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Tracing saline groundwater inputs to the Athabasca River using stable and radiogenic isotopes

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Summary

Here we compile and compare new isotope data collected from various groundwater seep sampling campaigns conducted along the Athabasca River north of Fort McMurray with regional groundwater and river water datasets to better understand the potential sources of dissolved solutes entering the river from natural groundwater discharge. Electrical conductivity surveys conducted along the Athabasca River were used to identify areas with elevated terrain conductivity to detect areas where high salinity groundwater could be discharging to the river. Samples of porewater from the alluvial sediment in these areas were obtained using drive point piezometers installed between 1- 3m below the sediment interface. The porewater, groundwater and river water isotope data provide information about the sources of the water ($\delta^{18}O$ and $\delta^{2}H$), and solutes ($\delta^{34}S\text{-}SO_4$ and $\delta^{18}O\text{-}SO_4$, and $^{87}Sr/^{86}Sr$) and groundwater ages (^{3}H, ^{14}C). The porewater in the alluvial sediment showed variable degrees of mixing with the overlying Athabasca River water, but the geochemical and isotopic composition of these samples are consistent with discharge of Cretaceous and Devonian Formation waters. The distribution of the seep geochemistry and some of the bulk river chemistry and isotopic labelling are related to changes in geology along this stretch of the Athabasca River. The results of this investigation provide insight into the geochemical and isotopic evolution of riverine water quality, specifically the significant influence of natural groundwater sources of salinity to the Athabasca River.

Introduction

The Athabasca Oil Sands Region (AOSR) of Northern Alberta represents an important oil reserve for Canada and the world. Identifying impacts of oil sands development to groundwater and surface water resources requires understanding of the natural background water quality and is complicated in this region because the Athabasca River and its tributaries are incised directly into bitumen saturated sands of the McMurray Formation, as well as other saline Cretaceous and Devonian Formations.

Chloride mass balance modelling using monthly data for the Athabasca River between Hinton and Old Fort (A-B) identified that the greatest inputs of saline groundwater occur between Fort McMurray and Old Fort where the river flows directly over Cretaceous and Devonian bedrock units (Jasechko et al., 2012).

Follow-up studies (Gibson et al., 2013; this study) are focusing in more detail on the stretch of the Athabasca between Fort McMurray and Old Fort (C-D) to better understand the natural sources of organics and salinity to the Athabasca. Here we compile and compare new isotope data with regional groundwater and river water datasets to better understand the potential sources of dissolved solutes entering the Athabasca River from natural groundwater discharge.

Theory and/or Method

Electrical conductivity surveys conducted along the Athabasca River were used to identify areas where high salinity groundwater could be discharging to the river. Samples of porewater from the alluvial sediment in these areas were obtained using drive point piezometers installed between 1-3 m below the sediment interface in the hyporheic zone at Zones 1-7 (Figure 1). Data from various surveys (Gibson et al., 2013: industry sponsored surveys) have been combined and compared with existing geochemical and isotopic datasets for the region (CEMA, 2010; Lemay, 2002; Ozoray, 1974).

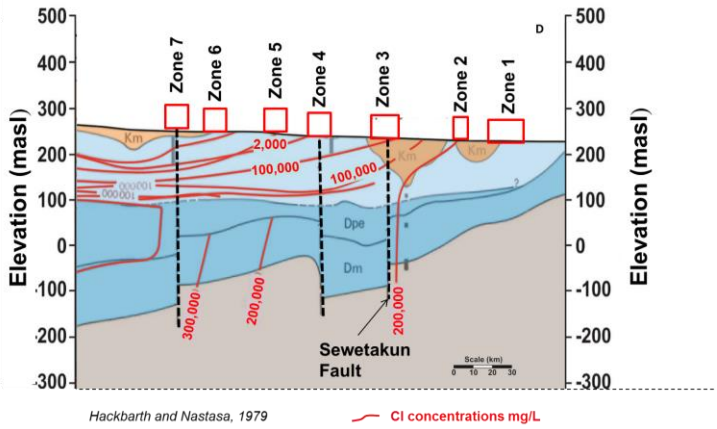

Figure 1: A cross section from Fort McMurray running north along the Athabasca River with Cl concentrations in the geological units adjacent to the river. The Sewetakun Fault is located near Zone 3.

Examples

Porewater profiles of field parameters, major and minor ions, and isotopes show varying degrees of mixing between Athabasca River water and more saline porewater present at depth in the alluvial sediments. The porewater profiles from Zone 1, 3 and 5 have large gradients consistent with the discharge of saline groundwater from Cretaceous or Devonian formations. This saline water is characterized by high TDS, high dissolved organic carbon, more negative $\delta^{18}O$ and $\delta^{2}H$ values and $^{87}Sr/^{86}Sr$ and $\delta^{34}S\text{-}SO_4$ and $\delta^{18}O\text{-}SO_4$ values consistent with Cretaceous or Devonian dissolved solutes. Porewater profiles from Zone 2, 4, 6 and 7 have more subdued geochemical and isotopic gradients consistent with greater mixing with river water or discharge of more dilute groundwater.

Conclusions

The porewater, groundwater and river water isotope data provides information about the sources of the water ($\delta^{18}O$ and $\delta^{2}H$), and solutes ($\delta^{34}S\text{-}SO_4$ and $\delta^{18}O\text{-}SO_4$, and $^{87}Sr/^{86}Sr$) and groundwater ages (^{3}H, ^{14}C). The porewater in the alluvial sediment showed variable degrees of mixing with the overlying Athabasca River water, but the geochemical and isotopic

composition of these samples are consistent with discharge of Cretaceous and Devonian Formation waters. The distribution of the seep geochemistry and some of the bulk river chemistry and isotopic labelling are related to changes in hydrogeological setting along this stretch of the Athabasca River. The results of this investigation provide insight into the geochemical and isotopic evolution of riverine water quality, specifically the significant influence of natural groundwater sources of organics and salinity.

Acknowledgements

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