line defined by the top of a trilobite genus assemblage zone — does not

stand critical scrutiny. Instead, the biostratigraphic and sedimentologic evidence strongly suggests that the Burgess Shale was deposited on a ramp as a sequence of tempestites.

The Cathedral Escarpment was confidently dubbed "a Cambrian great wall" by Aitken and McIlreath (1984). According to the conclusions of this critical appraisal, the "great wall" should instead be characterized as a "false front" nailed to a facies change.

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References

- Aigner, T., 1984, Dynamic stratigraphy of epicontinental carbonates. Upper Muschelkalk (M. Triassic), South German Basin: Neues Jahrbuch für Geologie und Paläontologie Abhandlungen, v. 169, p. 127-159.
- Aigner, T., 1985 Storm depositional systems. Dynamic stratigraphy in modern and ancient shallow-marine sequences: Springer-Verlag, New York, Lecture Notes in Earth Science, v. 3, p. 1-174.
- Aigner, T. and Reineck, H.E., 1982, Proximal trends in modern storm sands from the Helgoland Bight (North Sea) and their implications for basin analysis: Senckenbergiana Maritima, v. 14, p. 183-215.
- Aitken, J.D., 1971, Control of Lower Paleozoic sedimentary facies by the Kicking Horse Rim, southern Rocky Mountains, Canada: Bulletin of Canadian Petroleum Geology, v. 19, p. 557-569.
- Aitken, J.D. and Fritz, W.H., 1996, Burgess Shale project, British Columbia: Geological Survey of Canada, Paper 68-1A, p. 190-192.
- Aitken, J.D. and McIlreath, I.A., 1981, Depositional environments of the Cathedral Escarpment near Field, British Columbia, in Taylor, M.E., ed., The Cambrian System in the southern Canadian Rocky Mountains, Alberta and British Columbia: Second International Symposium on the Cambrian System, Guidebook for Field Trip 2, p. 35-44.
- Aitken, J.D. and McIlreath, I.A., 1984, The Cathedral Reef escarpment, a Cambrian great wall with humble origins: Geos. v. 13 (1), p. 17-19.
- Beales, G., Lee, J. and Ludvigsen, R., 1986, An alternative interpretation of the Middle Cambrian environment of the Burgess Shale, Yoho National Park, B.C., Canada: Society of Economic Paleontologists and Mineralogists, Annual Midyear Meeting, Abstracts, Volume III, p. 7.
- Boardman, R.S., Cheetham, A.H. and Rowell, A.J., 1987, eds., Fossil Invertebrates: Blackwell Scientific Publications, Palo Alto, p. 1-713.
- Brett, C.E., Speyer, S.E. and Baird, G.C., 1986, Storm generated sedimentary units: Tempestite proximity and event stratification in the Middle Devonian Hamilton Group of New York, in Brett, C.E., ed., Dynamic stratigraphy and depositional environments of the Hamilton group (Middle Devonian) in New York State: New York State Museum, Bulletin 457, p. 129-155.
- Briggs, D.E.G. and Robison, R.A., 1984, Exceptionally preserved nontrilobite arthropods and *Anomalocaris* from the Middle Cambrian of Utah: University of Kansas, Paleontological Contributions, Paper 111, p. 1-23.
- Conway Morris, S., 1986, The community structure of the Middle Cambrian Phyllopod Bed: Palaeontology, v. 29, p. 423-467.
- Conway Morris, S. and Robison, R.A., 1982, the enigmatic medusoids *Peytoia* and a comparison of some Cambrian biotas: Journal of Paleontology, v. 56, p. 116-122.
- Conway Morris, S. and Whittington, H.B., 1979, The animals of the Burgess Shale: Scientific American, v. 241, p. 122-133.
- Conway Morris, S. and Whittington, H.B., 1985, Fossils of the Burgess Shale, a national treasure in Yoho National Park, British Columbia: Geological Survey of Canada, Miscellaneous Report 43, p. 1-31.
- Conway Morris, S., Whittington, H.B., Briggs, D.E.G., Hughes, C.P. and Bruton, D.L., 1982, Atlas of the Burgess Shale: Palaeontological Association, London.
- Einsele, G. and Seilacher, A., 1982, eds., Cyclic and event stratification: Springer-Verlag, New York, p. 1-536.
- Fritz, W.H., 1970, Cambrian faunas, in Douglas, R.J.W., ed., Geology and Economic Minerals of Canada: Geological Survey of Canada, Economic Geology Report No. 1, p. 593-600.
- Fritz, W.H., 1971, Geologic setting of the Burgess Shale, in Proceedings of the North American Paleontological Convention, Chicago, 1969, v. 2: Allen Press, Lawrence, Kansas, p. 1155-1170.
- Kreisa, R.D., 1981, Storm-generated sedimentary structures in subtidal marine facies with examples from the middle and Upper Ordovician of southwestern Virginia: Journal of Sedimentary Petrology, v. 51, p. 823-848.
- Lochman-Balk, C. and Wilson, J.L., 1958, Cambrian biostratigraphy of North America: Journal of Paleontology, v. 32, p. 312-350.
- Ludvigsen, R., Westrop, S.R., Pratt, B.R., Tuffnell, P.A. and Young, G.A., 1986, Dual biostratigraphy: Zones and biofacies: Geoscience Canada, v. 13, p. 139-154.
- McIlreath, I.A., 1977, Accumulation of a Middle Cambrian, deep-water limestone debris apron adjacent to a vertical, submarine carbonate escarpment, southern Rocky Mountains, Canada: Society of Economic Paleontologists and Mineralogists, Special Publication 25, p. 113-124.
- McIlreath, I.A. and James, N.P., 1984, Carbonate slopes, in Walker, R.G., ed., Facies Models, Second Edition: Geological Association of Canada, Geoscience Canada Reprint Series 1, p. 245-257.

Palmer, A.R. and Halley, R.B., 1979, Physical stratigraphy and trilobite biostratigraphy of the Carrara Formation (Lower and Middle Cambrian) in the southern Great Basin: United States Geological Survey, Professional Paper 1047, p. 1-131.

Piper, D.J.W., 1972, Sediments of the Middle Cambrian Burgess Shale: *Lethaia*, v. 5, p. 169-175.

Rasetti, F., 1951, Middle Cambrian stratigraphy and faunas of the Canadian Rocky Mountains: Smithsonian Miscellaneous Collections, v. 116 (5), p. 1-277

Reader, J., 1986, The rise of life: the first 3.5 billion years: Alfred A. Knopf, New York, p. 1-192.

Robison, R.A., 1976, Middle Cambrian trilobite biostratigraphy of the Great Basin: Brigham Young University Geology Studies, v. 23, p. 93-109.

Robison, R.A., 1984, Cambrian Agnostida of North America and Greenland. Part 1, Ptychagnostidae: University of Kansas Paleontological Contributions, Paper 109, p. 1-59.

Walcott, C.D., 1911, Middle Cambrian Merostomata. Cambrian Geology and Paleontology II: Smithsonian Miscellaneous Collections, v. 57, p. 17-40.

Westrop, S.R., 1986, Taphonomic versus ecologic controls on taxonomic relative abundance patterns in tempestites: *Lethaia*, v. 19, p. 123-132

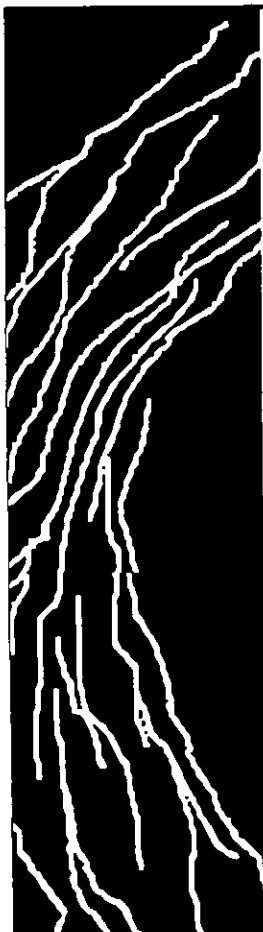
Whittington, H.B., 1971, The Burgess Shale: History of research and preservation of fossils, in Proceedings of the North American Paleontological Convention, Chicago, 1969, v. 2: Allen Press, Lawrence, Kansas, p. 1170-1201.

Whittington, H.B., 1980, The significance of the fauna of the Burgess Shale, Middle Cambrian, British Columbia: Proceedings of the Geologists' Association, v. 91, p. 127-148.

Whittington, H.B., 1985, The Burgess Shale: Yale University Press, New Haven, 151 p.

Young, G.A. and Ludvigsen, R., in press, Mid-Cambrian trilobites from the lowest Cow Head Group, western Newfoundland: Geological Survey of Canada Bulletin.

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