CABS CENTRE FOR APPLIED BASIN STUDIES

UNIVERSITY OF CALGARY

The Lower Triassic Sulphur Mountain (Montney) Formation, Mount Crum Section, east-central British Columbia:

AGE OF TURBIDITES, TECTONIC IMPLICATION AND MONTNEY LITHOFACIES INTERPRETATION

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ABSTRACT

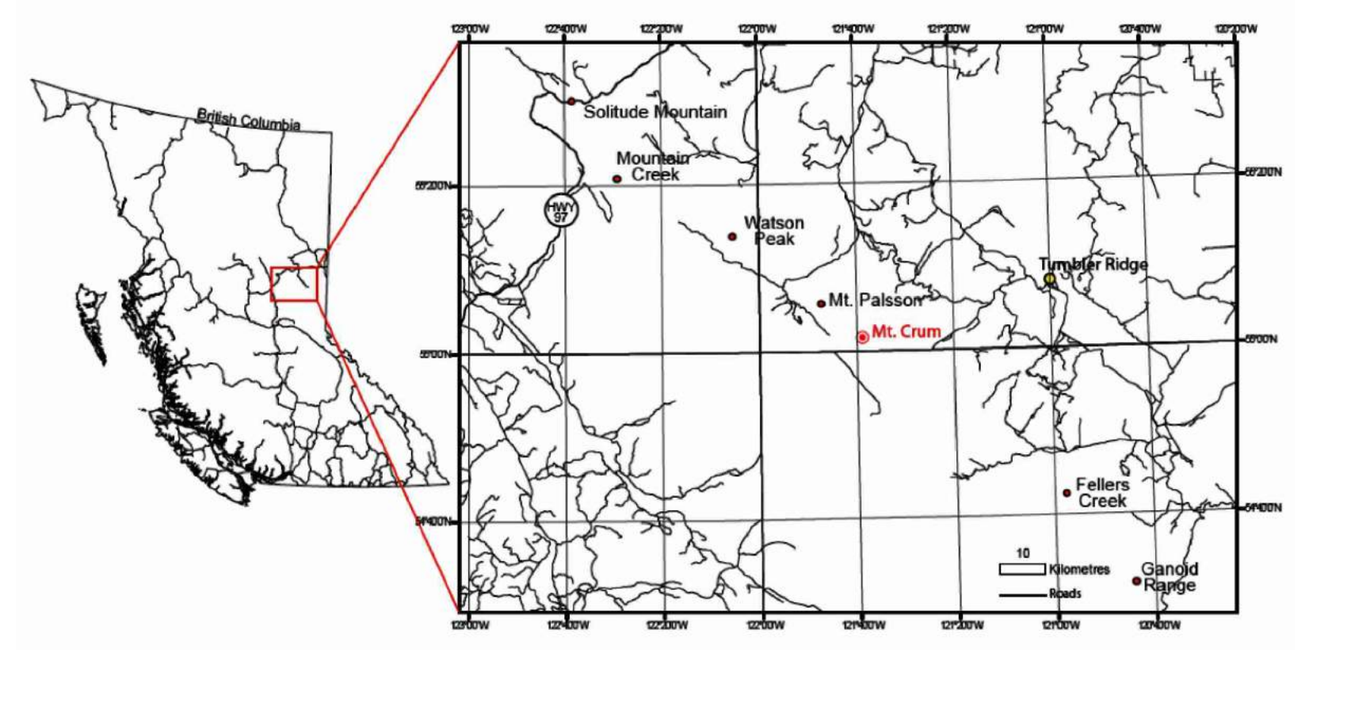
Turbidite successions of Lower Triassic strata (base of Montney Formation) in northeast British Columbia are variable in depositional trends and age. There are three proven turbidite stratigraphic levels and a fourth predicted from sequence stratigraphy. Sedimentation of each of these turbidite units is influenced by underlying structural elements and the Paleozoic unconformity immediately below lowermost Triassic rocks.

At the Mount Crum area, turbidites are not present. The area was structurally high during earliest Triassic time due to continued or renewed influence of the Sukunka Uplift. Preliminary analysis using isotopes and conodont biostratigraphy show that turbidite facies are diachronous from west-central Alberta to northeast British Columbia (work in progress; Orchard and Zonneveld, 2009; Kendall, 1999). Correlation of conodont biostratigraphy with $\delta^{13}C_{carb}$ values adds further insights into the paleostructural, age interpretation and facies relationships of the lowermost Triassic. A sharp positive excursion of $\delta^{13}C_{carb}$ value denotes the late Dienerian and a negative excursion represents the Smithian as determined by conodont biostratigraphy.

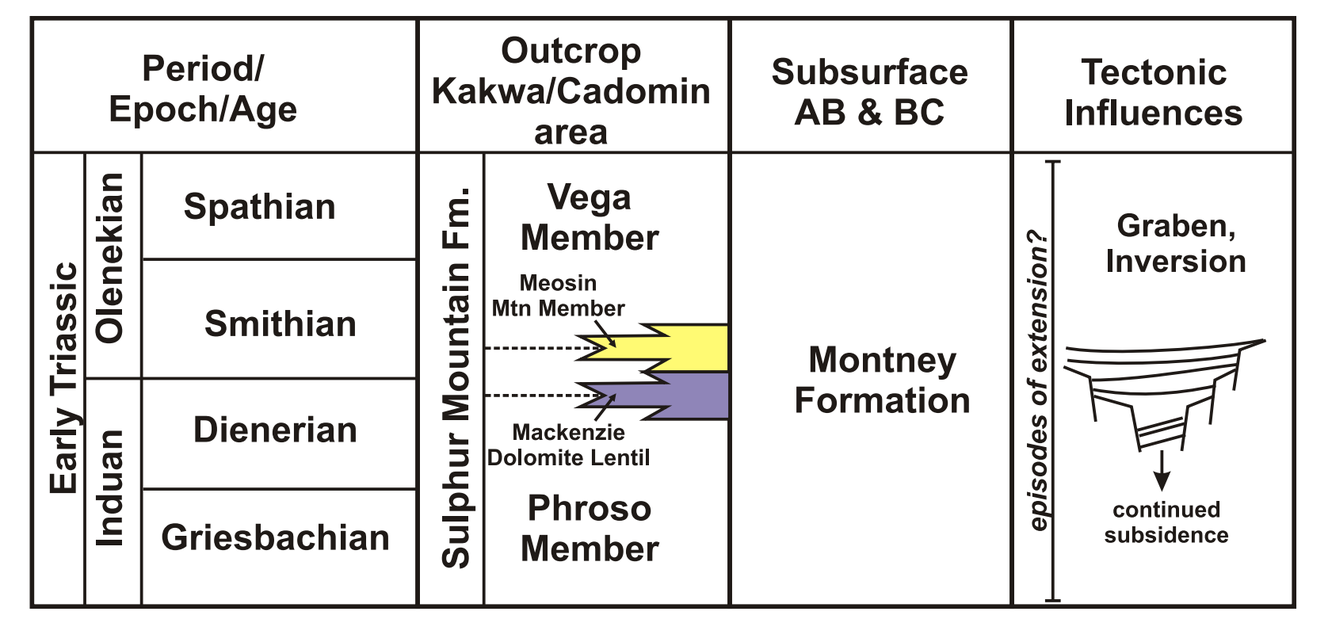
Lithofacies of the Mount Crum section show striking similarities with the Montney. Laminated siltstone is the dominant lithofacies of the Mount Crum section; it is dolomitic and feldspathic, with abundant muscovite and framboidal pyrite, with variable clay content similar to the Montney Formation. The other prominent lithologic component of the Mount Crum section are large limestone or calcareous nodules that show differential compaction of siltstones around them indicating early diagenetic emplacement of the calcite cement (similar to Montney calcite nodules). Internally, the nodules preserve abundant calcispheres, some with high concentrations of bivalve fragments. Rock-eval T_{max} data indicate inhomogenoues thermal exposures between the nodules and the surrounding siltstone. A single sample from one of the nodules also reveals conodonts with colour alteration index of 1.5 and 3.0.

Data collected in the east-central British Columbia region will provide a coherent framework that enhances our understanding of the Lower Triassic Montney successions. This will help lead to a better exploration strategy of the Montney tight gas play in the region.

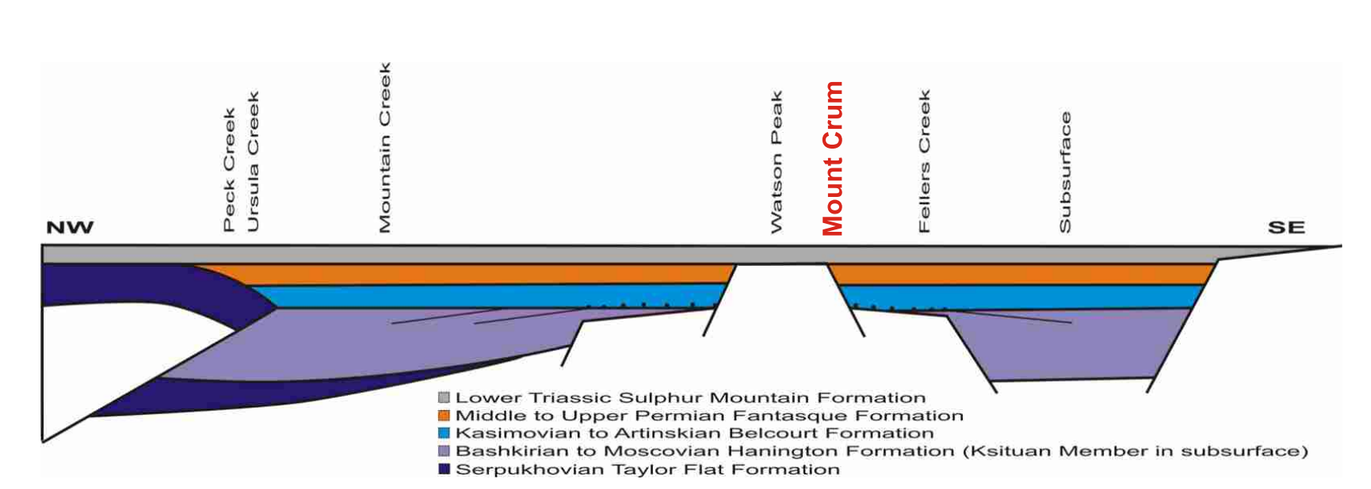
GEOLOGIC SETTING



Location of study area in east-central British Columbia. Mount Crum section is depicted in red



Stratigraphic framework of Lower Triassic for the study area. It consists of Sulphur Mountain Formation, which is equivalent to the Montney in the subsurface. The Sulphur Mountain is now divided into three members: the Phroso Member of mainly Griesbachian/Dienerian age in the lower part of the section, the Smithian/ Spathian Vega Member in the upper part of the formation, and the newly defined Meosin Mountain Member in the early to mid-Smithian (Orchard and Zonneveld, 2009). Active faulting during the Early Triassic, probably with a strong strike-slip component, influenced Montney deposition.

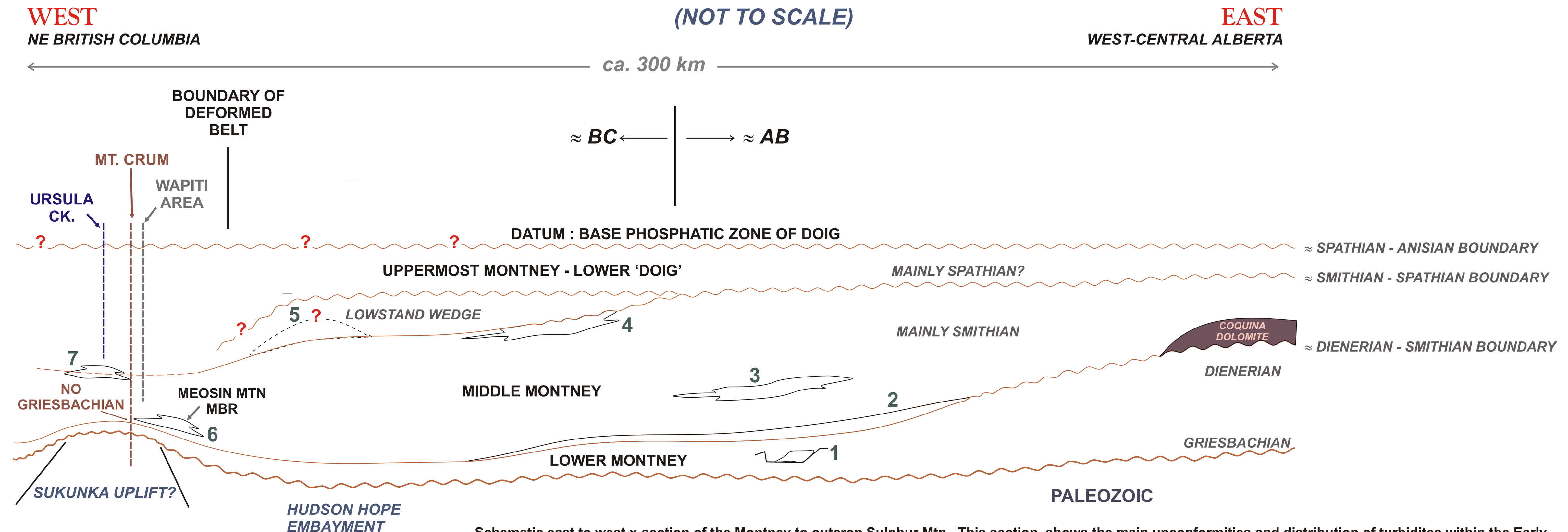


This diagram shows the location of the Mt. Crum section relative to the Sukunka Uplift. It shows that in this area, the Sulphur Mtn Fm overlies a structural high underlain by the Middle to Upper Permian Fantasque Formation. At this section, Griesbachian is missing, with Dienerian conodonts within 0 to 0.15 cm of the Paleozoic Unconformity. This data adds further significance to the role of the Sukunka Uplift as influencing early Triassic sedimentation within the Western Canada Sedimentary Basin (with implications of paleoslope to the east). Diagram is from Henderson *et al* (2010).

AGE OF TURBIDITES - REGIONAL CORRELATION

SCHEMATIC LOWER TRIASSIC SECTION, WITH MAJOR SEQUENCE BOUNDARIES, TURBIDITES

(NOT TO SCALE)



MONTNEY TURBIDITE : APPROX. AGES
(Davies, 1997; G.R.Davies, pers.comm., 2010; Moslow & Davies, 1997)
1. Dixonville-Glacier type : Late Dienerian?
2. Sexsmith-Valhalla type : latest Dienerian / Dienerian-Smithian boundary
3. Boundary Lake type: Early to mid-Smithian
4. Flatrock type : Late Smithian?/Early Spathian?
5. Lowstand Fan type (projected) : latest Smithian / Early Spathian?

LOWER TRIASSIC TURBIDITE : OUTCROP EXPOSURE
6. Meosin Mtn : Orchard & Zonneveld (2009) - Early- to mid-Smthian
7. Ursula Creek : Zonneveld & Henderson (1998) - Late Smithian - Early Spathian

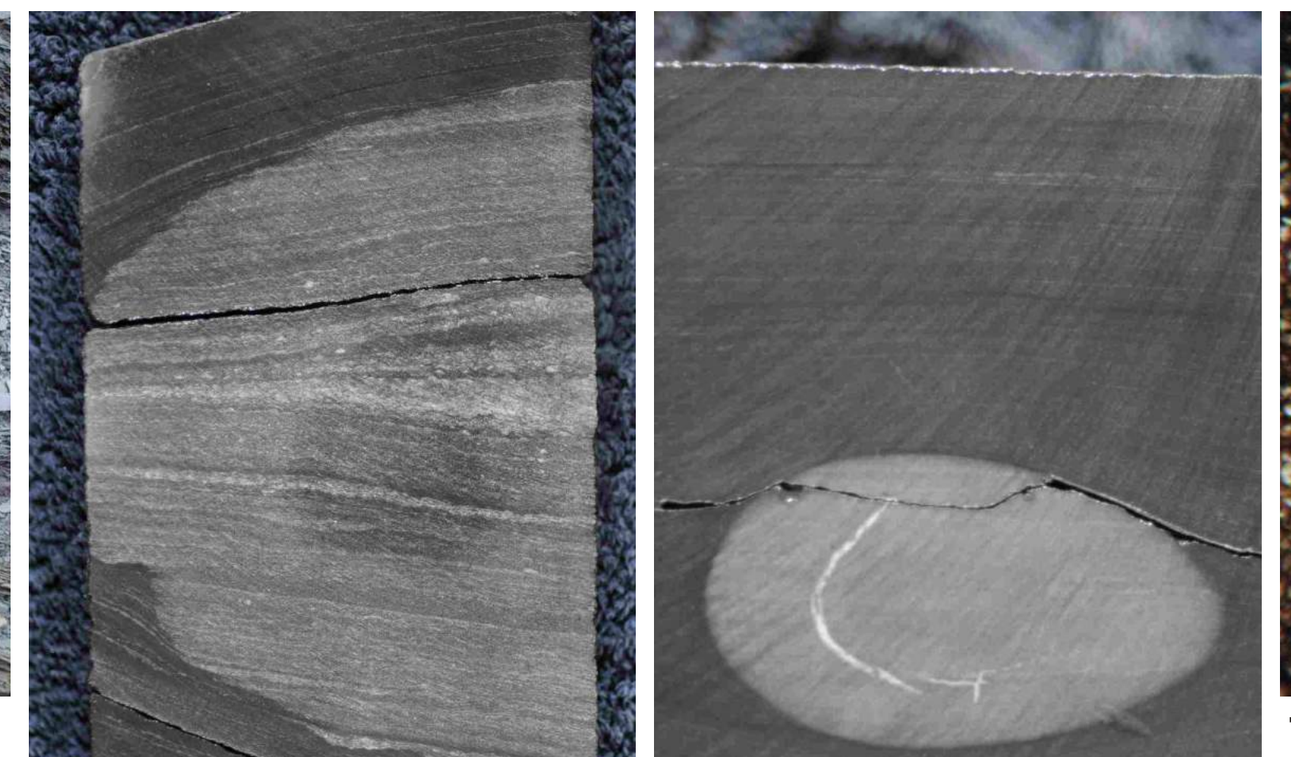
Schematic east to west x-section of the Montney to outcrop Sulphur Mtn. This section shows the main unconformities and distribution of turbidites within the Early Triassic, based on various sources. Also note that the main coquina dolomite unit at the Dinerian-Smithian boundary in the subsurface of Alberta is interpreted to be equivalent to the MacKenzie dolomite Lentil.

Age assignment of Montney turbidites are based on framework outlined by Davies (1997), Moslow & Davies (1997), and G.R. Davies (pers comm., 2010). It was initially based on palynology; some supported by conodont data, while some age assignments are based on their position in stratigraphic levels within global third-order sequence boundary.

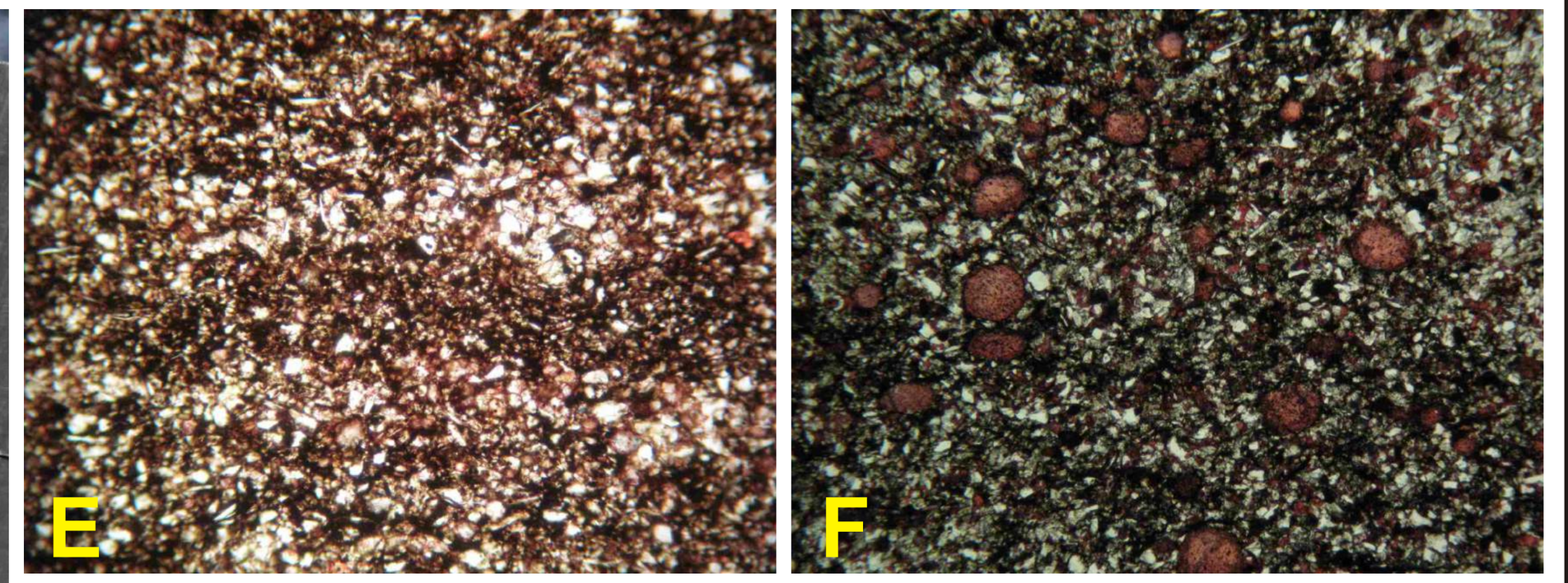
There are at least three distinct levels of turbidites (or may be more!). Structure plays a major role in their localization, thus age of their deposition is going to be influenced by intra-Triassic structural event.

MONTNEY LITHOFACIES COMPARISONS

Field photos of Mount Crum. Photo A shows the overall general lithology in this section, which is composed mainly of (black) subfissile, finely laminated to very thin-bedded fine to medium, shaley siltstone. Photo B shows carbonate nodules within the siltstone host. Gamma reading from this outcrop shows a coarsening-up profile over the first 60 m of section, with an indistinct "cleaning-up" or slightly upward-decreasing trend. The lower Montney is dominantly siltstone, with a similar irregular, but overall 'cleaning-up' gamma log profile (G.R. Davies, pers. comm., 2010). The entire outcrop has a fetid smell.



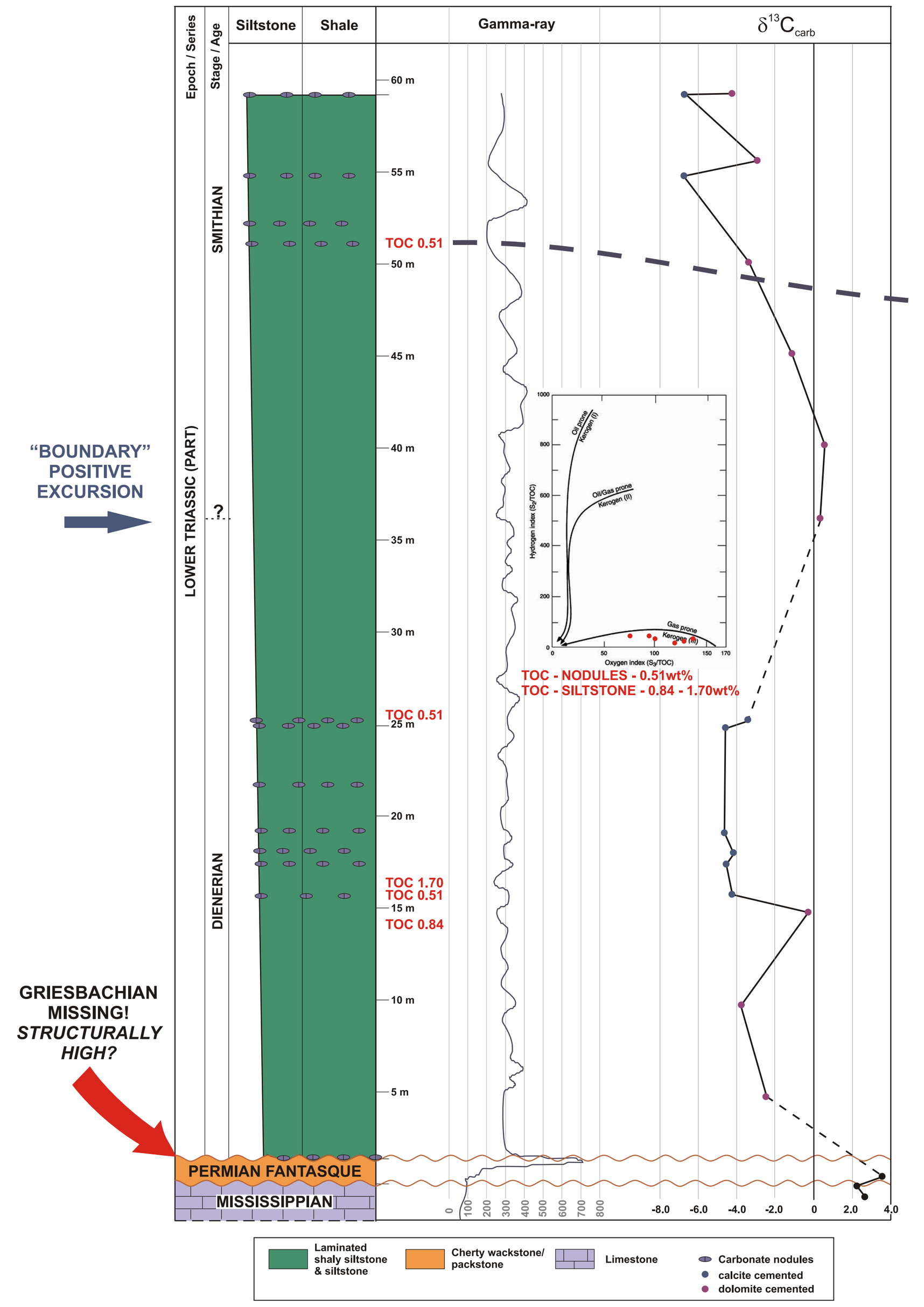
Calcite nodules in Montney core (Photos C & D) showing differential compaction of siltstones around them - indicating early diagenetic emplacement of calcite cement.



Thin-section photos of Mount Crum. Compositionally, the Mount Crum siltstone (Photo E) succession is very dolomitic and feldspathic, with high detrital muscovite mica, authigenic framboidal pyrite, and black, organic intergranular matrix. In all of these components, the Mount Crum siltstone is identical to the subsurface lower Montney, although grain size is slightly finer. Similar to Montney calcite nodules, Mount Crum nodules (Photo F) also preserve abundant calcispheres, some with high concentrations of bivalve fragments. Calcispheres may record the occurrence of algal blooms associated with coastal upwelling.

AGE, STRUCTURAL IMPLICATION, LITHOFACIES INTERPRETATION :

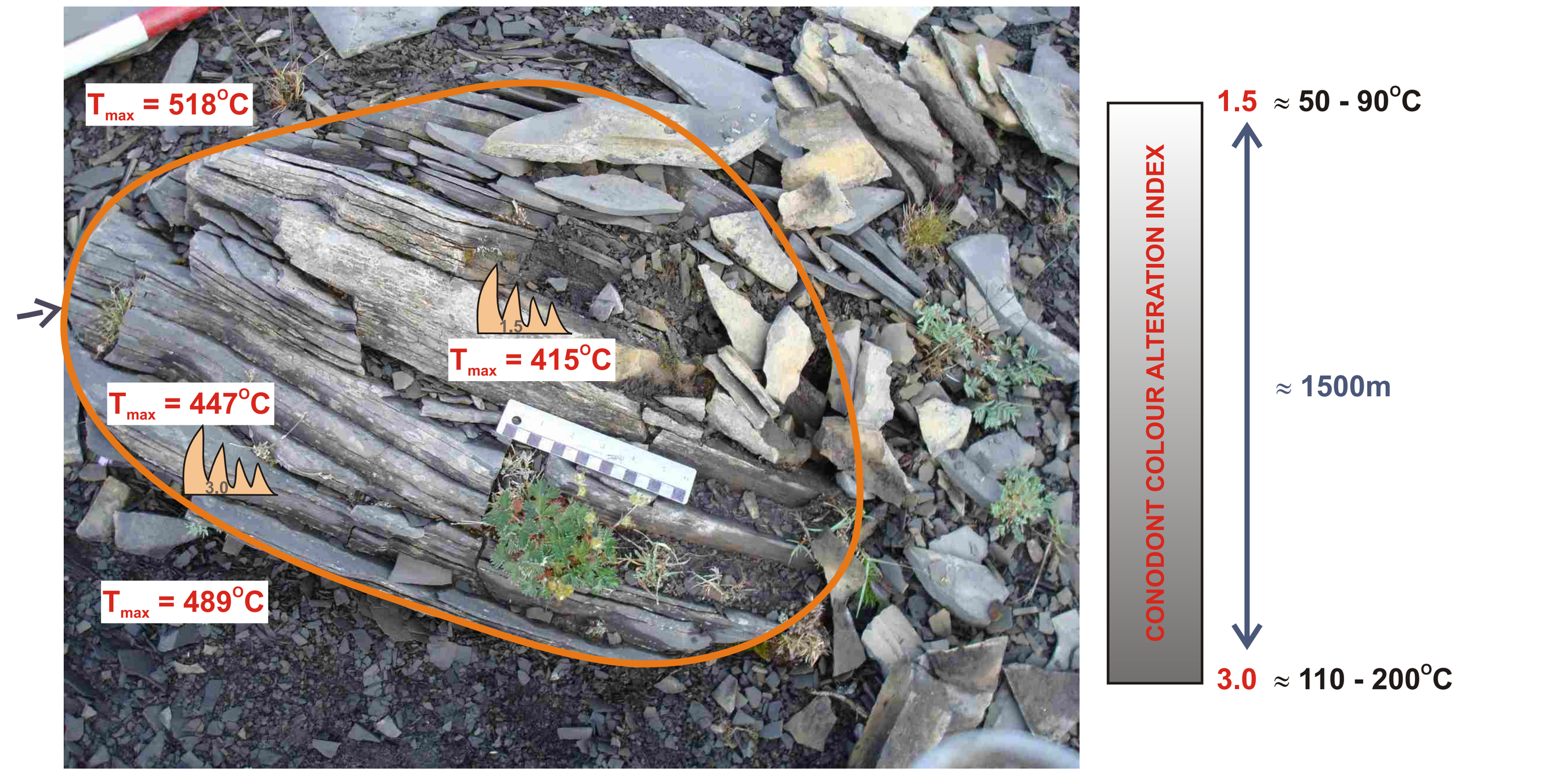
INHOMOGENEOUS THERMAL EXPOSURE OF EARLY DIAGENETIC CALCITE CONCRETIONS



Stratigraphic column of the lower 60 m of the Sulphur Mountain Formation at Mount Crum showing an indistinct coarsening-up profile over the first 60 m of section. This is confirmed in the gamma-ray profile that shows an indistinct "cleaning-up" or slightly upward-decreasing trend.

Conodonts extracted from a sample at the base of the Mount Crum section 0 – 0.15 cm above the top of the Paleozoic include *Neospathodus* sp. indet. and reworked fragments, indicating a probable upper Induan (Dienerian) age. The carbon isotopic composition ($\delta^{13}C_{carb}$) of this section shows a negative carbon isotopic excursion with a range of values between 0.5‰ to -6.8‰ that correlates with a similar trend as seen in the Early to Middle Triassic $\delta^{13}C_{carb}$ profile of Payne *et al.*, (2004). The peak of a positive excursion is correlated with the Dienerian-Smithian boundary based on comparison with the profile from Payne *et al.*, (2004).

The implications of these age assignments and tectonostratigraphy in the Mount Crum section are that the Griesbachian is not present, and thus the Mount Crum area was structurally high until about early Dienerian time. Turbidites are not present in the Mount Crum section; their absence plus the increased carbonate content is indicative of relatively slow (condensed) siliciclastic sedimentation away from a major direct clastic source. The Montney in the subsurface of NE BC also shows increased carbonate content in deeper, condensed settings (G. R. Davies, pers. comm., 2010).



Annotated field photo showing that the centre of a nodule has a T_{max} value of 415°C, the outer rim of the nodule has a T_{max} of 447°C, and the surrounding siltstone with T_{max} of 489°C. Difference in conodonts Colour Alteration Index (CAI) values within the nodule is also shown here. The difference in thermal maturity within the nodule is supported by the CAI values of 1.5 and 3.0.

The CAI difference represents a variation in temperature from 50 to 90°C for the 1.5 index to 110 to 200°C for the 3.0 index, which is calculated to represent about 1500m of burial depth difference.

Obviously, the nodules and the siltstone host have undergone the same degree of burial and thermal history. **Why isn't everything homogenized?**

The biggest difference, at least at first sight, is that the calcite nodules were the locus of very early calcite cementation - giving a very tight, low porosity low permeability fabric. Secondly, calcite has relatively low thermal conductivity. These factors could play a role in this thermal anomaly.

There are at least two ways of looking at this.
(1) the siltstone surrounding the nodule is anomalously hotter - Diagram A; (2) the inside of the nodule is anomalously cooler than the siltstone host - Diagram B

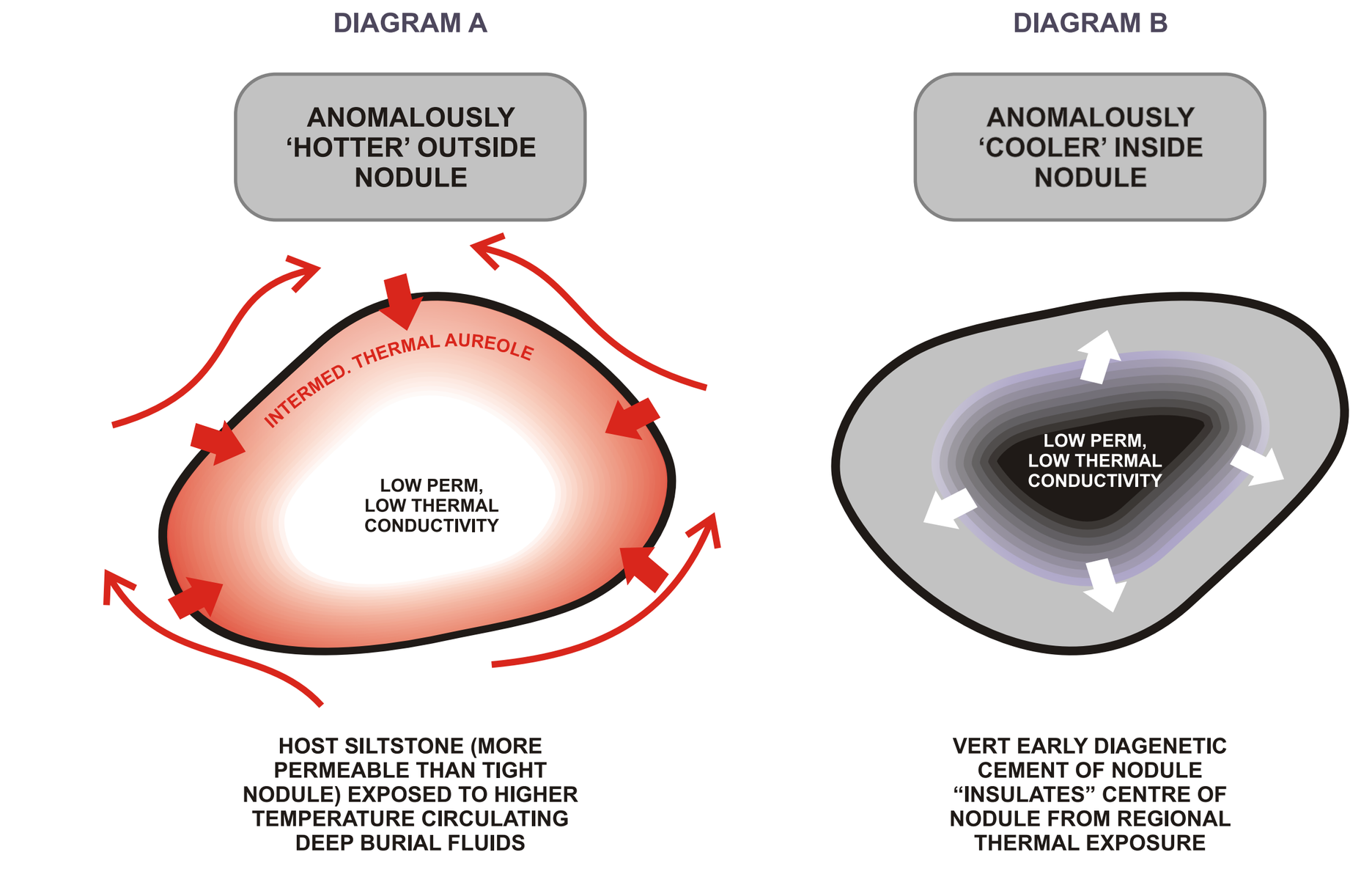


Diagram A shows the tight, low permeability nodule surrounded by more permeable siltstone in which hotter fluids may have circulated, contributing to higher thermal exposure of the siltstone and formation of a aureole or outer zone of intermediate thermal exposure around the rim of the nodule.

Diagram B suggests that the very low permeability of calcite nodules with its low thermal conductivity has operated as a closed diagenetic system with the calcite acting as a insulating blanket.

IMPLICATION

In the Montney, there appears to be a close tie between higher TOC values and higher calcite content with increased log resistivity. There is a strong suggestions that the early calcite cement, including nodules protect or insulate enclosed kerogen and reduced the degree of thermal alteration of this kerogen compared with kerogen in the surrounding siltstone (G.R. Davies, pers. comm., 2010)

CURRENT RESEARCH

STRONTIUM GEOCHRONOLOGY
+ ISOTOPE GEOCHEMISTRY
+ CONODONT BIOSTRATIGRAPHY = ^(High resolution) CORRELATION TOOL

The strontium isotopic signature of conodonts (and possibly other phosphatic materials?), compared to global secular seawater Sr isotopic curve may provide age constraints to Lower Triassic deposition and variation in timing of turbidite deposition. To confirm the Sr-conodont to Sr-seawater correlation, the relative age of conodonts obtained from conodont biostratigraphy is used. If this Sr-conodont to Sr-seawater to age-of-conodonts relation can be established successfully, this technique can be applied to other forms of sedimentary phosphate, skeletal phosphate (including bone fragments) and apatite cement, which are quite abundant in the subsurface and probably in outcrop. If such correlation could be established, it would be of great significance for providing higher resolution correlation of Early Triassic depositional units.

ONGOING WORK & RESEARCH FOCUS

My research focuses on age interpretation of regional turbidite successions, the role of paleostructure controls on timing and trends of deposition and facies variations and relationships of lowermost Triassic rocks.

Specific objectives include regional correlation of turbidite successions in the study area using a combination of sedimentologic, biostratigraphic and geochemical techniques - application of strontium isotopic signature of conodonts, stable isotope analysis, organic geochemical typing, and conodont biostratigraphy - are integral to achieving a high resolution correlation of turbidite facies.

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REFERENCES

Davies, G.R., 1997, The Triassic of the Western Canada Sedimentary Basin: Tectonic and Stratigraphic Framework, Paleogeography, Paleoclimate and Biota. Bulltein of Canadian Petroleum Geology, 45(4): 434-460.

Henderson, C.M., Zubin-Stathopolous, K., Dean. G., Spratt, D. and Chau, Y.P., 2010, Tectonic History, Biostratigraphy and Fracture Analysis of Upper Paleozoic and Lowest Triassic Strata of East-Central British Columbia (NTS 093I, O, P): Preliminary Report, in Geoscience BC Summary of Activity 2009, Geoscience BC, Report 2010, p.259-270.

Kendall, D.R., 1999, Sedimentology and Stratigraphy of the Lower Triassic Montney Formation, Peace River Basin, Subsurface of Northwestern Alberta: MSc thesis, University of Calgary, 367 pp.

Orchard, M.J. and Zonneveld, J.P., 2009, The Lower Triassic Sulphur Mountain Formation in the Wapiti Lake area: lithostratigraphy, conodont biostratigraphy, and a new biozonation for the lower Olenekian (Smithian). Canadian Journal of Earth Science, 46(10): 757-790.

Payne, J.L, Lehrmann, D.J., Wei, J., Orchard, M.J., Schrag, D.P. and Knoll, A.H., 2004, Large Perturbations of the Carbon Cycle During Recovery from the End-Permian Extinction. Science, 305: 506-509.

Richards, B.C., 1989, Upper Kaskasia Sequence: Uppermost Devonian and Lower Carboniferous. In: Western Canada Sedimentary Basin – a Case History. B.D. Ricketts (ed.). Canadian Society of Petroleum Geologists, Special Publication No. 30, 164-201.

Utting, J., Goodarzi, F., Dougherty, B.J. and Henderson, C.M., 1989, Thermal Maturity of Carboniferous and Permian Rocks of the Sverdrup Basin, Canadian Arctic Archipelago: Geological Survey of Canada, Paper 89-19.

Zonneveld, J.P. and Henderson, C.M., 1998, Sequence stratigraphic and depositional framework of the Lower-Middle Triassic succession, Williston Lake, NE British Columbia, Field Trip Guidebook, Geo-Triad 98 convention, p. 75.