# A Previously Unreported Bone Bed from the Triassic Sulphur Mountain Formation of Kananaskis, and its implications for Montney sequence stratigraphy

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## Summary

A bone bed can be defined as a single sedimentary stratum with a bone concentration that is unusually dense, relative to adjacent deposits. Many diverse and striking examples have been identified in the fossil record, ranging from Ordovician to sub-Recent in age. Recent fieldwork examining outcrops along Highway 40 in Kananaskis led to the identification of a bone bed in an outcrop of lower shoreface deposits of the Triassic Sulphur Mountain Formation, an analogue to the subsurface Montney Formation. The bone bed comprises bone fragments, shark teeth and coprolites in a siltstone matrix. Some of the smaller bones are thought to belong to plesiosaurs.

The bone bed occurs as pockets of fossiliferous sediment between concretionary ribs that are around 10 cm in diameter, oriented along three distinct axes. The concretions make up a laterally extensive bed, dipping subvertically, and overlain by a thick black mudstone interval. The depositional setting is interpreted as a storm deposit that was covered by sediment, allowing cementation to take place. A subsequent transgression removed the covering sediment, exposing the concretionary layer and depositing a transgressive lag or omission surface. A further transgression led to deposition of the thick mudstone interval.

The bedding of these outcrops is subvertical, with the strike running sub-parallel to the highway. Thus individual beds can sometimes be traced for hundreds of metres. This has allowed the bone bed horizon to be tied into the stratigraphy of the lower Sulphur Mountain Formation, and incorporated into a sequence stratigraphic framework that can be correlated to the Lower Montney Formation.

## Introduction

The Canadian Rockies is famous for its outstanding scenery, and also for its oil and gas production. Outcrops ranging from Devonian to Quaternary, stretching from 400 million years to less than a million years in age, provide analogues to producing formations. Most of our knowledge regarding the Lower Triassic Montney Formation has been garnered in the subsurface, but there are excellent age equivalent outcrops, such as the Sulphur Mountain Formation, which can provide valuable data and discussion points.

The Sulphur Mountain is around 275 m in thickness, and is typically a reddish brown siltstone, which outcrops in streams in Kananaskis that follow a series of ENE/WSW trending faults that have created creeks that cut perpendicular to stratigraphy. Elsewhere it weathers into slopes that are fertile ground for native grasses, and can often be recognized by the brilliant green stripe on the landscape. The beds typically dip subvertically, younging towards the WSW. These rocks are important in that they are stratigraphically equivalent to the Montney Formation, and share many of the same sedimentological characteristics. This makes them an excellent analogue, and lessons learned from these outcrops can readily be applied in the subsurface.

The Sulphur Mountain Formation comprises a grey to rusty brown sequence of calcareous and dolomitic siltstone and sandstone, silty limestone, dolomite and shale. It is dominated by siltstone with subordinate sandstone, deposited in a proximal clastic ramp setting (Zonneveld *et al* 2016). The beds are dominated by hummocky cross-stratification (HCS), with common wave ripples, suggesting deposition in a shoreface setting. Beds often have wrinkle structures indicative of microbial mats which have stabilized the sediment. Convolute bedding may indicate storm loading or seismites (earthquake triggered mass movement), depending on bed thickness. The overall depositional setting deepens to the West, though the dominant depositional grain size remains silt grade (Zonneveld *et al* 2016).

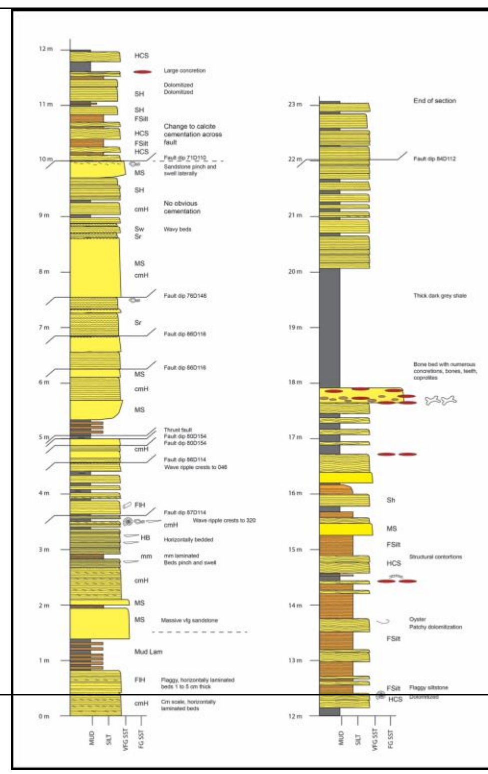
## Outcrop data

A series of logged sections were measured in creek sections exposed along Highway 40. Outcrops at Quarry Lake, in Canmore and on Mount Norquay were also examined as part of the study. The table below provides a summary of the main sedimentary structures observed at each outcrop. Note that most of the ouctcrops are faulted, and may have addiitonal low angle thrust faults that weould be difficult to discern due to the poor ouctrop quality in places.

| ***Outcrop*** | ***Thickness (m)*** | ***Succession*** | ***Interpretation*** |
|---|---|---|---|
| Norquay | 50 | Thin HCS sandstone beds with rippled tops, interbedded with | Lower shoreface tempestities |
| CANMORE | | | |
| Quarry Lake | 100 | Thicker HCS beds and gutter casts interbedded with thin mudstone beds | Middle shoreface tempestities |
| | 30 | Thinly bedded HCS or wavy laminated beds, sometimes with flutes; thick massive sandstone beds; thin mudstone beds | Debris flows, distal tempesitites and possible turbidites |
| KANANASKIS | | | |
| Grizzly Creek | 20 | Thinly bedded siltstones, some rippled, some contorted, occasional burrows; possible BCD Bouma turbidites | Montney style, aeolian sourced sediments, lower shoreface to offshore transition; seismites |
| | +/- 40 | Black shales | Offshore mudstone |
| | 10 | Grey micritic limestone, burrowed, chert nodules | Permian Ishbel Fm., shallow marine limestone |
| “Founder” Creek | 40 | Thick medium grey mudstone interval; HCS sandstone beds thicken up then thin up | Delta/depositional lobe switching |
| | 40 | Thicker stacked HCS sandstone beds; some beds show foundering | Middle shoreface tempestites; seismically triggered gravity flows |

| *Outcrop* | *Thickness (m)* | *Succession* | *Interpretation* |
|---|---|---|---|
| KANANASKIS (continued) | | | |
| Bedding plane | 10 | Siltsone with HCS, bedding planes have wave ripples, microbial mats, ammonites | Middle shoreface tempestities |
| Hood Creek | 15 | Thick HCS sandstone beds | Overall coarsening upward, with possible sequence boundary (Zonneveld and Moslow) |
| Hood Creek South | 10 | Thin HCS sandstone beds and interbedded mudstone beds | Lower shoreface tempestites |
| | 2 | Bone bed and concretionary bed capped by thick black mudstone | Transgressive sequence |
| | 8 | Thicker dolomitized, HCS sandstone beds and interbedded wavy laminated siltstone beds | Middle shoreface tempestities |
| | 10 | Thin HCS sandstoned and interbedded mudstone beds | Lower shoreface tempestites |

**The Bone Bed**



| | |
|---|---|
| Outcrop photograph showing the linear concretions, between which the pockets of bone bed material can be observed. | |

The genesis of the bone bed is certainly complex. Its presence between the concretionary “ribs” Is telling. The concretions must have formed beneath the surface of the seabed, possibly through cementation of *Thalassinoides* burrows, or due to cementation along structural trends. Subsequent erosion exposed the concretions at the seabed, and the bone bed material filled the pockets between the concretions. None of the concretions contain any bone bed material, suggesting that they formed prior to bone bed deposition. The vertebrate material and coprolites may have accumulated as a trangressive lag, or on an omission surface, before a subsequent transgression smothered the bone bed in thick mudstone beds.

## Applying a sequence stratigraphic framework to the Montney Formation

The outcrops of the Sulphur Mountain have been amalgamated to build up a general relative sea level curve, which can then be compared to published curves erected for the Montney Formation.

## Conclusions

The Sulphur Mountain Formation provides an important outcrop analogue to the subsurface Montney Formation. The newly recognized Triassic bone bed is of great academic interest, and can be correlated to a significant surface within the Lower Montney Formation. The bone bed merits further study on:

- the faunal contents
- its lateral extent
- its detailed sedimentological analysis


## Acknowledgements

I would like to acknowledge previous workers on the Sulphur Mountain Formation including J-P Zonneveld, Tom Moslow, Graham Davies and others.


#### References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