Lithium in groundwater in sedimentary rocks, southwestern Manitoba

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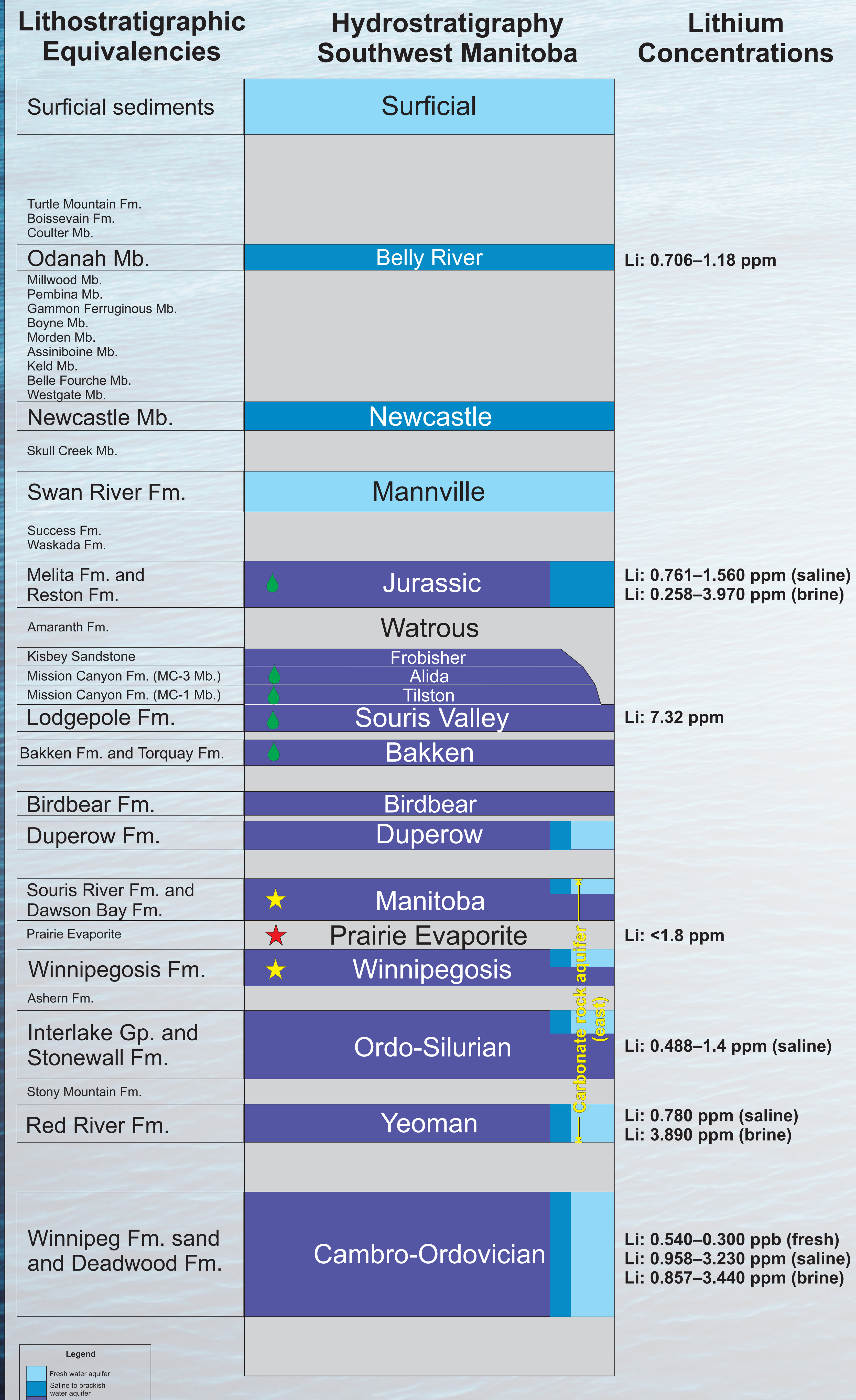

Figure 1: Hydrostratigraphy of southwestern Manitoba, modified from Palombi (2008), with equivalent southwestern Manitoba lithostratigraphic units. Red star indicates formation consisting dominantly of raw salt dominated by halite, potash and carnallite. Yellow star indicates formation with saline springs at surface. Horizons with oil production in Manitoba are indicated by green drops. The carbonate-rock aquifer range is as defined by Grasby and Betcher (2002). Aquifer-salinity changes are indicated by colour gradients where full-height boxes indicate salinity changes occur east- and northward, half-height boxes indicate salinity changes occur northward only. Salinity ranges are based on the classification of Hem (1985), and the total dissolved solids mapping of Palombi and Rostron (2013).

Introduction

Saline groundwater in continental sedimentary basins are generated from evaporitic concentration and/or halite dissolution, where the former is a primary process and the latter is a secondary (diagenetic) process. Both these mechanisms provide opportunities for trace elements to accumulate, potentially reaching economic concentrations. In Manitoba, the mineral potential of brines remains largely under explored and little understood. One example of a trace element under explored and with good potential is lithium. Production of lithium from these deep saline waters in continental sedimentary basins is currently the most common and cost-effective source of this element.

Southern Manitoba has a complex groundwater aquifer system, with salinities ranging from brines in the deeper aquifers to freshwater in the shallower and eastern aquifers (**Figure 1**). Manitoba's oil and gas operations produce large quantities of these brines, which contain a wide range of trace elements. Although very limited preliminary results indicate that the lithium concentrations in Manitoba's brines are low, extrapolation of better, more comprehensive results from Saskatchewan suggests that there is potential for lithium concentrations to be higher than currently recorded in Manitoba and that more work needs to be done to evaluate the deeper aquifers.

This project seeks to evaluate the current level of knowledge of lithium concentration in the deep brines, as well as the freshwater aquifers, to develop a better understanding of the mineral potential of brines in southern Manitoba. Nicolas (2017) reports on these most recent findings, and a summary is presented here.

Southern Manitoba Hydrogeology

The regional flow system in the Western Canada Sedimentary Basin (WCSB) is characterized by influx of freshwater from the topographic highs in the northwestern United States, at the western edge of the WCSB, with a regional movement of formation water to the northeast resulting in a western regional-scale updip flow of saline water into Manitoba. These waters partially or completely dissolve the Prairie Evaporite in its path, further increasing the salinity of the groundwater. In Manitoba, a hydrologic divide separates saltwater from freshwater. Saline springs occur west of this divide, where deep basinal waters flow updip to the surface (**Figure 2**).

In the east, the regional flow trend is reversed along the eastern erosional edge of the basin in the Interlake and Sandilands regions, where freshwater flows from east to west (**Figure 2**; Simpson et al., 1987; Betcher et al., 1995). This eastern freshwater system is referred to as the carbonate-rock aquifer and consists of gently west-dipping, carbonate-dominated strata spanning from the Red River Formation up to the Souris River Formation, and includes minor shales and evaporites (Grasby and Betcher, 2002). A major hydrological divide separates these two regional groundwater-flow systems (**Figure 2**; Grasby and Betcher, 2002).

In southwestern Manitoba there are up to 16 separate regional aquifers, as defined by Palombi (2008), all with varying salinities (**Figure 1**). In the west, the Jurassic and Paleozoic aquifers are dominantly brines, with total dissolved solids (TDS) levels >35 000 mg/L; in the east, the Paleozoic aquifer, referred to as the carbonate-rock aquifer (Grasby and Betcher, 2002), is dominantly freshwater, with a TDS level <2000 mg/L. Narrow transition zones of saline to brackish water occur between these two end members; saline water has TDS levels between 10 000 and 35 000 mg/L, and TDS levels of brackish water range from 2000 to 10 000 mg/L. **Figure 1** shows the variation in salinity from west to east.

Lithium Concentrations

The hydrogeochemistry of the saltwater is variable, depending on the source formation and location within the basin, which is itself related to the generative mechanism for these brines, whether it is by evaporitic concentration or halite dissolution. The concentration of lithium in Manitoba's groundwater is variable, with values from brines in the oil wells ranging from 0.258 to 7.32 ppm; values from freshwater to brackish water wells ranging from 0.01 ppb to 0.3 ppm; and values from shallow saline waters to brines in monitoring wells ranging from 0.488 to 3.84 ppm (**Figure 1**; Nicolas, 2017). Despite the small number of results from deep brines, lithium concentrations in Manitoba's groundwater are low, with overall higher concentrations in the deep Jurassic and Paleozoic brines of southwestern Manitoba's oil region. Shallower brines and saline waters measured from the groundwater monitoring wells have slightly lower values for lithium, compared with the brines derived from deep oil wells (**Figure 2**). Freshwater-dominated Cambro-Ordovician aquifers along the eastern erosional edge of the Williston Basin have extremely low lithium concentrations.

Recent studies in Saskatchewan report higher lithium concentrations (Jensen, 2012, 2016) in deeper horizons than those tested in Manitoba and the regional groundwater flow is to the east and northeast (**Figure 2**), therefore there is the possibility that higher Li concentrations can also be found in Manitoba. The highest lithium concentrations in Saskatchewan are derived from brines evolving from evaporitic concentration mechanisms (Jensen, 2012), with Devonian-aged aquifers measuring the highest values.

Economic Considerations

Saltwater production and disposal from oil wells is a constant issue for the petroleum industry and is one of the dominant reasons for marginal well abandonment. The mineral potential of these brines may serve as an excellent economic opportunity for the operators to improve their profits and extend the life of marginal oil wells, taking advantage of the array of infrastructure already in place for these operations.

Future Work

In the next phase of the project, archival data will continue to be searched and compiled, while infill sampling of brine from existing oil-well operations, as well as from the saline springs, will be collected, as needed or available, for analyses of a range of trace elements and evaluate their mineral potential.

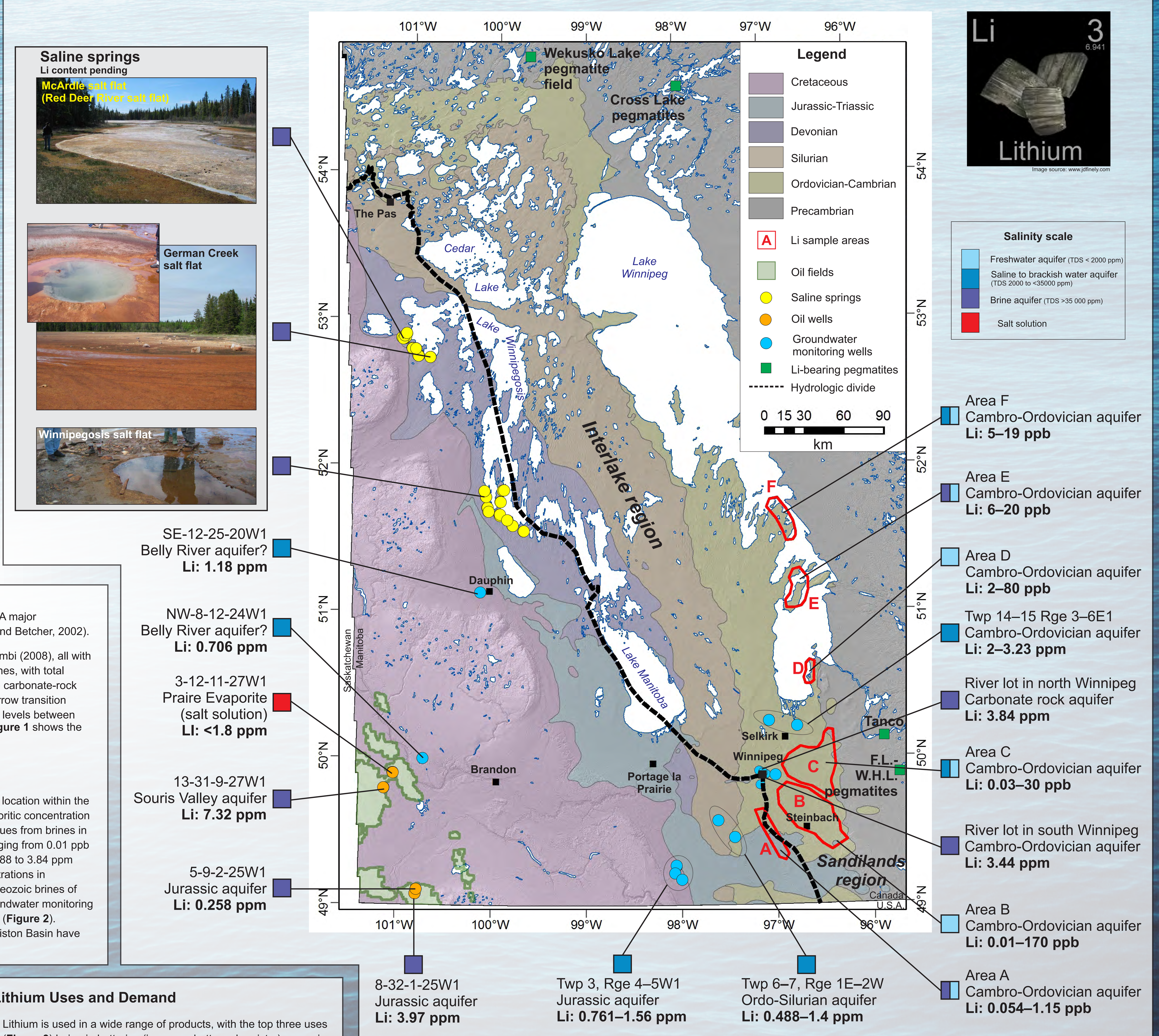

Figure 2: Regional geological map with digital elevation model of southern Manitoba showing hydrological divide (follows the 2000 mg/L total dissolved solids contour) with the location of saline springs and freshwater recharge regions from Grasby and Betcher (2002); areas A through F group multiple water sampling points (data from Ferguson et al., 2005); oil wells and groundwater monitoring wells with Li analyses are shown. Digital elevation model from United States Geological Survey (2002). Abbreviation: F.L.–W.H.L., Falcon Lake–West Hawk Lake.

Lithium Uses and Demand

- Lithium is used in a wide range of products, with the top three uses (**Figure 3**) being in batteries (improves battery chemistry), ceramics and glass (for strength and resistance to temperature change), and in lubricating greases (to enhance heat resistance; USGS, 2017).
- Increasing demand for lithium for use in cell phones, laptops and electric/hybrid car batteries is currently driving the market.
- Less than 1% of Li is recycled, therefore a steady supply of primary lithium is required.

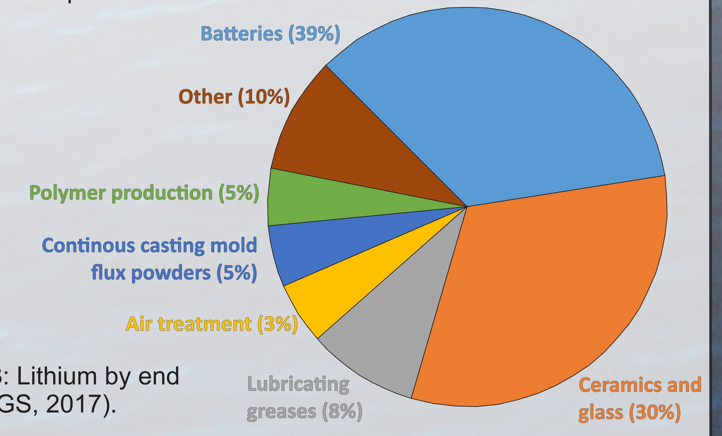

Figure 3: Lithium by end use (USGS, 2017).

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