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Using elemental and isotopic geochemistry to identify the geochemical signatures of diagenetic events in the Montney Formation and their relationship with H_2S formation and distribution

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Introduction

The Montney Formation is a prolific hydrocarbon reservoir with a highly complex history of diagenesis. Previous studies document the occurrence of multiple phases of cementation, hydrocarbon migration, and hydrothermal fluid flow (e.g. Liseroudi et al., 2020). In this study we used trace and major element profiles along with stable isotope geochemistry to identify diagenetic events both stratigraphically and laterally throughout the basin. Continuous Montney cores that sampled the whole Montney Formation were selected to offer stratigraphic continuity at various locations in the basin. For lateral continuity two cores in the northern region (Graham–Blueberry) and three in the southern region (Karr-Kakwa) were selected and new results are presented alongside previous datasets from the central region (Liseroudi et al., 2020; 2021). In addition, these wells are located in areas with both high and low H_2S concentrations to provide insight into the effects of diagenetic events on H_2S distribution in the Montney.

Preliminary results from stable isotope analysis ($\delta^{34}S$, $\delta^{18}O$) of sulfur bearing materials (sulfate and sulfides) suggest a complex diagenetic history that is laterally discontinuous. Vertical upward migration of sulfur bearing fluids including H_2S from Devonian sources appears to be more prevalent in the southern and central parts of the basin, whereas there is less evidence for this process in the northern region. This illustrates regional differences in the diagenetic histories within the Montney Formation.

South Montney

In the southern Montney region trace and major element profiles are highly variable and strongly correlated with facies. Generally, enrichments in Ba, Ca, Mg, and Mn are associated with heavily cemented coarser-grained siltstone beds. In contrast, finer grained beds are enriched in almost every other element (e.g. S, Fe, Al, Mo, As, Li, rare earth elements, and organic carbon). Elemental profiles from the Lower Montney Formation display reduced variability compared with the Upper Montney Formation, due to the absence of the highly cemented coarser-grained siltstone beds of the Upper Montney Formation. Upper Montney sediments contain abundant pyrite and anhydrite compared with Lower Montney sediments, which are dominated by pyrite with minor amounts of anhydrite.

Sulfur isotope analysis indicates that Montney $\delta^{34}S_{anhydrite}$ values (20 to 27‰) are consistent with Devonian $\delta^{34}S_{anhydrite}$ values (*e.g.* Claypool, 1980) and distinct from $\delta^{34}S_{anhydrite}$ values of the Triassic Charlie Lake Formation (14 to 17‰). Pyrite in southern Montney sections occurs in several forms (e.g. framboidal, euhedral, and coalesced) similar to the central Montney region (see Liseroudi et al., 2021) with a wide range in $\delta^{34}S_{pyrite}$ values (–38 to +20‰) reflecting diverse sulfide formation processes. For example, analysis of several pyritic layers from the Lower Montney Formation exhibit corresponding enrichments in Cd and Zn, but not Mo or As. Cd and Zn have faster water exchange reaction kinetics than Fe and are often associated with hydrothermal sulfide deposits (Morse and Luther, 1999) hinting at the potential role of hydrothermal fluid flow. Sulfur isotope values from these pyrite layers are high (–5‰) and preclude a bacterial sulfate reduction (BSR) origin. These high $\delta^{34}S$ values are instead consistent with a thermochemical sulfate reduction (TSR). Pyritized microfossils from the Lower Montney Formation display the lowest sulfur isotope values (–38 to –20‰), indicative of BSR during early diagenesis. Pyrite from Upper Montney sections generally have higher sulfur isotope values (–20 to +20‰) suggesting a combination of BSR and TSR formation pathways.

North Montney

Trace element profiles from this region show a reduced contrast between the Lower and Upper Montney sections compared with the southern Montney cores. In general, these cores have higher concentrations of redox sensitive elements (e.g. Mo, V, As). Cores from this region have abundant pyrite while anhydrite occurrence is rare. High sulfur isotope values of pyrite (2 to 32‰) from these northern sections suggest that either thermochemical sulfate reduction played a role in pyrite formation, or that there was a significant perturbation to the regional seawater sulfate pool. Initial results from this region show minimal evidence of vertical upwards migration of sulfur bearing fluids from Devonian sources, but further work needs to be done to fully understand the diagenetic history of this region, which differs distinctly from the southern Montney region.

Summary

The diagenetic history and related sources of sulfur for H_2S occurrence in the Montney Formation is complex and varies both stratigraphically and laterally within the basin. Using elemental and isotopic geochemistry we have illustrated some of the potential pathways for H_2S generation (e.g. BSR and TSR) including geochemical evidence for hydrothermal fluid migration, which likely all contribute to H_2S occurrence in the Montney Formation. Due to the complex diagenetic history of the Montney Formation including high regional variability, more work is needed to better constrain these interpretations, especially at a basin-wide scale.

References

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