geoconvention
Calgary • Canada • May 12-14 2025

Sequence stratigraphic framework for sediment-hosted ore deposits, Late Devonian, Yukon, Canada

Sarah K. Schultz[1], Octavian Catuneanu[2], and John Gordon[3]
[1]Yukon Geological Survey, [2]University of Alberta, [3]Spectrum Geosciences

Summary

The Late Devonian deposits of the Selwyn basin region contain a series of Pb-Zn±Ag sediment-hosted ore bodies within organic-rich stratiform pyritic to calcareous mudstones of the Portrait Lake Formation (Earn Group). Deposition occurred in a deep-water setting, with the distribution of depositional systems largely controlled by syn-depositional fault reactivation. The mineralization that formed as a result of this fault reactivation is in part characterized by syn-depositional and diagenetic textures, which highlights the need to understand the evolution of the depositional systems for future mineral exploration. In this study, a sequence stratigraphic approach to mapping the deposits was taken in order to map the extent and distribution of mineralized intervals, as well as predict where other prospective facies may form targets within the basin.

Correlation through mud-dominated intervals can be challenging by using a sedimentological approach alone. In this study, x-ray fluorescence (XRF) and organic carbon isotope ($\delta^{13}C$) data were collected to characterize the geochemical signatures that are diagnostic of each systems tract. Systems tracts that host mineralization were characterized to use as a tool to predict other possible targets for future exploration outside of Macmillan Pass.

Selwyn basin

The Cambrian to Devonian rocks at Macmillan Pass were deposited in Selwyn basin, a depocenter along the northwestern margin of Laurentia (Gordey and Anderson, 1993). The Devonian rocks belong to the Earn Group, which is subdivided in this region into the Portrait Lake and Itsi formations (Fig. 1). Intermittent periods of extension are marked in the area by normal faults that were reactivated during the deposition of the Portrait Lake Formation. The reactivation led to significant compartmentalization and rapid lateral variability of sedimentary units (e.g., thick conglomerates adjacent to thick mudstone successions) and complicated the correlation of genetically related strata in the area.

Mineralization occurs within the Portrait Lake Formation and formed in the Late Devonian (Magnall et al., 2020). During this time, barite was replaced by sphalerite and galena, leading to the formation of the Tom, Jason, and Boundary deposits. Mineralization is thought to have occurred in two ways. The first is from a metal-rich brine sourced from deeper-seated faults interacting with an euxinic water column causing minerals to form and accumulate along depositional planes and within organic-rich intervals. The second is through subsurface replacement of carbonate material within reduced and sulphide-bearing lithologies (Magnall et al., 2020). The distribution of depositional systems that would be suitable candidates to host mineralization become important when exploring for future locations in the basin that may host these types of deposits.

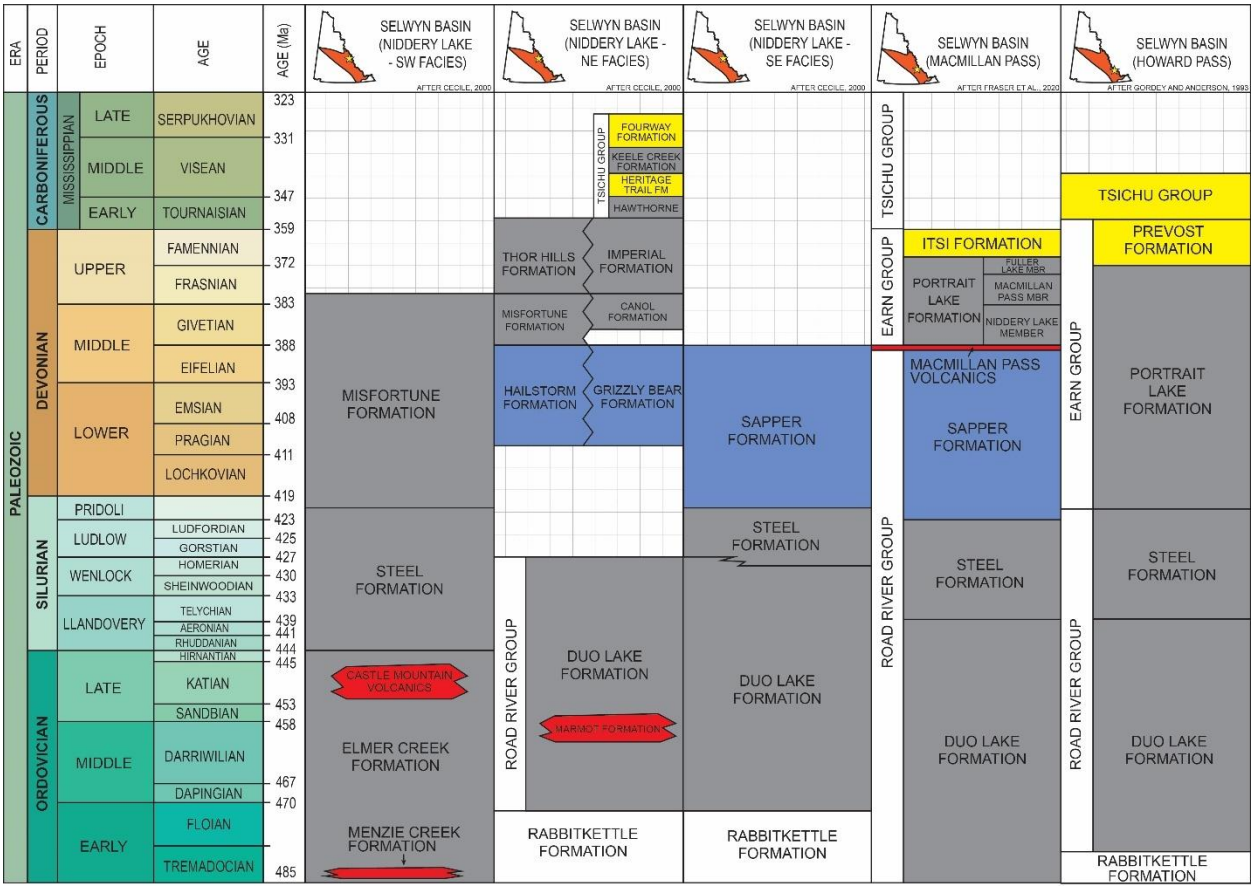

Figure 1: Table of formations for the deposits of Selwyn basin. The study area is Macmillan Pass (modified from Gordey and Anderson, 1993; Cecile, 2000; Fraser et al., 2020).

Sequence stratigraphy in deep-water settings

Deep-water settings are sequence stratigraphically complex systems to model due to the interplay between multiple allogenic and autogenic processes active during deposition, the co-existence of multiple sediment sources, and the mode of sediment transport into the basin (Catuneanu, 2022). Depositional systems recorded in these settings may exhibit a high degree of variability over relatively short distances. Deep-water settings do not form the same predictable stratal stacking patterns that are commonly seen in shallow water settings. In these situations, identifying how sediment was delivered to the deep-water setting is key to unravelling the depositional history of the basin.

Study area and methods

In the summer of 2024, 4 cores totaling approximately 1700 m were logged at Macmillan Pass from the Tom, Jason and Boundary deposits (Fig. 2). Cores were sampled at a 2 m interval for the XRF study while avoiding intervals that were heavily mineralized or conglomeratic. Ten samples were collected for whole rock geochemistry and total organic carbon (TOC) to calibrate the XRF dataset. From the XRF dataset, biogenic proxies, TOC and enrichment factors can be

calculated to use in correlations across the study area. These values and trends are used to characterize the systems tracts in the study area.

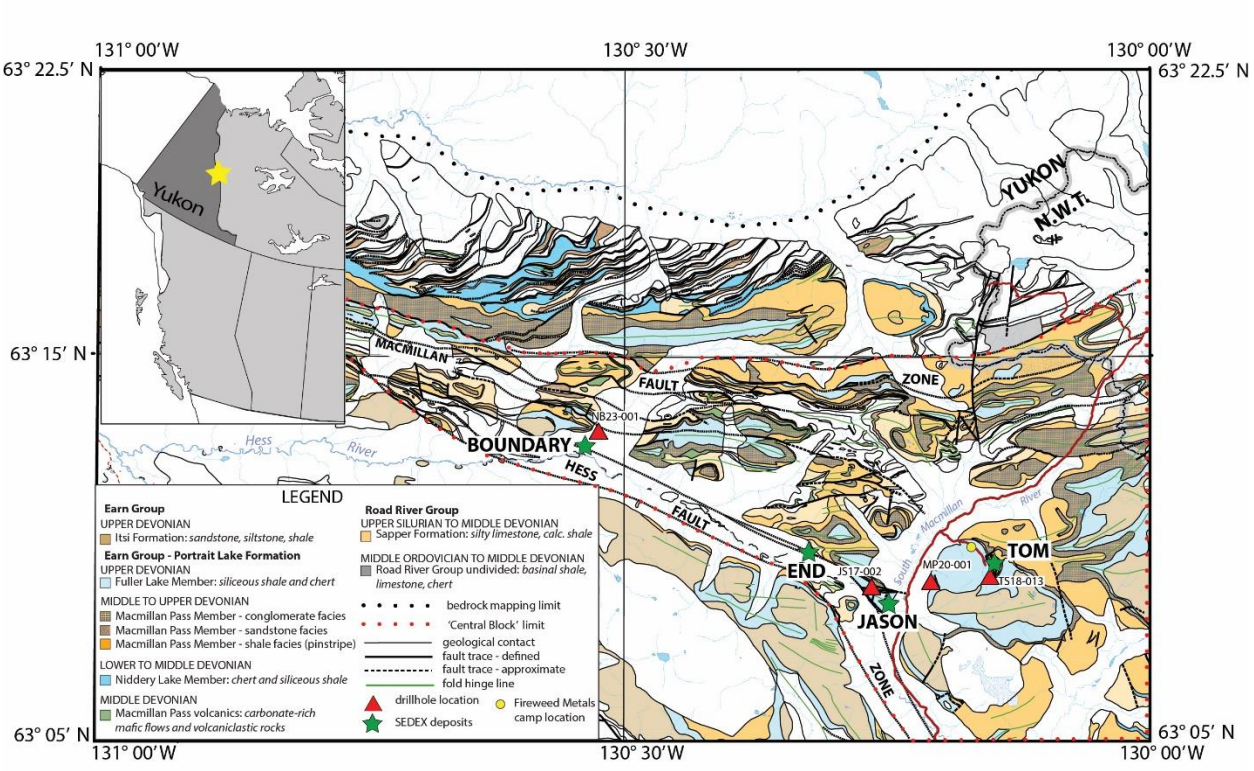

Figure 2: The study area of Macmillan Pass (modified from Abbott, 2013; Fraser et al., 2020). The four cores that were logged from the study are denoted by the green star.

A subset of samples from the cores MP20-001 and NB23-001 were sent for $\delta^{13}C$ isotopes. The values of $^{13}C/^{12}C$ in oceans varies throughout time, providing a broad chronostratigraphic component to basin-wide correlations. Changes in the carbon isotope signature are particularly useful in correlations through mudstone-dominated intervals. On a local scale, the Devonian deposits at Macmillan Pass have limited biostratigraphic and chronostratigraphic data available for the Earn Group deposits. The inclusion of the $\delta^{13}C$ isotopic data in cross-sections will allow for refined correlations to be developed in the study area.

Discussion

The most prolific delivery of siliciclastic sediment to the deep-water setting occurs during the falling-stage and lowstand systems tracts. With progressive lowering of relative sea level, the shelf becomes destabilized leading to mass transport complex and gravity-driven deposition being initiated into the basin. Sediment may also accumulate during this time in high-density and low-density turbidite complexes that are fed from deltas that rapidly approach the shelf with each lowering of sea level and/or tectonic uplift of the continental margin. Hemipelagic sedimentation occurs in all four systems tracts. Mudstone may accumulate in significant thicknesses in all systems tracts when the main sediment sources are delivering coarser sediment elsewhere in the basin.

In extensional settings, such as the Late Devonian deposits at Macmillan Pass, turbidites may not form well-developed fan architectures due to sedimentation being compartmentalized within horst and graben features of the basin. Thick conglomerate units are intersected in core from the Tom and Jason deposits. To the east and west of these deposits, the thickness of conglomerate rapidly decreases over distances of approximately 15 km. This necessitates the integration of a geochemical and isotopic dataset to facilitate sequence stratigraphic correlations throughout the basin.

Acknowledgements

Thank you to Fireweed Metals for providing access to the core at Macmillan Pass, company datasets, and for hosting the Yukon Geological Survey in camp during the summer of 2024.

References

Abbott, J.G. 2013. Bedrock geology of the Macmillan Pass area, Yukon and adjacent Northwest Territories (NTS 105O/1,2 and parts of 105O/7,8, and 105P/4,5; 1:50 000 scale). Yukon Geological Survey,

Geoscience Map 2013-1.

Carne, R.C. 1976. Stratabound barite and lead-zinc-barite deposits in eastern Selwyn Basin, Yukon Territory. Department of Indian and Northern Affairs, Open File Report EGS 1976-16, 41 p.

Catuneanu, O. 2022. Principles of Sequence Stratigraphy, Second Edition. Elsevier, 486 p.

Cecile, M.P. 2000. Geology of the northeastern Niddery Lake map area, east-central Yukon and adjacent Northwest Territories. Geological Survey of Canada, Bulletin 553, 120 p.

Fraser, T.A., Milton, J. and Gouwy, S.A. 2021. New geochemistry from old drill holes at the Tom property, Macmillan Pass, Yukon. In: Yukon Exploration and Geology 2020, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 19 – 46.

Gordey, S.P. and Anderson, R.G. 1993. Evolution of the northern Cordilleran miogeocline, Nahanni map area (105I), Yukon and Northwest Territories. Geological Survey of Canada, Memoir 428, 214 p.

Magnall, J.M., Gleeson, S.A. and Paradis, S. 2020. A new subseafloor replacement model for the Macmillan Pass clastic-dominant Zn-Pb±Ba deposits (Yukon, Canada). Express Letter, Economic Geology, v.

115, p. 953 – 959.