geoconvention
Calgary • Canada • May 12-14 2025

The Lower Cambrian Gog Group of the southern Canadian Rockies: Its role as an outcrop analogue of CCS Reservoirs in Alberta

Patricio Desjardins
Shell International Exploration and Production

Introduction

Shallow-marine sandstones of the Gog Group in the southern Rocky Mountains are part of extensive siliciclastic deposits that rimmed the ancient continental margin of Western Canada during the early Cambrian (Desjardins et al., 2010a). These deposits, notable for their extraordinarily large quantities of sand, were laid down on a broad, low-relief, and low-gradient continental shelf, influenced by high accommodation rates driven by thermal subsidence and global sea-level rise. The Cambrian transgression persisted into the middle Cambrian, with the Basal Sandstone Unit ('BCS') in the Southern and Central Plains recording the basin's expansion into the cratonic interior (eastward) due to rising sea levels. This unit is extensively developed in the subsurface of the foothills and plains, where it lies unconformably on crystalline Precambrian rocks of the Canadian Shield, reaching as far north as approximately 54° N latitude in Alberta and Saskatchewan, and extending into southwestern Manitoba (Slind et al., 1994). In recent years, Cambrian sandstones in the subsurface of North America have gain significant research and commercial interest due to its potential for CO2 storage and as an emerging helium play.

Objective, Area of Study and Methods

This study focuses on comparing, relating, and integrating the sedimentary facies and stratal architecture of outcrops of the Gog Group in the Canadian Rockies with core descriptions of the 'BCS' CO2 reservoir at Shell's Quest Project in Alberta. Field geology allowed to describe geological features providing precise measurements and characterization of lithofacies, environments of deposition, and geobodies' dimensions and shapes. On the other hand, core descriptions provided an accurate record of lithological, structural, sedimentary, pore system and diagenetic features. By integrating core descriptions at Quest with outcrop studies in the Gog Group, we attempt to elevate our understanding of the vertical and spatial variability of the 'BCS' Alberta to enable the construction of robust and reliable subsurface models to help manage uncertainty and risk.

Results

In the following paragraphs, we present a few examples of how the Gog Group was used as an outcrop analogue for the 'BCS'; however, this is not an exhaustive list.
The Fort Mountain Formation is considered the is the best outcrop analogue to highlight the vertical stacking pattern of the 'BCS' in the subsurface of Alberta. Figure 1 shows a core description of the 'BCS' at a similar scale to an outcrop at Lake O'Hara. Note the weathering profile of the outcrop highlights an increase of mudstone (and bioturbation) towards the top, like what is observed in the subsurface.
Near the base of the 'BCS' in the subsurface, its common to encounter the product of high-energy bars developed as part of channel belts. Outcrops of the Jasper Formation at the Athabasca Falls comprise similar type of deposits and provided insights to stacking patterns and architecture of this type of fluivio-dominated/influenced intervals.

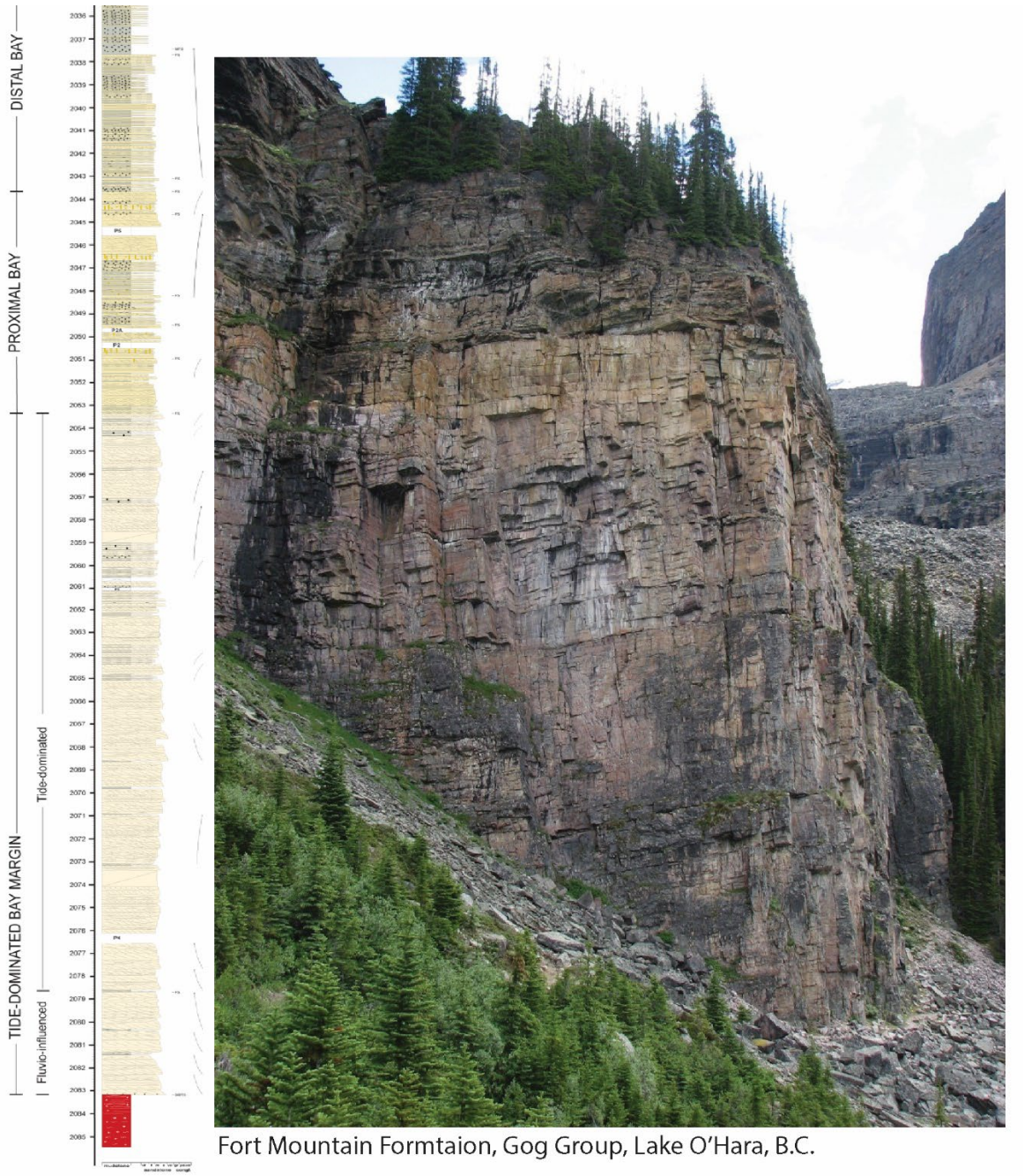

Figure 1: Core description of 'BCS' next to outcrop analogue displayed at similar scales.

Subtidal compound dunes and bars, recorded in cross-stratified sandstone with mud drapes, and sandy heterolithic packages, are common within the 'BCS' tide-dominated bay margin deposits. They are also very common within the Gog Group and some of their best outcrop examples can be found within the Lake O'Hara Formation. These are usually organized as coarsening- and thickening-upward intervals and record deposition within large subtidal compound-dune fields or sand sheets (Desjardins et al., 2012).

Intensively bioturbated sandstone and muddy sandstone are both common in the cores, specially toward the top of the 'BCS' interval. They tend to be dominated by vertical burrows such as *Skolithos*, *Diplicraterion*, *Arenicolites*. *Palaeophycus* is also common. Outcrops examples of this intensively bioturbated sandstones are refer as Pipe Rocks in the Gog Group (Desjardins et al., 2010b). Coarsening and shallowing upward trends are both observed in outcrop and cores. These bioturbated intervals are a record of the fringes of subtidal compound dune fields or sand sheets.

Conclusion

The Gog Group in the Rocky Mountains can be used as an outcrop analog for the 'BCS' CO2 reservoirs in the subsurface of Alberta. Despite the different tectonic scenarios and stratigraphic architecture, similarities were found when comparing the sedimentary facies and environments. These findings have been of paramount importance for developing a robust and reliable understanding of the subsurface. In the absence of high-quality seismic data, the integration of outcrops, cores, and well logs provided critical insights into the depositional environment and facies distribution, helping characterize the spatial variability of the reservoir. This integration was vital for constructing accurate subsurface models, which were used to predict the size and geometry of the CO2 plume. Understanding how different geobodies are connected was crucial for predicting CO2 flow within the 'BCS', enabling effective reservoir management. This, in turn, improved the quality of our decisions.

Acknowledgements

The author would like to thank Shell Canada for granting permission to share insights from the extensive technical work undertaken to best characterize the CO2 storage complex at the Quest injection site.

References

Desjardins, P.R., Pratt, B.R., Buatois, L.A. and Mangano, M.G. (2010a) Stratigraphy and sedimentary environments of the Lower Cambrian Gog Group in the southern Rocky Mountains of western Canada: evolution of transgressive sandstones on a broad continental margin. Bulletin of Canadian Petroleum Geology, 58, 1–37.

Desjardins, P.R., Mangano, M.G., Buatois, L.A. and Pratt, B.R. (2010b) Skolithos pipe rock and associated ichnofabrics from the southern Rocky Mountains, Canada: colonization trends and environmental controls in an Early Cambrian sand-sheet complex. Lethaia, 43, 507–528.

Desjardins, P.R., Buatois, L.A, Mangano, M.G. and Pratt, B.R. (2012) Sedimentological–ichnological model for tide-dominated shelf sandbodies: Lower Cambrian Gog Group of western Canada. Sedimentology, 59, 1452–1477.

Slind, O.L., Andrews, G.D., Muray, D.L., Norford, B.S., Paterson, D.F., Salas, C.J., Tawadros, E.E. 1994. Middle Cambrian to Lower Ordovician strata of the Western Canada Sedimentary Basin, 87–108. In: Geological Atlas of the Western Canada Sedimentary Basin. G.D. Mossop, I. Shetsen (comps.). Canadian Society of Petroleum Geologists and Alberta Research Council.