GEOCHEMICAL TEMPERATURE ANALYSIS OF SALINE LAKES OF THE NORTHERN GREAT PLAINS

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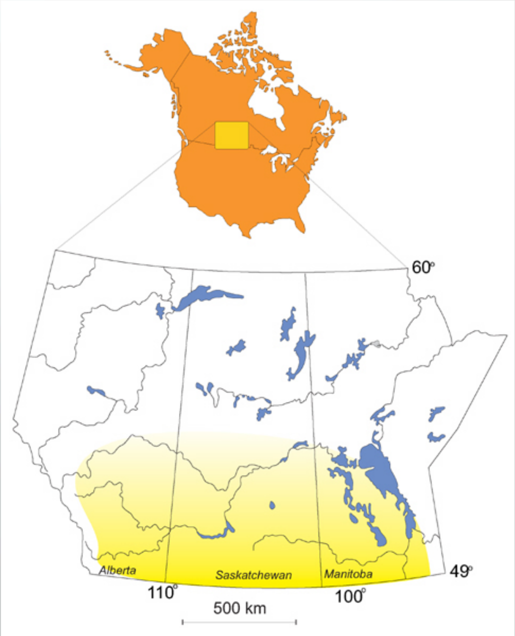
Overview

- Introduction of study area
- Hypothesis/Guiding Question
- Study overview
- Phreeqc results
- Conclusion

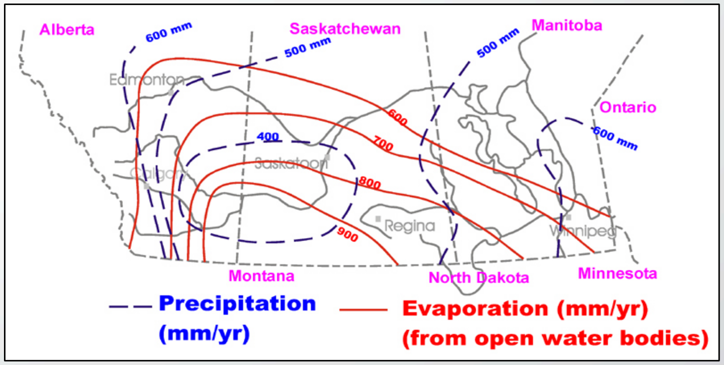
Northern Great Plains

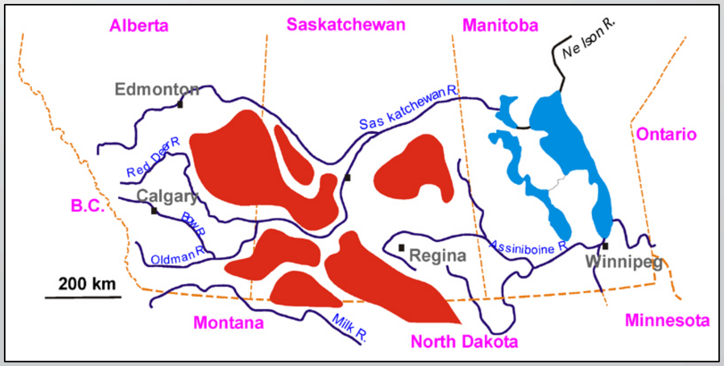
- Approximately 3.5 million saline lakes
- Breeding ground for 80% of North America ducks
- "Glauber's Salt" (mirabilite: Na_2SO_4 * $10H_2O$)
    - $50,000,000 to area economy



Northern Great Plains

- High evaporation to precipitation ratios
- Endorheic drainage: No outflow to external bodies of water
- Salinity varies greatly amongst saline lakes.





How will the geochemistry of saline lakes be affected by increases in temperature?

Table 1. Average brine compositions of lakes in the northern Great Plains (ion concentrations in mmol L^{-1}).

Area	TDS (ppt)	Ca	Mg	Na	K	HCO_3	CO_3	Cl	SO_4
Eastern Prairies	3	3	23	4	1	6	1	2	24
Central Saskatchewan	24	15	156	192	5	9	2	50	251
SW Sask. & SE Alberta	81	18	98	1094	4	98	36	29	1070
West-central Sask & East-central Alta	103	4	141	1369	10	287	44	107	1215

The Study

- With increases in Earth temperatures and $CO_{2,}$ a series of phreeqc analyses were conducted
- Increase in temp = 25°C + 5°C
- pCO_2 Equilibrium phase doubled

Low T | High T

Eastern Prairies

```
TITLE Run 1
SOLUTION 1
    temp 25
    pe
    units mmol/L
    Ca 3
    C 1 as CO3-2
    Cl 2
    Mg 23
    K 1
    Na 4
    S 24 as SO4-2
EQUILIBRIUM_PHASES 1
    CO2(g) 0.00039
END
```

```
TITLE Run 2
SOLUTION 1
    temp 30
    pe
    units mmol/L
    Ca 3
    C 1 as CO3-2
    Cl 2
    Mg 23
    K 1
    Na 4
    S 24 as SO4-2
EQUILIBRIUM_PHASES 1
    CO2(g) 0.00078
END
```

West-Central Sask & East-Central Alberta

```
TITLE Run 3
SOLUTION 1
    temp 25
    pe
    units mmol/L
    Ca 4
    C 44 as CO3-2
    Cl 107
    Mg 141
    K 10
    Na 1369
    S 1215 as SO4-2
EQUILIBRIUM_PHASES 1
    CO2(g) 0.00039
END
```

```
TITLE Run 4
SOLUTION 1
    temp 30
    pe
    units mmol/L
    Ca 4
    C 44 as CO3-2
    Cl 107
    Mg 141
    K 10
    Na 1369
    S 1215 as SO4-2
EQUILIBRIUM_PHASES 1
    CO2(g) 0.00078
END
```

Low T

High T

Eastern Prairies

Low T:

```
---------------------------Description of solution---------------------------

                                       pH  =   4.652      Charge balance
                                       pe  =  13.246      Adjusted to redox equilibrium
                        Activity of water  =   0.999
                           Ionic strength  =   6.405e-02
                       Mass of water (kg)  =   1.000e+00
                 Total alkalinity (eq/kg)  =   8.641e-04
                       Total CO2 (mol/kg)  =   3.448e-02
                      Temperature (deg C)  =  25.000
                  Electrical balance (eq)  =   6.159e-03
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =   9.05
                               Iterations  =  16
                                  Total H  = 1.110133e+02
                                  Total O  = 5.567236e+01
```

High T:

```
---------------------------Description of solution---------------------------

                                       pH  =   4.687      Charge balance
                                       pe  =  12.578      Adjusted to redox equilibrium
      Specific Conductance (uS/cm, 30 oC)  = 3490
                          Density (g/cm3)  =   0.99896 (Millero)
                        Activity of water  =   0.999
                           Ionic strength  =   6.194e-02
                       Mass of water (kg)  =   1.000e+00
                 Total alkalinity (eq/kg)  =   8.712e-04
                       Total CO2 (mol/kg)  =   3.044e-02
                      Temperature (deg C)  =  30.000
                  Electrical balance (eq)  =   6.152e-03
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =   9.33
                               Iterations  =  12
                                  Total H  = 1.110133e+02
                                  Total O  = 5.566427e+01
```

West-Central Sask & East-Central Alberta

Low T:

```
---------------------------Description of solution---------------------------

                                       pH  =   6.217      Charge balance
                                       pe  =  -1.068      Adjusted to redox equilibrium
                        Activity of water  =   0.950
                           Ionic strength  =   2.800e+00
                       Mass of water (kg)  =   1.000e+00
                 Total alkalinity (eq/kg)  =   4.971e-02
                       Total CO2 (mol/kg)  =   6.754e-02
                      Temperature (deg C)  =  25.000
                  Electrical balance (eq)  =  -1.081e+00
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  = -29.22
                               Iterations  =   9
                                  Total H  = 1.110615e+02
                                  Total O  = 6.146679e+01
```

High T:

```
---------------------------Description of solution---------------------------

                                       pH  =   6.252      Charge balance
                                       pe  =  -1.025      Adjusted to redox equilibrium
                        Activity of water  =   0.950
                           Ionic strength  =   2.787e+00
                       Mass of water (kg)  =   1.000e+00
                 Total alkalinity (eq/kg)  =   4.993e-02
                       Total CO2 (mol/kg)  =   6.563e-02
                      Temperature (deg C)  =  30.000
                  Electrical balance (eq)  =  -1.082e+00
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  = -29.34
                               Iterations  =   7
                                  Total H  = 1.110615e+02
                                  Total O  = 6.146310e+01
```

Eastern Prairies

Low T

Saturation indices

Phase	SI	log IAP	log KT	
Anhydrite	-0.92	-5.28	-4.36	CaSO4
Aragonite	-3.57	-11.90	-8.34	CaCO3
Calcite	-3.42	-11.90	-8.48	CaCO3
CH4(g)	-119.00	-121.86	-2.86	CH4
CO2(g)	0.00	-1.47	-1.47	CO2
Dolomite	-5.85	-22.94	-17.09	CaMg(CO3)2
Gypsum	-0.70	-5.28	-4.58	CaSO4:2H2O
H2(g)	-36.19	-39.34	-3.15	H2
H2O(g)	-1.51	-0.00	1.51	H2O
H2S(g)	-114.71	-115.71	-1.00	H2S
Halite	-6.88	-5.30	1.58	NaCl
O2(g)	-10.80	-13.69	-2.89	O2
Sulfur	-84.40	-79.52	4.88	S

High T

Saturation indices

Phase	SI	log IAP	log KT	
Anhydrite	-0.91	-5.30	-4.39	CaSO4
Aragonite	-3.46	-11.83	-8.37	CaCO3
Calcite	-3.32	-11.83	-8.51	CaCO3
CH4(g)	-113.03	-115.93	-2.90	CH4
CO2(g)	0.00	-1.52	-1.52	CO2
Dolomite	-5.60	-22.80	-17.20	CaMg(CO3)2
Gypsum	-0.71	-5.30	-4.58	CaSO4:2H2O
H2(g)	-34.51	-37.69	-3.17	H2
H2O(g)	-1.38	-0.00	1.38	H2O
H2S(g)	-108.88	-109.93	-1.05	H2S
Halite	-6.89	-5.30	1.59	NaCl
O2(g)	-12.46	-15.39	-2.93	O2
Sulfur	-80.16	-75.40	4.77	S

West-Central Sask & East-Central Alberta

Low T

Saturation indices

Phase	SI	log IAP	log KT	
Anhydrite	-0.12	-4.48	-4.36	CaSO4
Aragonite	-0.82	-9.16	-8.34	CaCO3
Calcite	-0.68	-9.16	-8.48	CaCO3
CH4(g)	-13.99	-16.85	-2.86	CH4
CO2(g)	0.00	-1.47	-1.47	CO2
Dolomite	0.31	-16.78	-17.09	CaMg(CO3)2
Gypsum	0.06	-4.52	-4.58	CaSO4:2H2O
H2(g)	-9.95	-13.10	-3.15	H2
H2O(g)	-1.53	-0.02	1.51	H2O
H2S(g)	-11.63	-12.63	-1.00	H2S
Halite	-2.69	-1.11	1.58	NaCl
O2(g)	-63.32	-66.22	-2.89	O2
Sulfur	-7.55	-2.67	4.88	S

High T

Saturation indices

Phase	SI	log IAP	log KT	
Anhydrite	-0.11	-4.50	-4.39	CaSO4
Aragonite	-0.72	-9.09	-8.37	CaCO3
Calcite	-0.58	-9.09	-8.51	CaCO3
CH4(g)	-16.67	-19.57	-2.90	CH4
CO2(g)	0.00	-1.52	-1.52	CO2
Dolomite	0.52	-16.68	-17.20	CaMg(CO3)2
Gypsum	0.04	-4.54	-4.58	CaSO4:2H2O
H2(g)	-10.44	-13.61	-3.17	H2
H2O(g)	-1.40	-0.02	1.38	H2O
H2S(g)	-14.44	-15.49	-1.05	H2S
Halite	-2.71	-1.11	1.59	NaCl
O2(g)	-60.66	-63.59	-2.93	O2
Sulfur	-9.80	-5.04	4.77	S

Discussion

- Subtle pH increases with temperature and $CO_{2.}$
- Slight change in SI values
- Samples with different TDS notice similar changes

Conclusion

- Results vary subtly with Temperature and CO_2 increase in saline lakes
- pH increase in both Eastern Prairies and West-Central Saskatchewan
- More accurate predictions for temp and CO_2 can be analyzed, as well as other variables that may cause differences in SI and pH.

Last, W.M., Ginn, F.M. The chemical composition of saline lakes of the Northern Great Plains, Western Canada. Geochemical News 141, October 2009.