Soil Bicarbonate: A Forgotten Anion

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CLRA Alberta Chapter 2022 AGM & Conference

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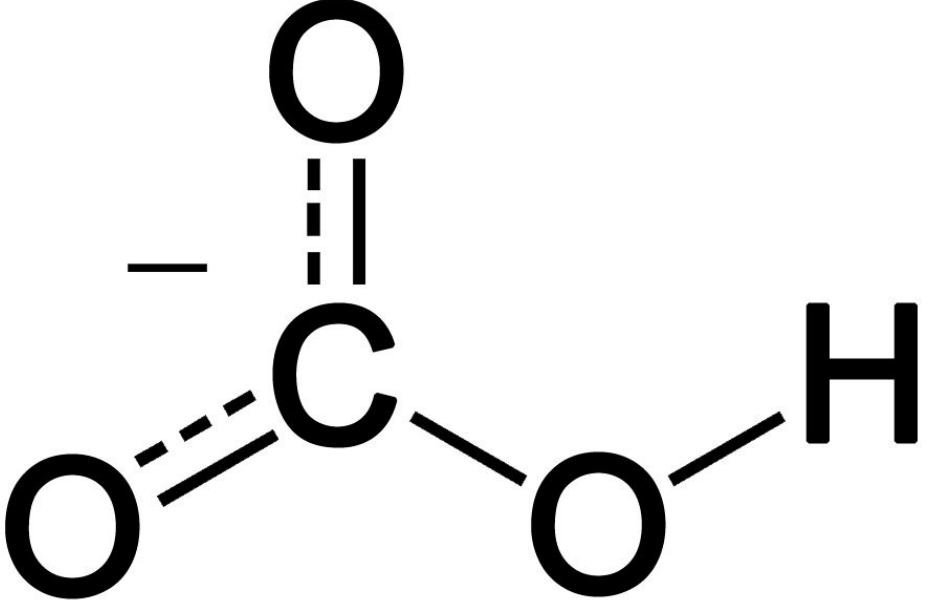
Outline

- Background
- Formation Water Chemistry
- Linear Regression Analysis
- Other Considerations



Why is bicarbonate analyzed in routine water packages but not soil salinity?

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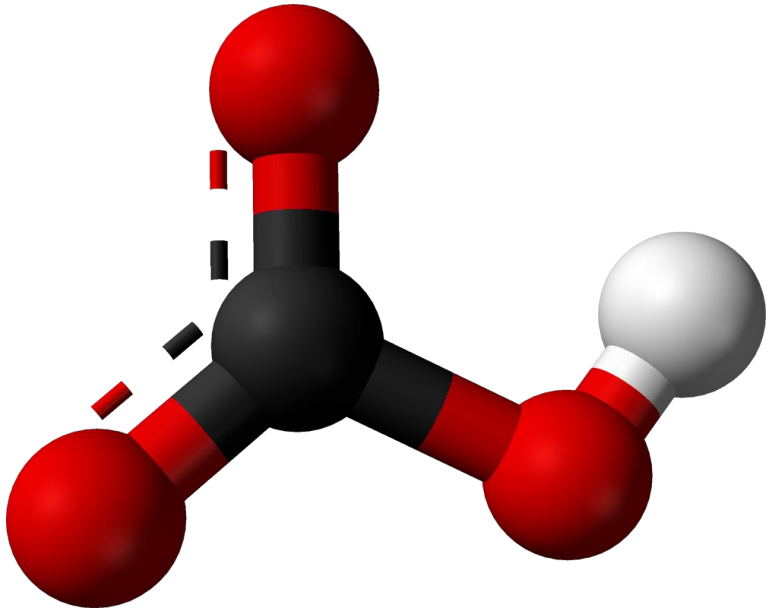
Background

What is bicarbonate?

- Polyatomic *anion* with the chemical formula HCO_3^-
- Conjugate base of carbonic acid H_2CO_3
- Prominent form of alkalinity



Bicarbonate-ion-3D-balls.png (1100×895) (wikimedia.org)

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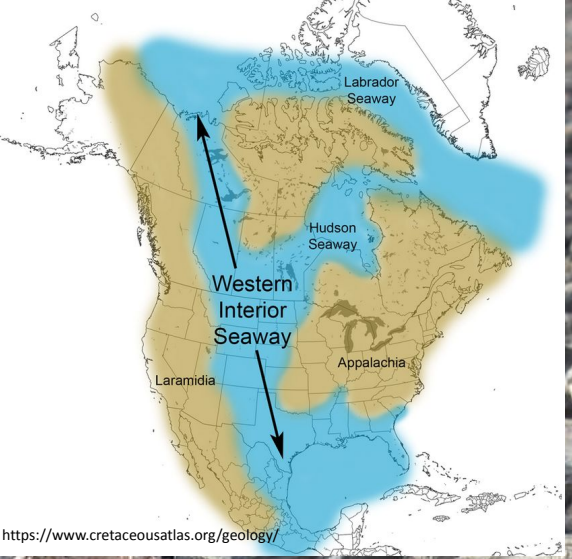

https://www.cretaceousatlas.org/geology/

https://gsilva.photoshelter.com/image/I0000WrmFswxvnCY

Where does bicarbonate come from?

- The pyrite present in the soil undergoes oxidation:

$2FeS_2 + 7O_2 + 2H_2O \longrightarrow 2Fe^{2+} + 4SO_4^{2-} + 4H^+$

$4Fe^{2+} + O_2 + 4H^+ \longrightarrow 4Fe^{3+} + 2H_2O$

$Fe^{3+} + 3H_2O \longrightarrow Fe(OH)_3 + 3H^+$

Overall Reaction:

$FeS_2 + 3.75O_2 + 3.5H_2O \longrightarrow Fe(OH)_3 + 2SO_4^{2-} + 4H^+$

- Protons from sulphuric acid react with carbonates in soils:

Calcite

$H^+ + CaCO_3 \longrightarrow Ca^{2+} + HCO_3^-$

Dolomite

$2H^+ + CaMg(CO_3)_2 \longrightarrow Ca^{2+} + Mg^{2+} + 2HCO_3^-$

- Dissolution of calcite:

$H_2O + CO_2 + CaCO_2 \square Ca^{2+} + 2HCO_3^-$

Grasby et al., 2010
Wallick, 1981

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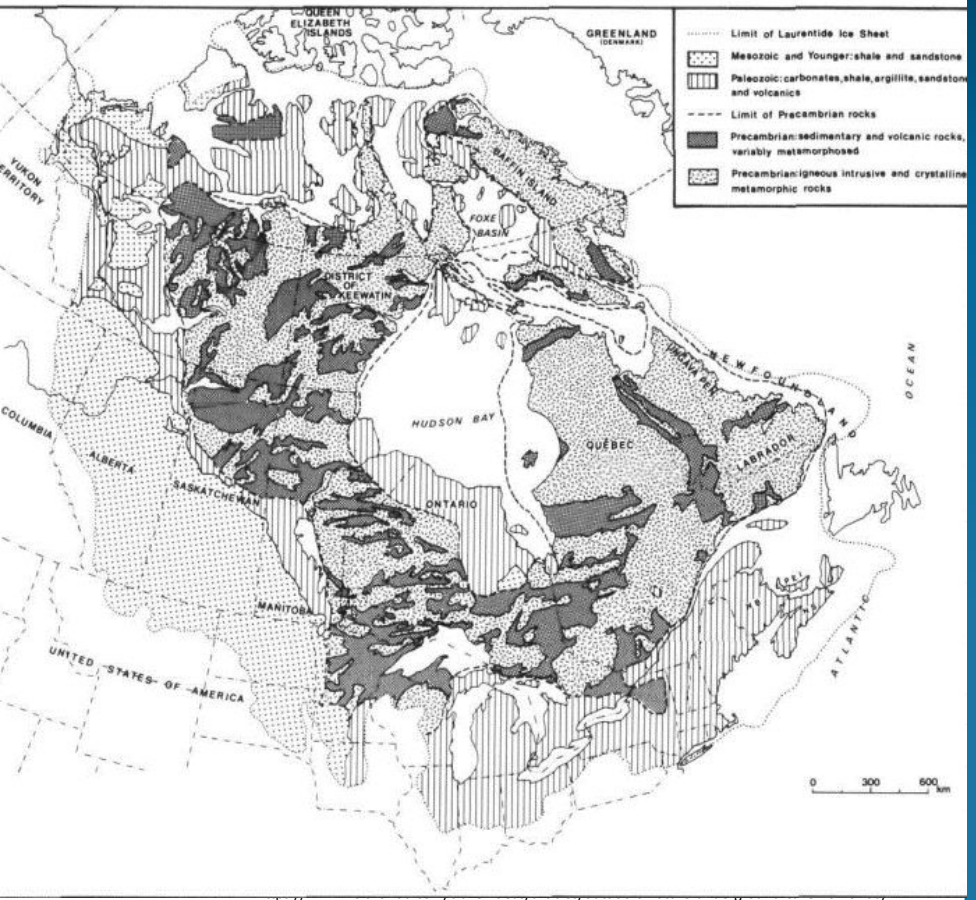

Where does bicarbonate come from?

- Laurentide deposits have significant amounts of feldspars including albite which can weather to form clay minerals

$$2NaAlSi_3O_8 + 11H_2O + 2CO_2 \longrightarrow 2Na^+ + 2HCO_3^- + 4H_4SiO_4 + Al_2Si_2O_5(OH)_4$$

Grasby et al., 2010

Introduction: The Laurentide Ice Sheet and its Significance (erudit.org)

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Formation Water Chemistry

Process Water – *"the Canary"*

- SAGD facility in NE Alberta
- 2021 process (brackish) water release

	pH	EC (µS/cm)	Ca (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	SO_4 (mg/L)	HCO_3 (mg/L)	TDS (mg/L)
Fluid	**6.79**	**5,300**	**370**	**110**	**840**	**760**	**<1.0**	**1,500**	**2,900**

Formation Water

- Data mine of geoSCOUT
  - Alberta data
- Formation Water
  - QA/QC
- 56,951 formation water samples
- Median bicarbonate: 654 mg/L
- Bicarbonate up to 55,020 mg/L

Bicarbonate (mg/L)

Count

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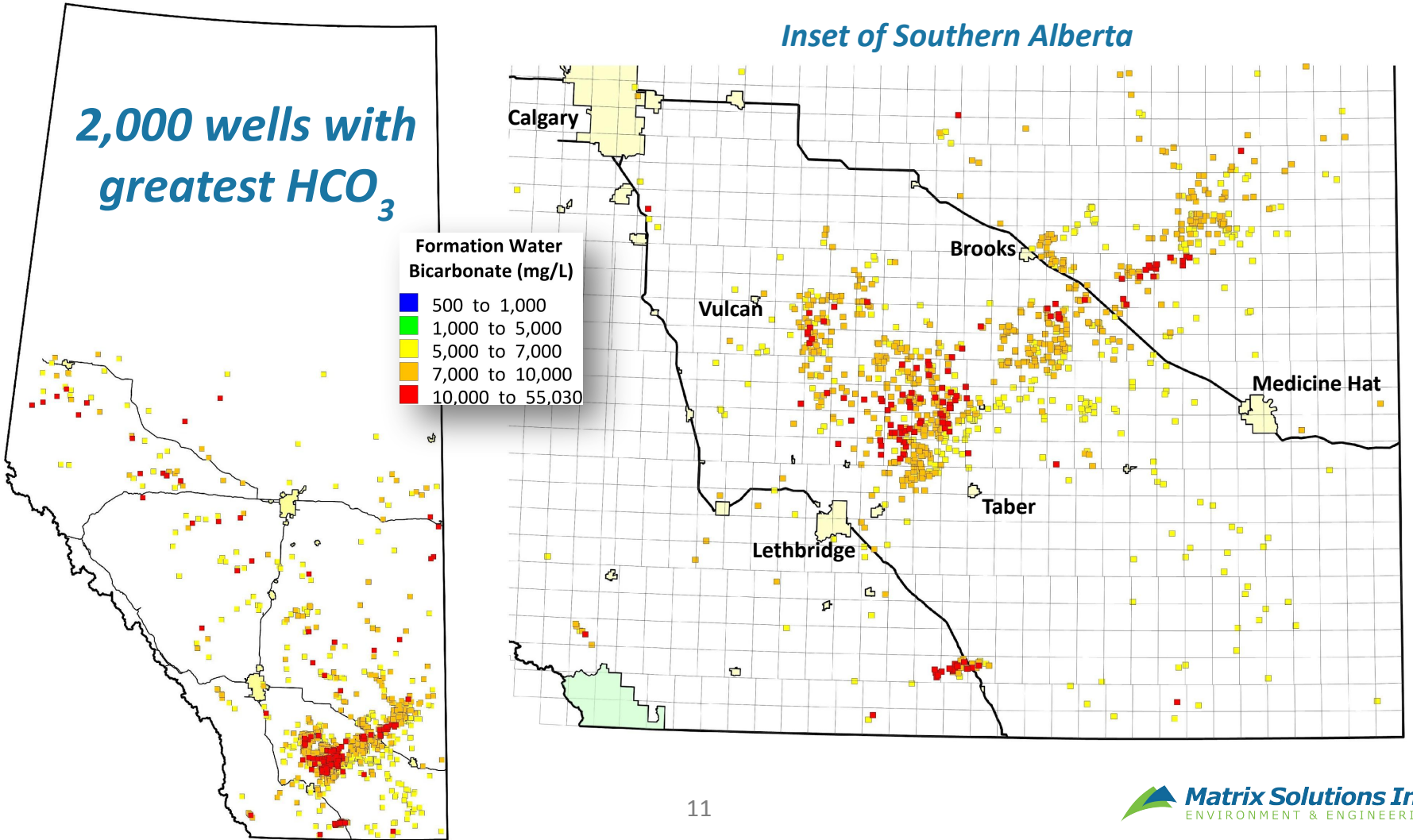
2,000 wells with greatest HCO_3



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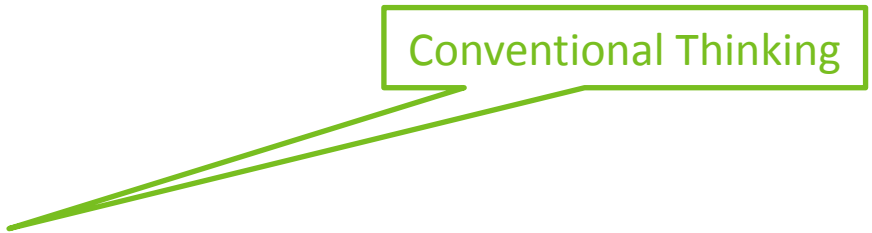
Common Formations – Alberta

Group	Subunit	Relative Location
Mannville	Sunburst	Southern Alberta
	Glauconic Sandstone	Central & Southern Alberta
	Lower Mannville	Central & Southern Alberta
	Ellerslie Member	Central & Southern Alberta
	Taber Sandstone	Southern Alberta
	Ostracode Beds	Central & Southern Alberta
Colorado	Bow Island Sandstone	Southern Alberta
	Viking	Central & Southern Alberta
Rundle	Pekisko	Foothills & Plains
	Turner Valley Formation	Foothills & Plains
Ellis	Sawtooth	Southern Alberta
	Rierdon Formation	Southern Alberta

Formation Water



Linear Regression Analysis

Linear Regression Analysis

- *Diagnosis and Improvement of Saline & Alkali Soils* (Richards 1954)

- Strong correlation between solute concentrations & EC
  - *meq/L*
  - ***Higher meq weight of HCO_3***

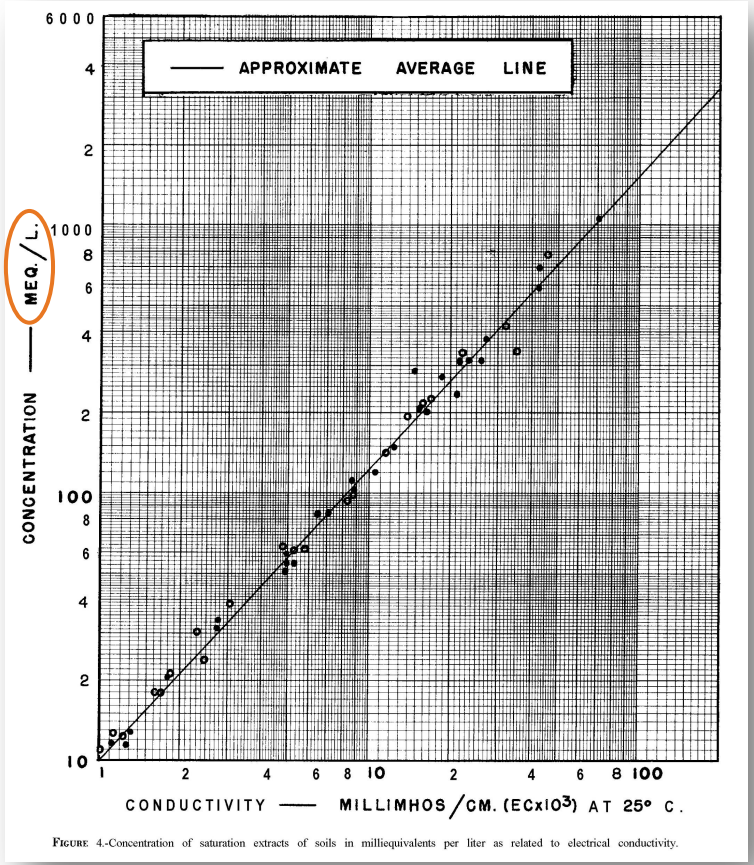


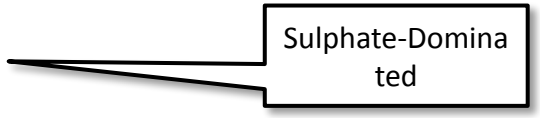
FIGURE 4.-Concentration of saturation extracts of soils in milliequivalents per liter as related to electrical conductivity.

$$y0 = 0.440$$

The Bicarbonate Soil Data Set

- 4 sites
  - 2021 analysis
- One each in:
  - HCO_3 formation water ‘belt’
  - NE Alberta – SAGD
  - SW Sask.
  - NW Sask.
- *Only 72 soil samples*

Soil Anions



Electrical Conductivity (dS/m)

$r^2 = 0.9850$
SEE = 0.7959

y0 = 1.0087
a = 0.0486

Electrical Conductivity (dS/m)

$r^2 = 0.9890$
SEE = 0.6693

y0 = 0.8554
a = 0.0477

Shallow Groundwater Bicarbonate

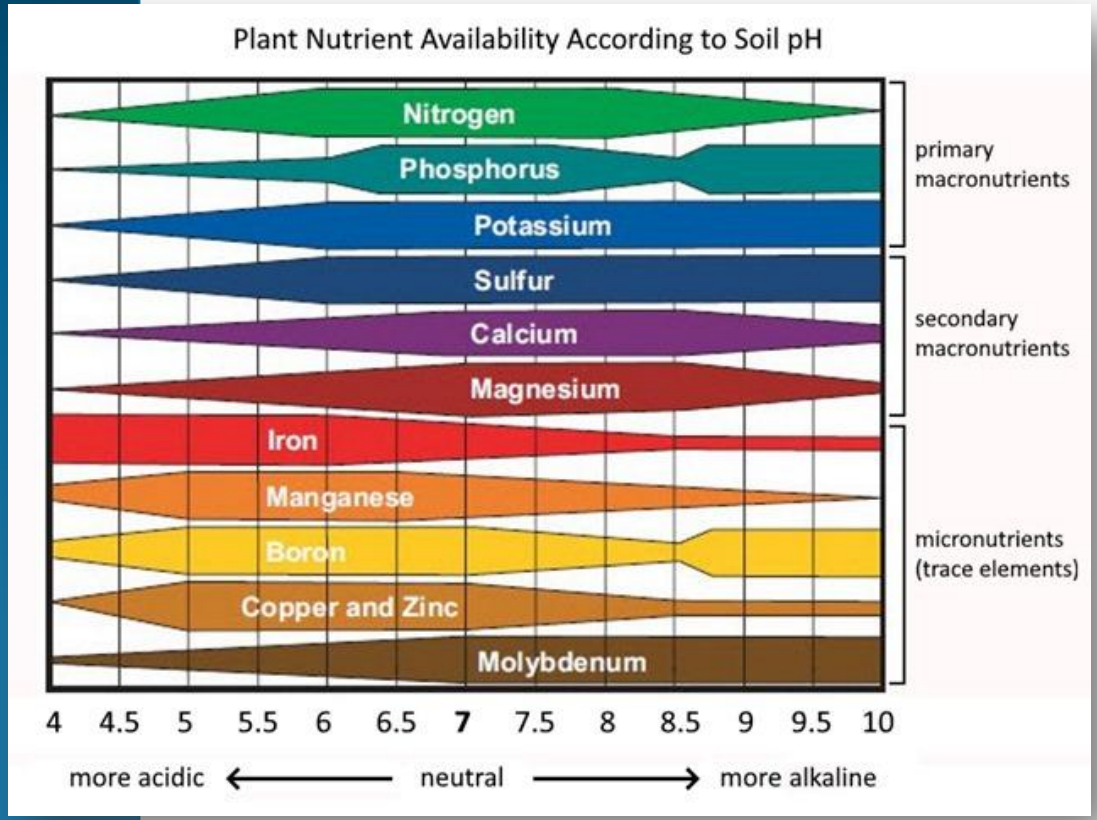
Other Considerations

Sodium Adsorption Ratio Influence

- Through solodization (dealkalization), HCO_3 (and CO_3) can precipitate Ca and Mg
  - Precipitated $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$
- Reduced soluble Ca and Mg
- Process can also allow precipitated Na to hydrate
  - Na^+ Vs. Ca^{2+} and Mg^{2+} (2 Na for each Ca and Mg)
- *Thus increased SAR values*

pH Effects

- Bicarbonate increases the pH of soils
  - Source of OH^-
- pH of soil affects nutrient availability
- In alkaline soil, some nutrients become unavailable and some become toxic



Credit: Soil Chemistry Fundamentals, Part 1 – Understanding Soil pH and How it Affects Plant Nutrient Availability – Deep Green Permaculture

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TDS Calculations

- Tier 2A SST (soils)
  - Background HCO_3
  - Groundwater suitability

$$TDS_{Cal} = 0.6 \times \left(\frac{HCO_3}{1.22} + \frac{CO_3}{0.6}\right) + Cl + Ca + Mg + K + Na + (0.17 \times OH) + NO_3 + NO_2 + SO_4$$

Conclusions

- Important to characterize produced water
  - Potential CoC

- Why not add HCO_3 to detailed soil salinity packages?

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- Maurice Shevalier
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Questions ?

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