

RAMP lakes in northeastern Alberta – Evidence of potential for groundwater and surface water interaction

Francisco Castrillon Munoz; John J. Gibson, Jean Birks

InnoTech Alberta

Introduction

Lakes in the boreal forest are important to understand and preserve as they serve as wildlife habitat, provide water supply to communities, fishing, and because they promote development and recreation (Mitchell and Prepas, 1990). A number of previous studies have focused on water balance and geochemistry of lakes in the region with the purpose of understanding and monitoring potential sensitivity to forest management practices (e.g. Prepas et al., 2001; Gibson et al., 2002; Devito et al., 2005; Smerdon et al., 2005), surface/groundwater interaction (Schmidt et al., 2010), and acidification due to deposition of sulfur and nitrogen compounds related to Alberta Oil Sands development (Gibson et al., 2010a, 2010b). Previous isotopic assessments have established that hydrology and geochemistry of lakes and watersheds may also be controlled by permafrost thaw, which serves to buffer acidification (Gibson et al., 2015, Gibson et al., 2016, Gibson et al. 2019). A recent trend analysis has indicated widespread pH increase in lakes over the past two decades that may be occurring due to climatic shifts including permafrost thaw and bog/fen collapse (see Gibson, 2019; Gibson et al., 2019), although the role of groundwater/surface water interaction has yet to be thoroughly evaluated. Groundwater recharge, surface water/groundwater interaction and permafrost thaw are expected to leave geochemical fingerprints on lake water similar to that noted for area rivers (Jasechko et al., 2012; Gibson et al., 2013; Birks et al., 2018, 2019) and may play a direct or indirect role in controlling the pH of runoff and/or lake water. Here we explore the hypothesis that changes in pH may be related to changes in the carbonate equilibria mechanisms operating in the watershed system including the effect of mobilization of dissolved inorganic carbon (DIC) from collapse fens to lakes (Gibson 2019). As a first step in this investigation, we present results of a hydrochemical evaluation conducted in 50 lakes situated in the northeastern region of Alberta, Canada that have been monitored by the Regional Aquatics Monitoring Program (RAMP). Bilinear plots and PHREEQC-derived saturation indices were used to gain a better understanding of the natural potential geochemical processes including those potentially leading to the observed pH changes in the lake water. We provide a basic overview of geochemical controls including initial evidence that geochemical changes in the lakes may also reflect regional groundwater/surface water interaction due to changes taking place in watershed recharge zones and recent climatic shifts. This assessment is based on analysis of data collected over a 17-year period (1999 and 2015) as part of the RAMP database.

Site location and methods

The lakes are located within the boreal plains and boreal shield regions of northeastern Alberta (Figure 1). The monitoring program has included 40 lakes situated within a 200 km radius from

the Oil Sands development region, five lakes situated in the Caribou Mountains and five lakes located north of Lake Athabasca (Figure 1). A review of major ions and ion balance errors (IBE) calculation was conducted (Aquachem ver. 2014.2) followed by calculation of saturation indices (PHREEQC ver. 3.5.0.14000). Additionally, to facilitate construction of bilinear diagrams (Figure 2), we substituted values equal to half of the detection limit (0.5DL) in place of zero values for several minor ions in the database.

Results and conclusions

A significant number of waters were identified with large IBE values (Figure 2a). The large ion balance errors (IBE) values observed are frequent in waters with high concentrations of dissolved organic carbon (DOC) and organic acids (Reeve et al, 1996). Large negative IBE values show a positive relation with dissolved organic carbon indicative of cation imbalance. Metal complexations (cation binding to organic matter) is frequent at high DOC concentrations (Tipping 1998) and at high pH, possibly causing high negative imbalance errors in these waters. Based on the bilinear relations, the main hydrochemical processes observed in the lake's waters are organic matter dissolution (Figure 1a) which contributes to the alkalinity and Total Dissolved Solids (TDS) concentration. Peatland forms leave a clear signature in the RAMP lakes water chemistry. Lower range alkalinities appear to be largely controlled by DOC dissolution (Figure 2b), and basification of lakes appears to accompany collapse of bog plateaus altering delivery of dissolved solids (Gibson 2019), whereas high alkalinity concentrations appear to be controlled by carbonate dissolution processes that might be taking place in shallow groundwaters surrounding the lakes (Figure 2c). Calcite dissolution appears to generate four times more bicarbonates than organic matter dissolution, thereby proportionately increasing alkalinity in several lakes (Figure 2d). While our calculations are based on lake water chemistry, they reflect the influence of contributions from surface waters and groundwater inputs as well as discharge processes. Overall, while DOC dissolution controls the acidic to circumneutral pH range, carbonate dissolution clearly controls lake water pH in the alkaline range (Figure 2e). We also note that carbonate dissolution appears more prevalent for lakes situated in low elevation areas, whereas lakes with low pH and with high DOC tend to be situated in higher elevation areas. A one-time assessment of carbon-13 in DIC of lake water confirms that high alkalinity waters tend to be dominated by marine carbonate sources whereas low alkalinity waters are dominated by DOC sources. One complicating factor in this interpretation is that methanogenic DIC may also be present (Figure 2f). Recommended future work includes surface/groundwater interaction studies supported by additional water and carbon isotope analysis combined with soil mineralogy to confirm the presence of controlling mineral phases including calcite precipitate.

Acknowledgements

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Figure 1. Lakes location (after Gibson 2019)

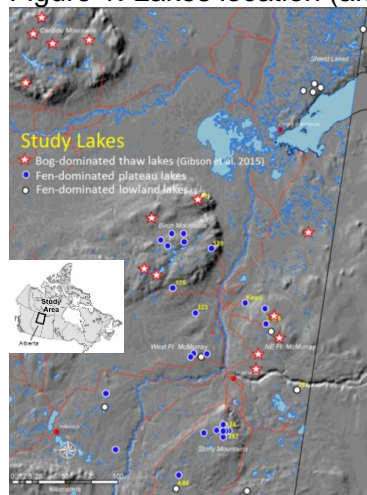


Figure 2 Bilinear plots

