Prediction of Selenium Leaching

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- NEMI: Trend Mine.

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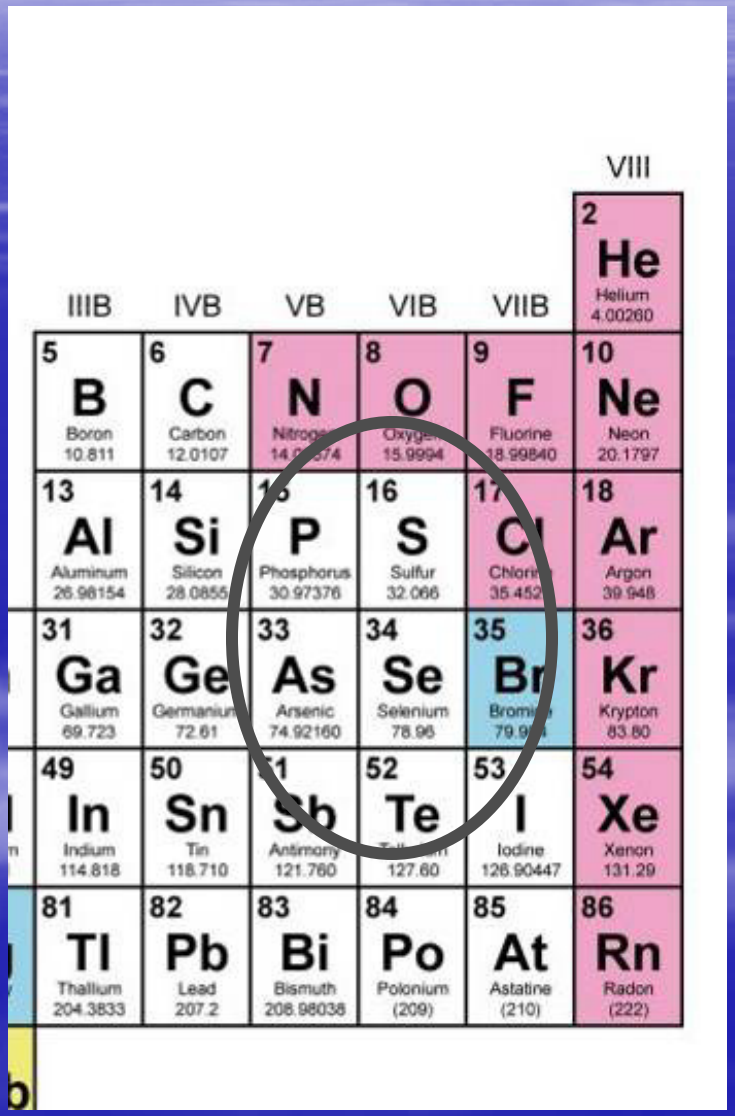
Topics

- Why selenium?
- Overview of selenium chemistry.
- Observations from the Elkview Coal Mine.
  - Mineralogical occurrence.
  - Aqueous chemistry.
- Considerations for predicting selenium leaching.

Why Selenium?

- Routine low level (below ppb) analysis in waters.
- Routine low level (low ppm) analysis in rock.
- Low receiving water standards (low ppb).
- Typically, only heavy element of concern leaching from coal wastes at neutral pH.

Overview of Selenium Geochemistry



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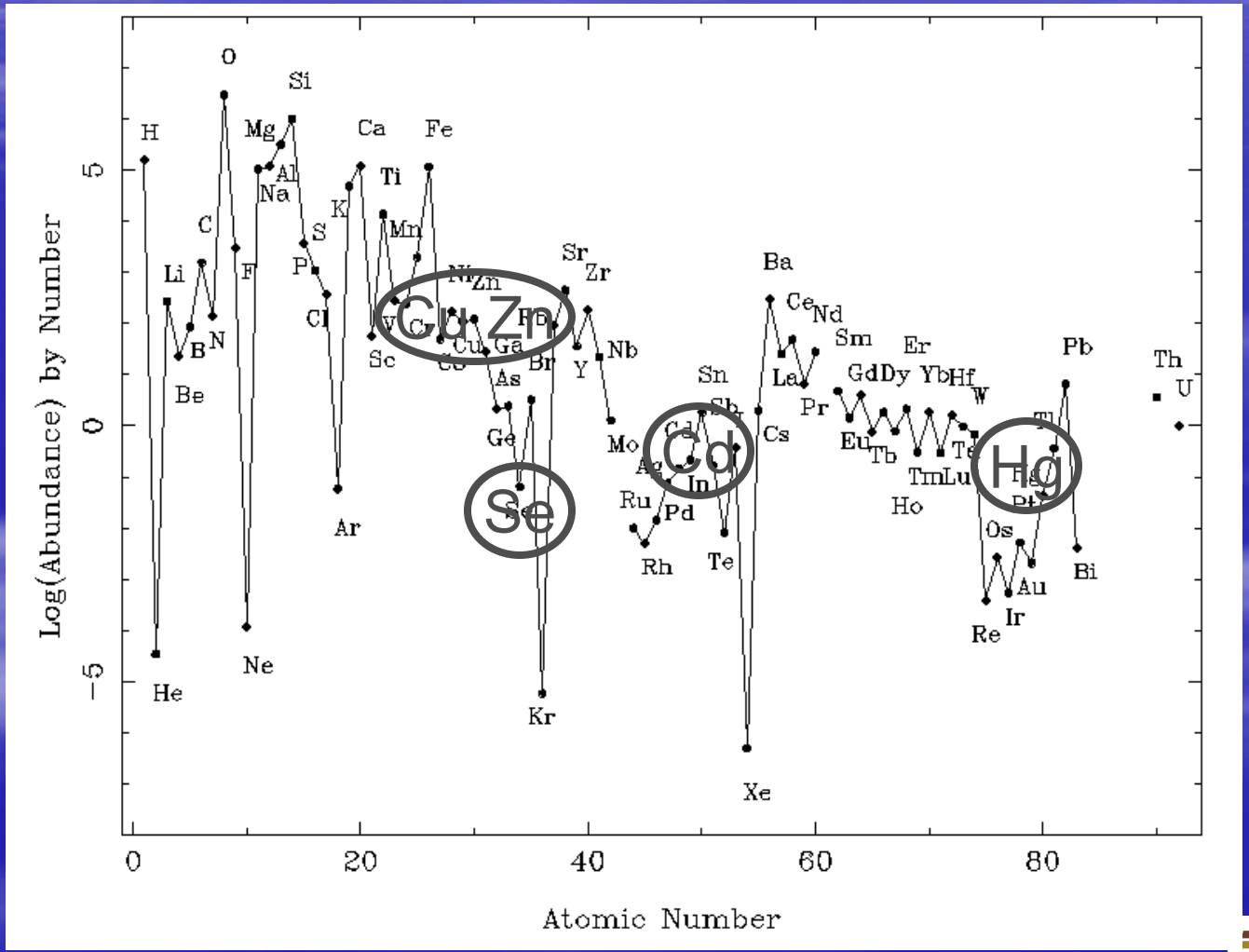
Overview of Selenium Geochemistry

Crustal Abundance of Selenium Relative to Other Elements



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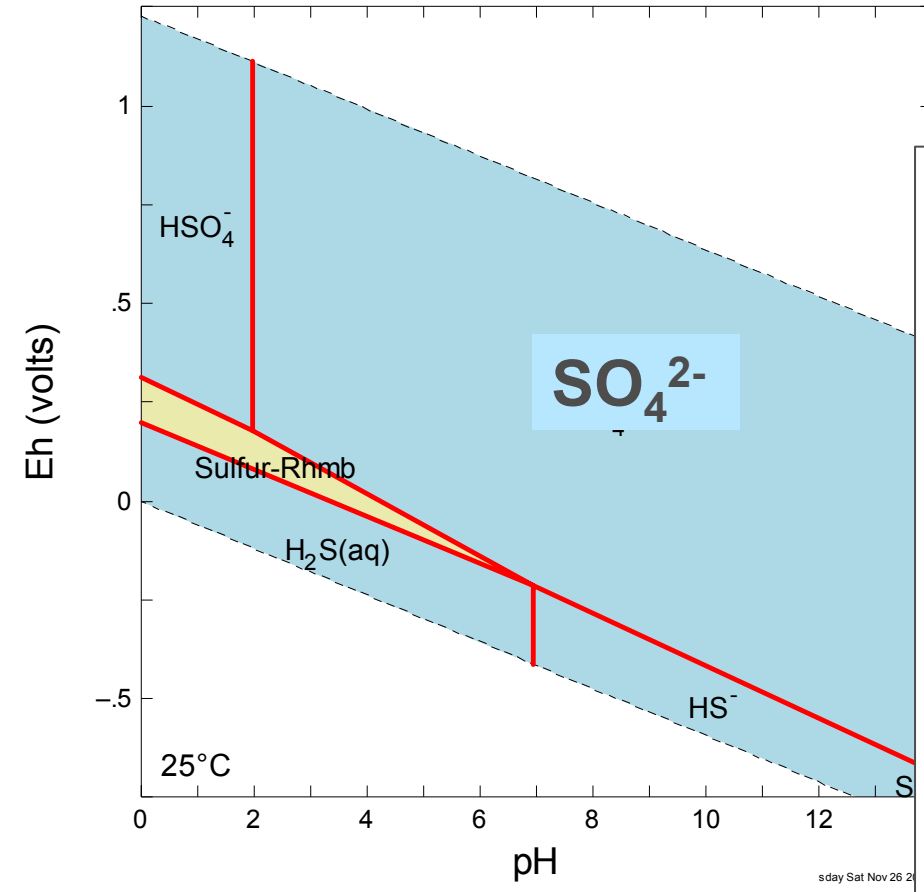
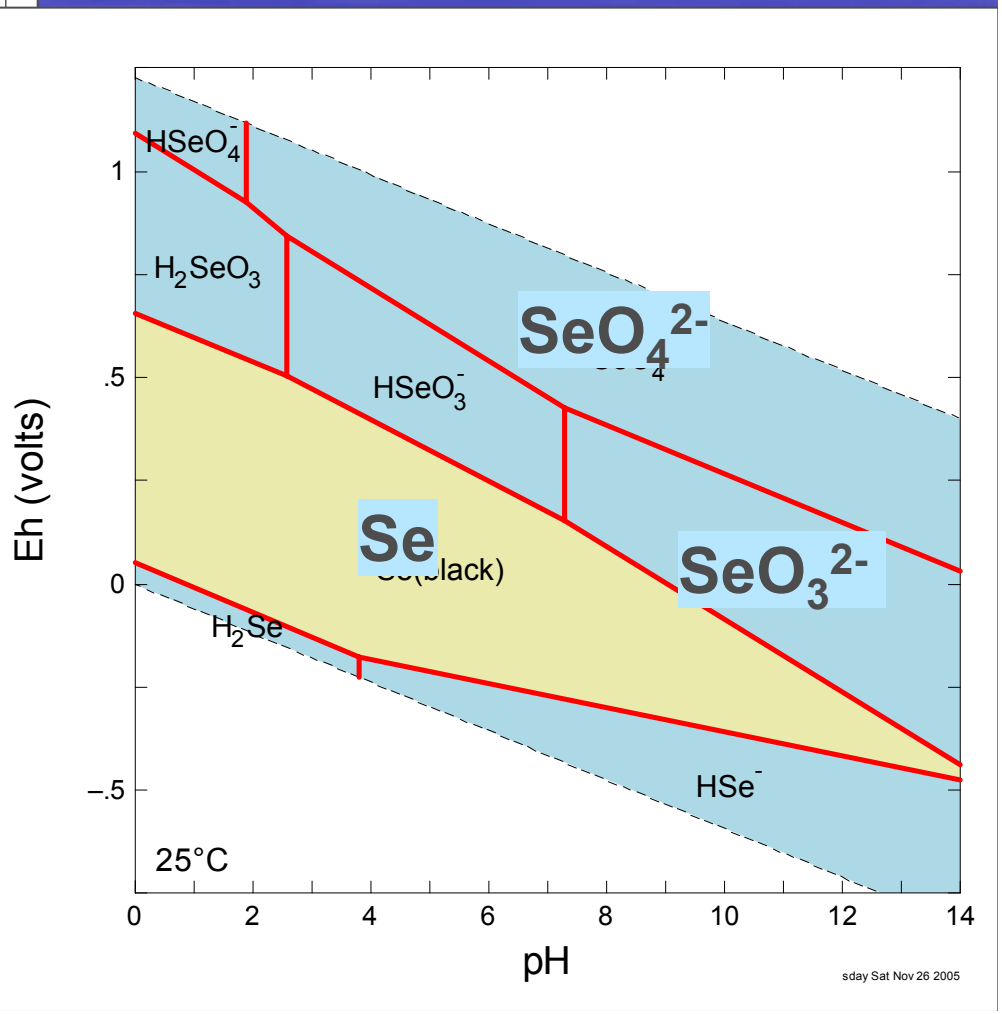
Mineralogy of Selenium

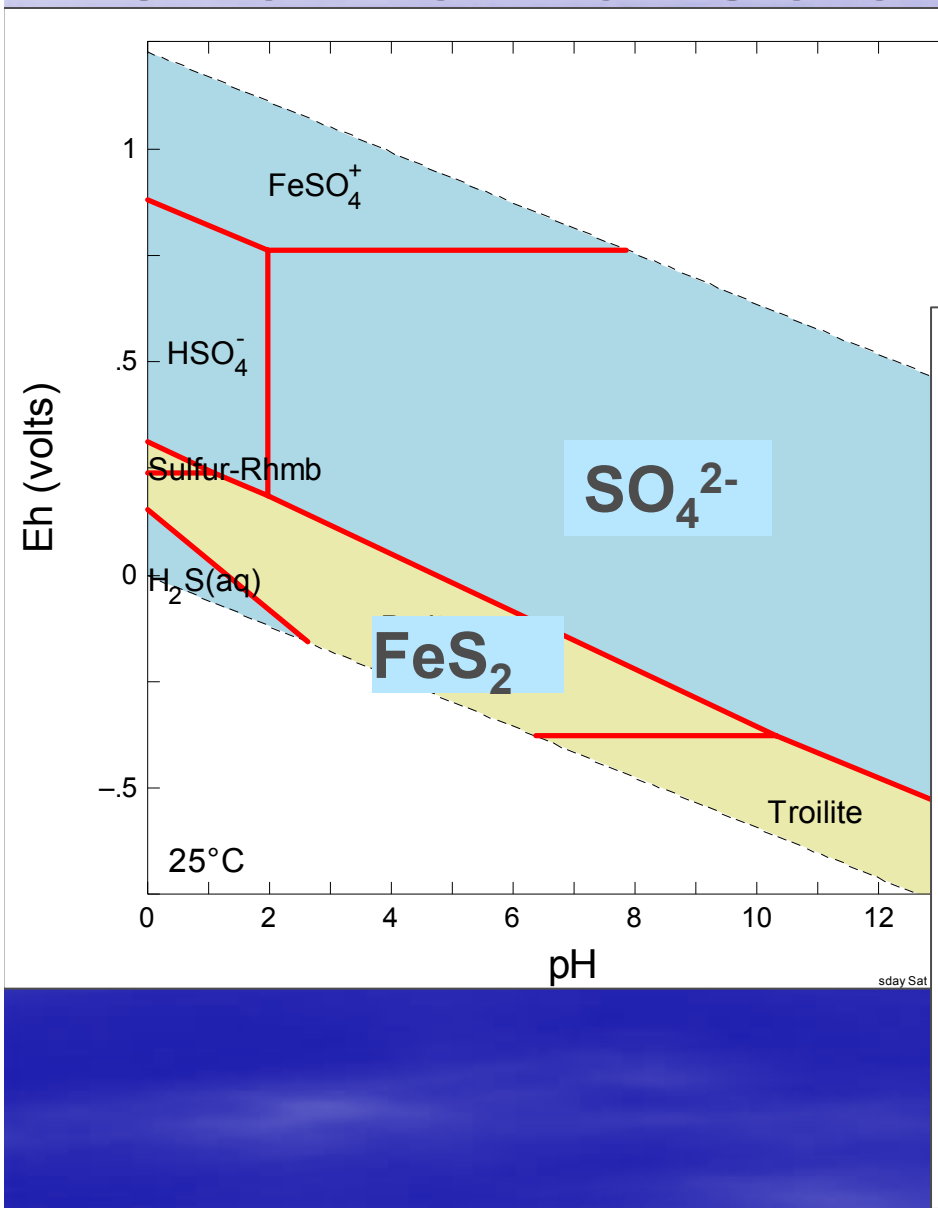
- Selenium and Sulphur Minerals (~100, compared to ~1000)
  - Native selenium
  - Sulphide (S^{2-}) analogues
    - Ferroselite – $FeSe_2$
    - Clausthalite – PbSe
  - Sulphate (SO_4) analogues
    - Rare lead selenates (SeO_4)
  - Sulphite (SO_3) analogues (~6 natural sulphites)
    - 20 lead, copper selenites (SeO_3)
- Organic sulphur and selenium association

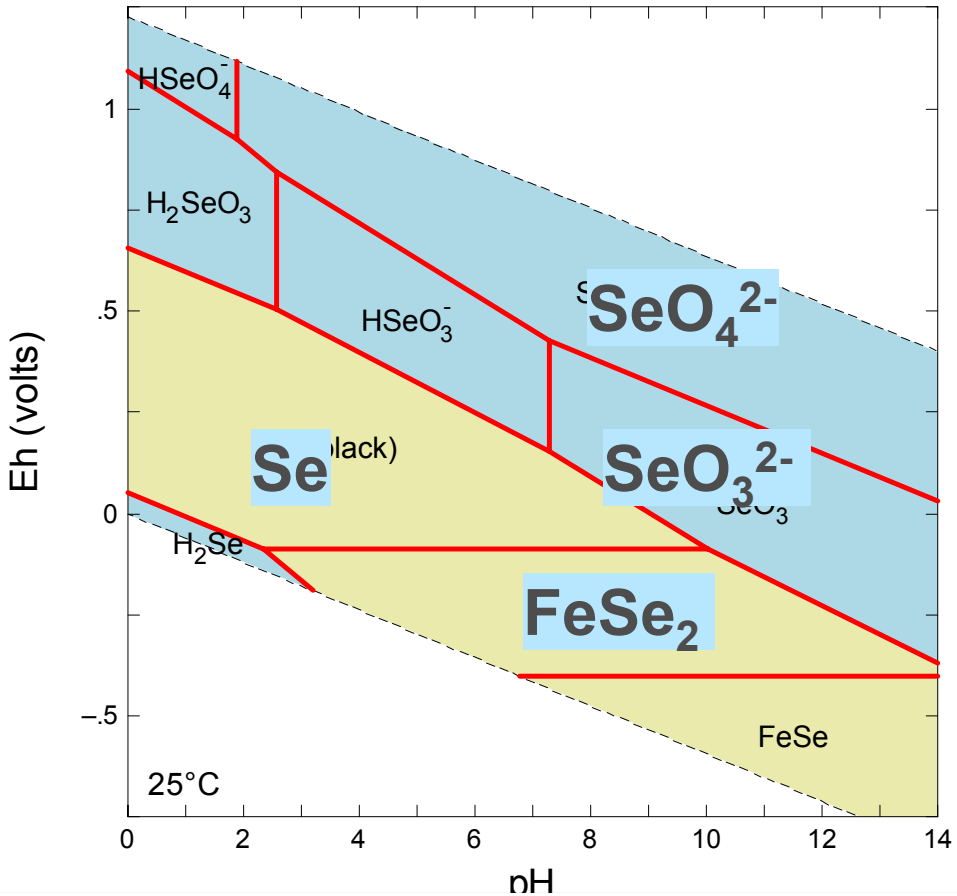
Overview of Selenium Geochemistry





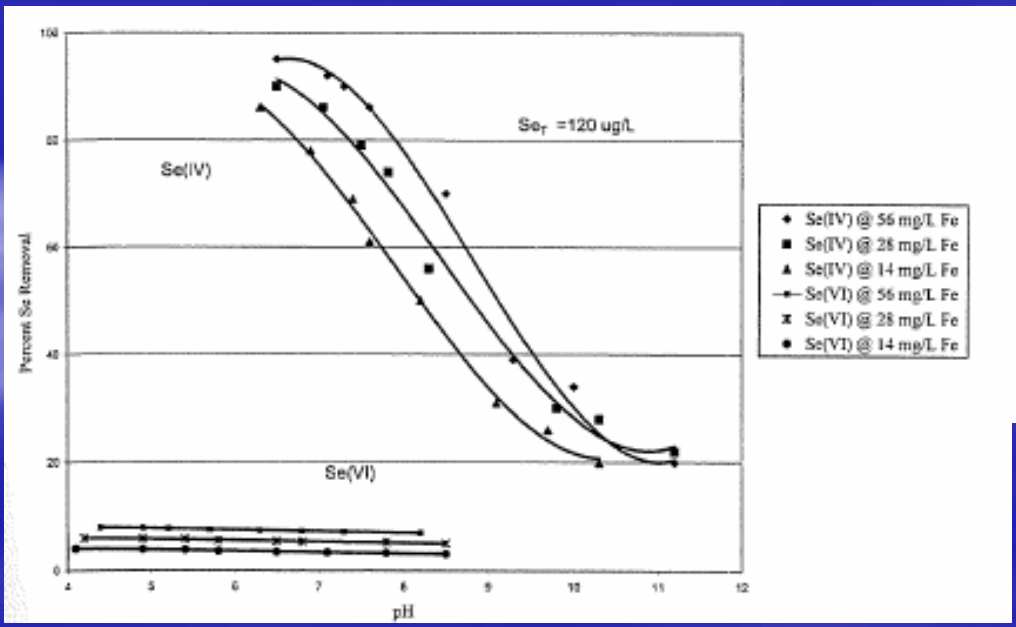
Overview of Selenium Geochemistry

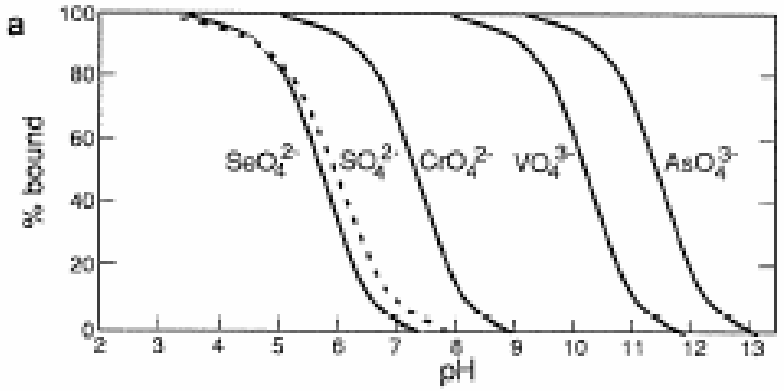




Overview of Selenium Geochemistry

- Adsorption
  - SeO_3 more adsorbable than SeO_4.
  - Oxyanions – expect sorbed fraction to decrease as pH increases.





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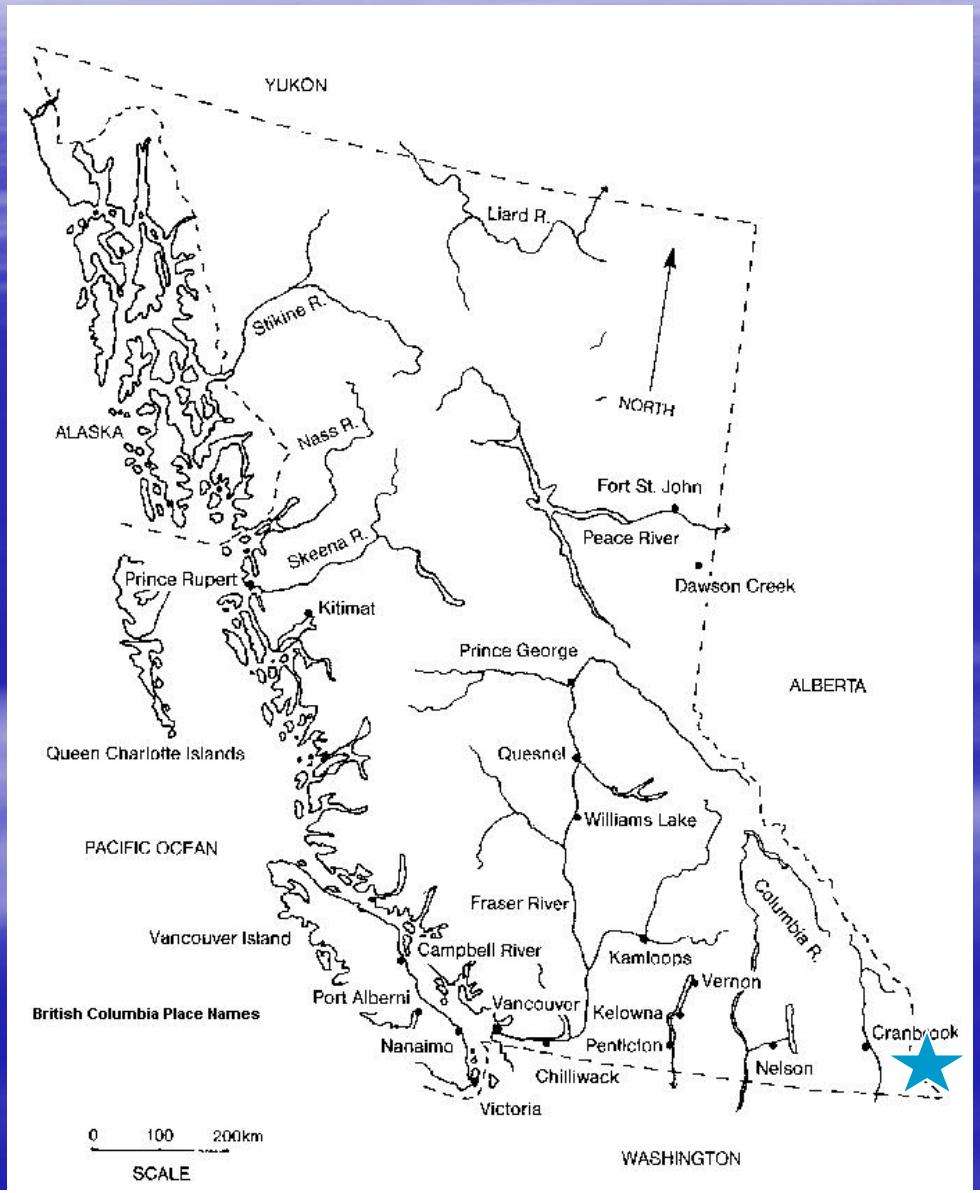
Summary of Selenium Geochemistry

- Analogous to sulphur
- Crustal abundance is very low compared to other important heavy elements.
- Pure selenium minerals are rare.
- Similar Eh-pH fields as sulphur but….
  - ….Se more readily reduced under natural conditions.
- Difference between Se(VI) and Se(IV) sorption effects.

Elkview Coal Se Assessment Project



- Elkview Coal
  - Open pits.
  - Waste rock.
  - Coarse Coal Reject.
  - Tailings.

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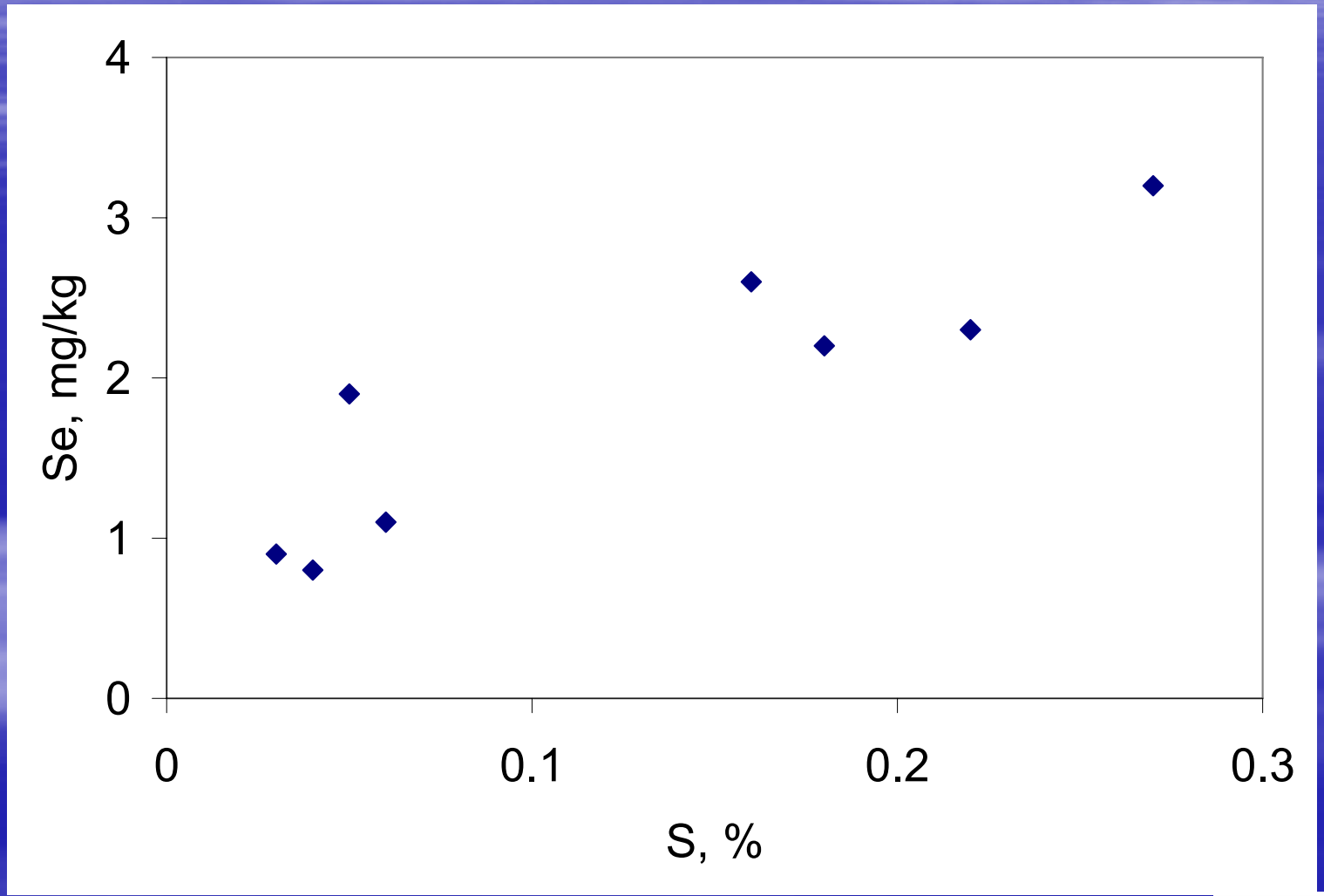
Se Content of Rock

Elkview Coal Se Assessment Project
Se Content of Rock



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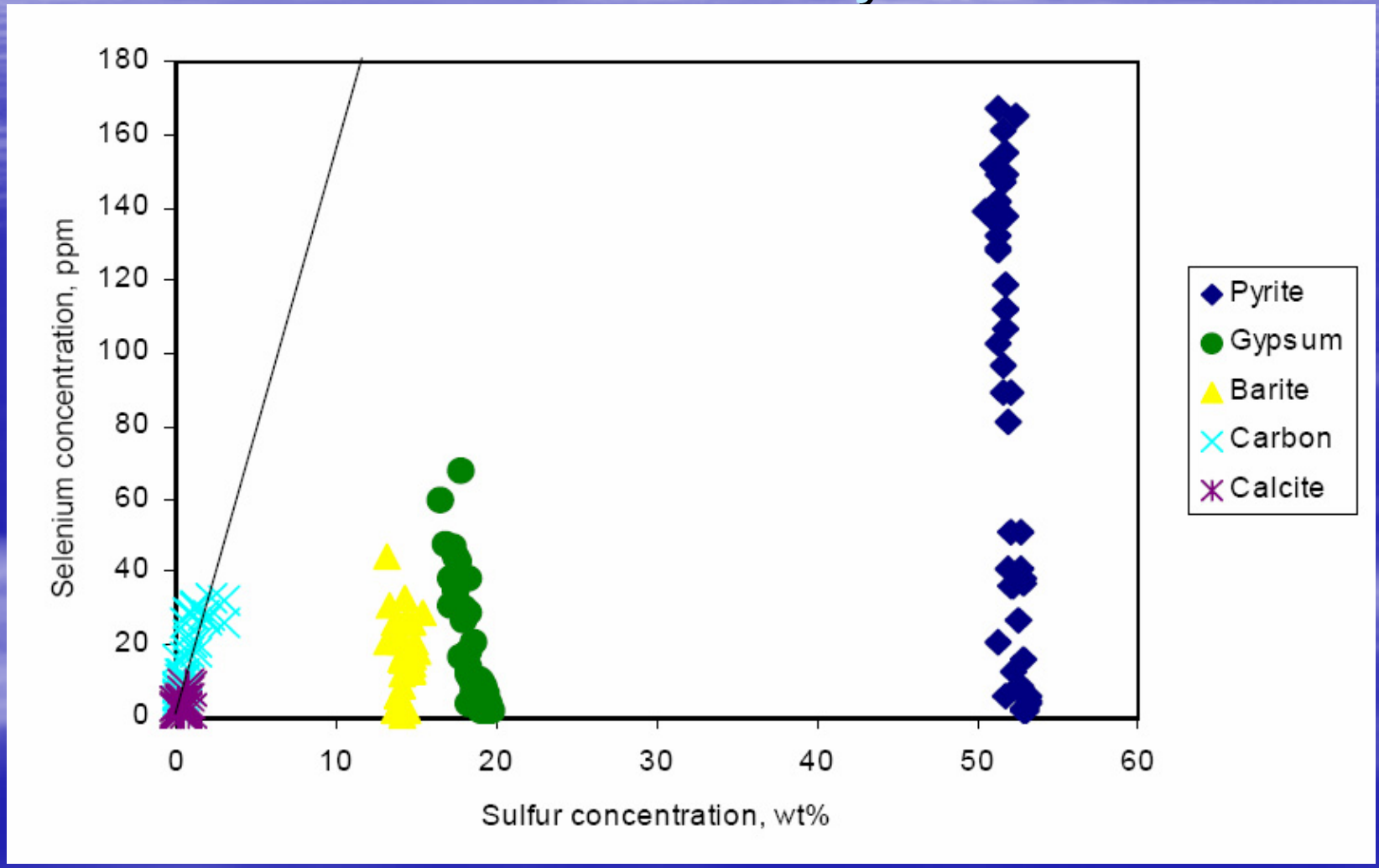
Elkview Coal Se Assessment Project Mineralogical Findings

- Sulphur minerals
  - Pyrite (FeS_2)
  - Gypsum ($CaSO_4.2H_2O$)
  - Barite ($BaSO_4$)
- Carbonaceous matter
- No pure Se minerals observed.

Elkview Coal Se Assessment Project

Se Content of Minerals by Laser Ablation



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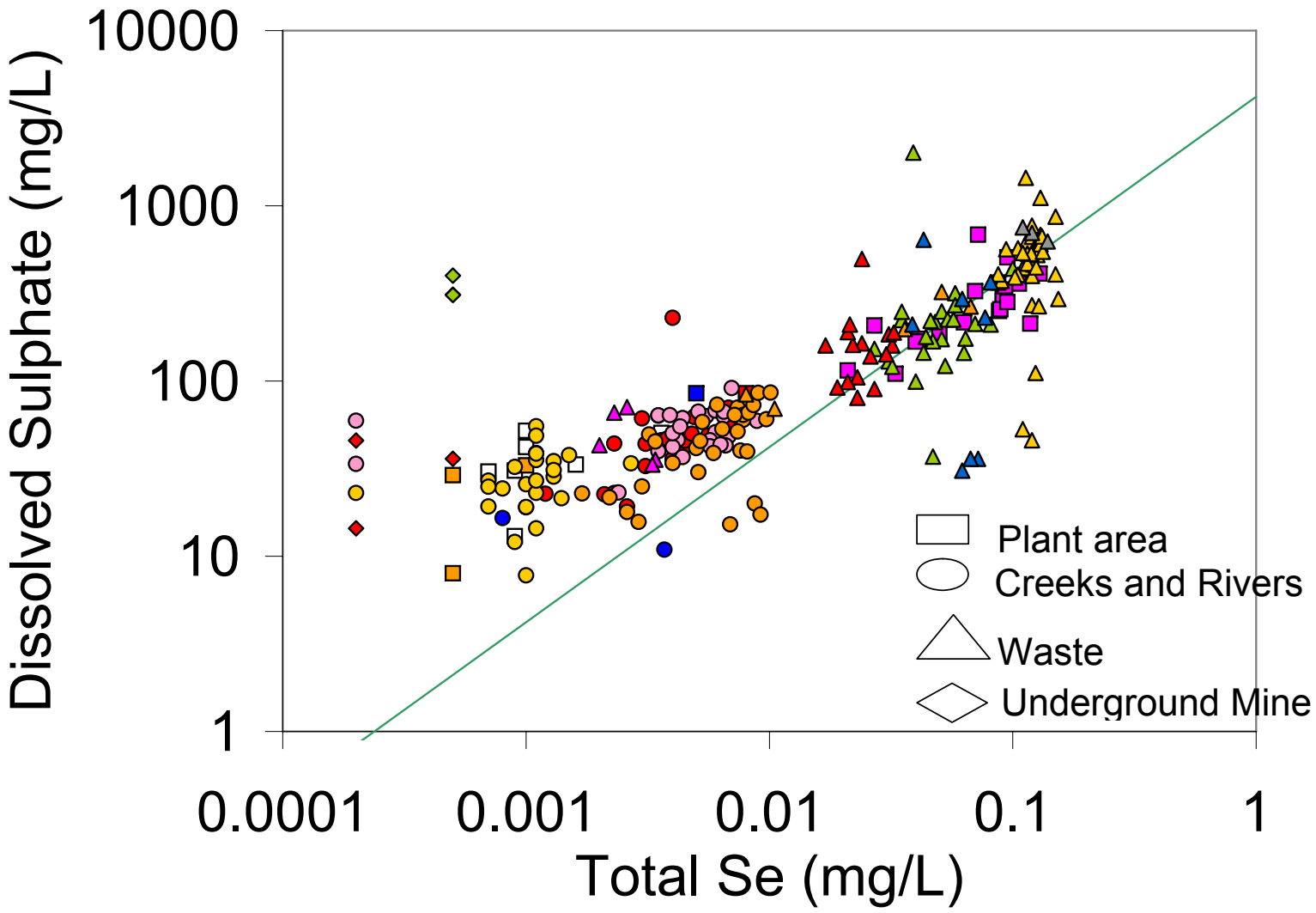
Elkview Coal Se Assessment Project
Se in Waters

- Waters
  - Non-acidic.
  - Ca-SO_4 dominated.
  - Se as SeO_4
  - Lowest Se (<0.0002 mg/L) in reduced waters.
  - SeO_3 detected in tailings pond water.
- Theoretical mineralogical controls
  - Calcite, dolomite, barite (over)saturated.
  - Gypsum and selenates well undersaturated

Elkview Coal Se Assessment Project
Se in Waters



Elkview Coal Se Assessment Project
Se in Seep Precipitates and Salts

- Calcite, dolomite, gypsum and anhydrite were primary components.
- Se content variable
  - 1 to 61 ppm selenium.
- Carbonate type precipitates had higher Se/S compared to gypsum precipitates.

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Elkview Coal Se Assessment Project Conclusions

- Se content is typical of coal-bearing sequences.
- Se contained mainly in several sulphate and sulphide minerals
- Se/S ratio in waters suggest common site source.
- Se/S in waters lower than rocks.
- Possible upper limit on Se concentrations.
- Se reduction occurs in reduced waters.

Prediction Thoughts

- Release of Se analogous to S:
  - Oxidation of iron sulphide releases sulphate.
  - Oxidation of selenide associated with sulphide releases selenate.
  - Dissolution of calcium or barium sulphate releases sulphate and selenate.

  - Since SO_4 and SeO_4 are both highly mobile under oxidizing conditions:
    - Se/S should be comparable in rocks and waters….

    ……..but not – why?

Prediction Thoughts

- An attenuation mechanism is implied for oxidized waters.
  - Co-precipitation?
  - Sorption?
  - Ion exchange?

Prediction Thoughts

- Co-precipitation candidates
  - Gypsum – but probably only precipitates from surface waters due to local evaporation.
  - Barite – Chemistry implies barite does precipitate
    - Barium from dissolution of carbonates and weathering of silicates.
    - Barite has low solubility.
    - Good potential Se sink.

Prediction Thoughts

- Sorption Mechanism
  - Requires Se as SeO_3.
  - Could occur near pyrite grains if Se goes through intermediate step as pyrite oxidizes.
  - Sorption with precipitated ferric hydroxide.

- Ion exchange
  - ??

Prediction Thoughts

- Reduced waters
  - Low Se concentrations most likely due to:
    - Sorption of SeO_3 by ferric oxides.
    - Precipitation of elemental Se.
    - Precipitation of selenides.
    - Sulphide co-precipitation.

Conclusions

- Se at Elkview Coal occurs in association with several sulphur minerals.
- Se is highly mobile but occurs at aqueous concentrations too low to form its own minerals.
- Attenuation of Se appears to be occurring perhaps by sulphate co-precipitation or sorption with ferric hydroxide.
- Reduction of selenium effective removal mechanism under reducing conditions.

Questions