The Biostratigraphy and Evolution of a Pennsylvanian-Permian Carbonate Ramp, East-central British Columbia

K. D. Zubin-Stathopoulos*
University of Calgary, Calgary, Alberta
kdzubins@uclagary.ca

C. M. Henderson
University of Calgary, Calgary, Alberta

and

B. Beauchamp
University of Calgary, Calgary, Alberta

1. Introduction

A carbonate succession in east-central British Columbia in the Sukunka-Kakwa area is characterized by oolitic and bioclastic shoals, shallow ramp and restricted inner ramp deposits. These carbonate deposits are interstratified with several conglomerates that are interpreted to represent erosion linked with tectonic activity (Henderson *et al.,* 2010). This study uses biostratigraphy to constrain the timing of climatic and tectonic events documented by this carbonate succession. The detailed carbonate petrology of this succession shows faunal and rock fabric changes that provide a window into the changing depositional environments during the Pennsylvanian-Permian along the north-western margin of Pangea. The most representative section in the study area is Fellers Creek (Figure 1), which provides an example of the major units found in east-central British Columbia.

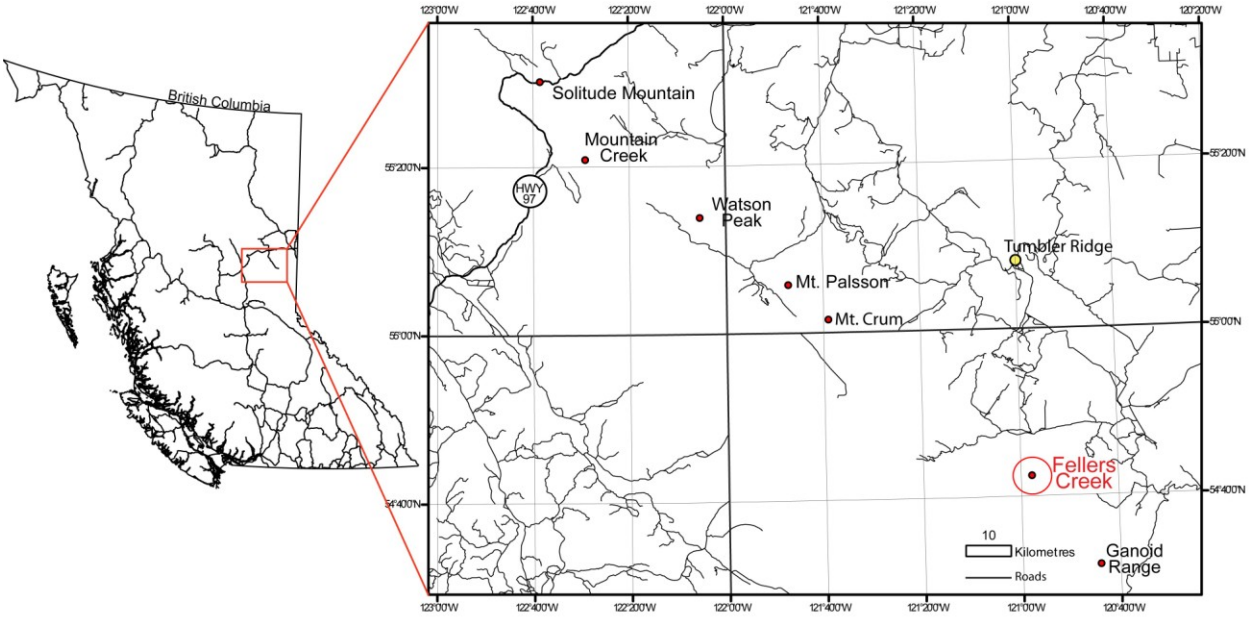

Figure 1: Location map showing all studied outcrops within the area with Fellers Creek highlighted. Modified from Henderson *et al.,* 2010.

2. Biostratigraphy

Conodont biostratigraphy indicates Moscovian (Pennsylvanian), Asselian and Sakmarian (Permian) successions of the Belcourt Formation and Capitanian of the Fantasque Formation at Fellers Creek. Asselian fauna includes *Streptognathodus verus* and *Adetognathus spp.* including *A. cf. paralautus*. Sakmarian taxa include transitional forms of *Sweetognathus merrilli*, *S. binodosus,* and *S. anceps*. *Mesogondolella bitteri* indicates a Capitanian age at the top of the section. In addition to the conodont biostratigraphy, fusulinid and endothyrid biostratigraphy was used to augment the conodont ages. The age for the base of Fellers Creek was confirmed as Late *Viséan* (Mississippian) based on *Eoendothyranopsis sp*. and *Globoendothyra sp.* The first conglomerate (Figure 2, ~27 m) marks the base of the Belcourt Formation and was thought to be Permian in age (Bamber and Macqueen, 1979), but is now known to be Pennsylvanian (Henderson *et al*., 2010). Based on the occurrence of *Pseudofusulinella sp.* and *Pseudostafella sp*. above the basal conglomerate, the Upper Moscovian (Pennsylvanian) is assigned to this unit.

This biostratigraphy constrains the timing and duration of unconformities. The base of the Belcourt Formation is regionally marked by a conglomerate, which represents erosion related to tectonic activity. Several other conglomerates in this section probably mark similar events. These tectonic events may be equivalent to events recorded in rocks in Nevada, termed as C1-C6 and P1-P5 unconformities associated with tectonism between the Antler and Sonoma orogenies (Trexler *et al*., 2004). A Middle Pennsylvanian unconformity (C5 or C6) in Nevada closely correlates with the basal conglomerate at Fellers Creek. The next conglomerate at the approximate boundary between the Pennsylvanian and Lower Permian correlates with the P1 unconformity seen in Nevada. It appears that the Artinskian and Kungurian stages (Permian) are missing from Fellers Creek, representing the P3 and P4 unconformities.

3. Sedimentology and Paleoclimate

The Belcourt Formation at this section includes ooid grainstone, bioclastic grainstone and packstone, algal-foraminifer grainstone, echinoderm-bryozoan wackestone and packstone, wrinkly laminated dolomitic mudstone and one facies containing sponge spicules and minor algae. The Fantasque Formation consists of chert and phosphate nodules within a carbonate matrix at the base, grades into a brachiopod packstone with minor amounts of quartz grains, into fine sandstone at the top.

Overall, this carbonate package was predominantly deposited within a shoal. Moscovian deposits include a bryonoderm-extended association representing a cool water fauna with some warm water components, most likely deposited on the mid-upper slope. An Asselian shoal is composed of ooids, fusulinids and echinoderms, representing a chloroforam association indicating a warm water assemblage (Beauchamp and Desrochers, 1997). The oolitic shoals were probably subaerially exposed as recognized by the presence of *Microcodium*. These warm water deposits grade into a bryonoderm-extended association (cool water) forming bioclastic shoals and restricted back-reef deposits. Warmer water deposits are again seen in the Sakmarian with algal-foraminifer grainstones deposited in a high-energy environment close to a shoal. The Fantasque Formation also contains brachiopod packstone (bryonoderm) that represents deposition in cool water.

The change from a warm to cool water biotic and abiotic assemblage correlates with a similar record in the Canadian Arctic, where a faunal turnover is initiated in the Late Asselian (Wamsteeker, 2009). Warm water associations (chloroforam) were restricted to very shallow environments and only cold water deposits were seen by the latest Permian (Beauchamp and Desrochers, 1997). At Fellers Creek there is a marked shift in deposits from a chloroforam to a bryonoderm-extended association during the middle Asselian, though a chloroforam association returns by the Sakmarian. Wamsteeker (2009) provides evidence suggesting that chloroforam

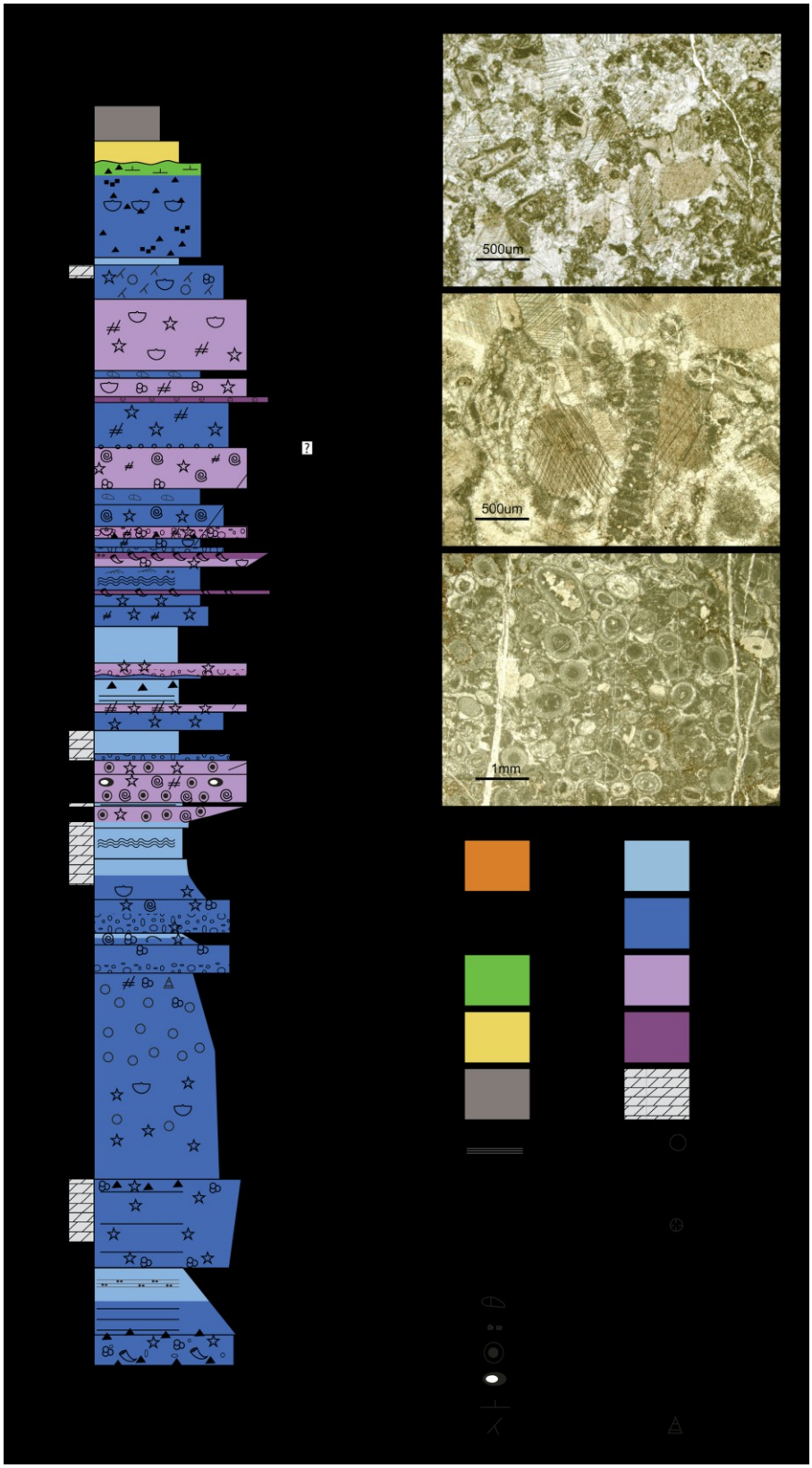

Figure 2: Lithostratigraphic column with formations and stages based on biostratigraphy. Lithology photos from bottom: ooid grainstone (shoal) in the chloroforam association, dasycladacean-echinoderm grainstone in the chloroforam association and bryozoan-echinoderm grainstone in the bryonoderm-extended association. SM=Sulphur Mt. Formation, In=Induan, Tr=Triassic.

assemblage refuges were found in proximal sub-basins of the Canadian Arctic. It was interpreted that this shift in deposits is due to changing oceanic circulation, and more specifically upwelling (Wamsteeker, 2009). A change in upwelling intensity may explain the observed shifts in biotic assemblages at Fellers Creek.
Active tectonics in the study area during this time interval could be linked to the Sakmarian re-occurrence of warm water fauna. Correlative units south of the study area, for example the Johnston Canyon Formation, are predominantly cool water deposits. This difference in temperature may be a result of the presence of cold, upwelling waters that influenced the Johnston Canyon Formation in the south, but did not reach the Belcourt Formation as it may have been protected by local topographic highs (Henderson *et al*., 2002; Dunn, 2004).

4. Petroleum Potential

A better understanding of these carbonate ramp deposits will further constrain the hydrocarbon bearing facies. The Pennsylvanian portion of the Belcourt Formation is equivalent to the Ksituan member, an important gas play. The Permian portion of Belcourt Formation is equivalent to the Lower Belloy and the Fantasque is equivalent to the Upper Belloy; both units are known hydrocarbon targets in the subsurface (Dunn, 2004).

5. Conclusions

This study constrains the timing of paleoclimatic and tectonic events that affected the depositional environment at Fellers Creek. The timing of tectonic events recorded at Fellers Creek correlates with those described by Trexler *et al*., (2004) from Nevada. This study extends a shift in ocean circulation first recognized in the Canadian Arctic for the Sakmarian along the northwest margin of Pangea. These paleo-reconstructions will become more complete with the addition of data from other outcrops within the study area.

Acknowledgements

The fieldwork for this study was financially supported by Geoscience BC and Talisman Energy. In addition, research for this project was supported by a Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery Grant.

References

Bamber, E.W. and Macqueen, R.W. 1979. Upper Carboniferous and Permian stratigraphy of the Monkman Pass and southern Pine Pass areas, northeastern British Columbia: Geological Survey Bulletin, p. 301, 1-26.

Beauchamp, B. and Desrochers, A. 1997. Permian warm-to very cold-water carbonates and cherts in northwest Pangea: Society for Sedimentary Geology Special Publication, 56, p. 327-347.

Beauchamp, B. 1994. Permian climatic cooling in the Canadian Arctic, in: Klein, G.D., ed., Pangea: Paleoclimate, tectonics and sedimentation during accretion, zenith and break-up of a super-continent, 288, p. 229-246.

Dunn, L. 2003. Sequence biostratigraphy and depositional modeling of the Pennsylvanian-Permian Belloy Formation, northwest Alberta and northeast British Columbia: unpublished Ph.D. thesis, University of Calgary, 316pp.

Henderson, C.M., Zubin-Stathopoulos, 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 Activities 2009, Geoscience BC, Report 2010-1, p. 259–270.

Henderson , C.M., Fossenier, K., Dunn, L. and Moore, D. 2002. Sequence Biostratigraphy and Paleogeography of the Pennsylvanian-Permian Belloy Formation and outcrop Equivalents in Western Canada: Carboniferous and Permian of the World, XIV International Congress of the Carboniferous and Permian: CSPG Memoir 19, p. 934-947.

Trexler, J.H., Cashman, P.H., Snyder, W.S. and Davydov, V.L. 2004. Late Paleozoic tectonism in Nevada: Timing, kinematics, and tectonic significance: GSA Bulletin, 116(5/6), p. 525-538.

Wamsteeker, M.L. 2009. Sequence stratigraphy, conodont biostratigraphy and sedimentology of Lower Permian strata of the Fosheim-Hamilton sub-basin, Sverdrup Basin, Ellesmere Island: unpublished M.Sc theis, University of Calgary, 309pp.