Fluid-Rock Interactions at the Interface between Reservoir Rock and Cap Rock: An Experimental Case Study of Mineral Trapping

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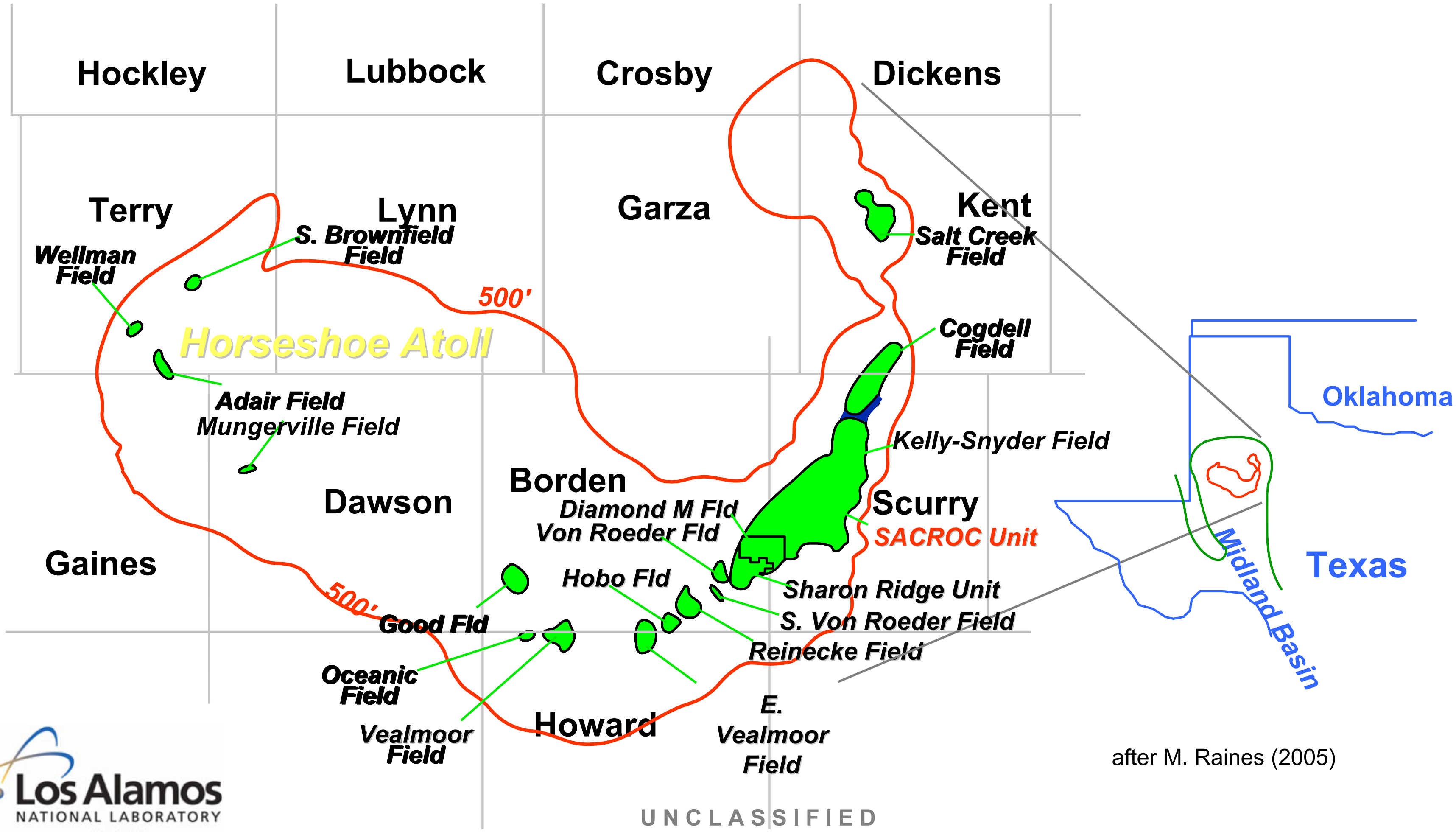
OUTLINE

- Introduction
- Core flood experiments
- Modeling and interpretation

GEOCHEMICAL TRAPPING

- Solubility trapping
  - CO_2(gaseous) + $H_2O \rightarrow H_2CO_3$(aq)
- Ionic trapping
  - 3 K-spar + $2H_2O$ + $2CO_2 \rightarrow$ Muscovite + 6 Quartz + $2K^+$ + $2HCO_3^-$
  - H_2CO_3 (aq) + OH^-(aq) $\rightarrow HCO_3^-$(aq)
  - HCO_3^-(aq) + OH^-(aq) $\rightarrow CO_3^=$ (aq)
- Mineral Trapping
  - $CO_3^=$(aq) + $Ca^{++} \rightarrow CaCO_3$ (solid)
  - $CO_3^=$(aq) + $Fe^{++} \rightarrow FeCO_3$ (solid)
  - $CO_3^=$(aq) + $Mg^{++} \rightarrow MgCO_3$ (solid)
  - CO_2 (aq) + K-spar + $Na^+ \rightarrow NaAl(CO_3)(OH)_2$ (Solid) + SiO_2 + K^+

SACROC LOCATION MAP



after M. Raines (2005)

Modified from Vest (1970)

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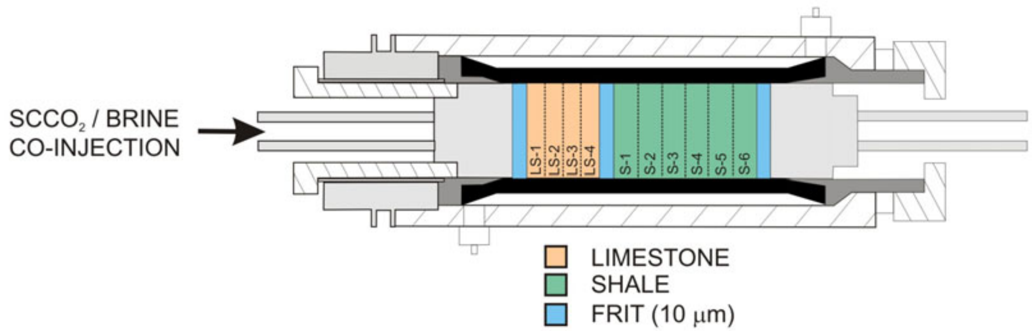
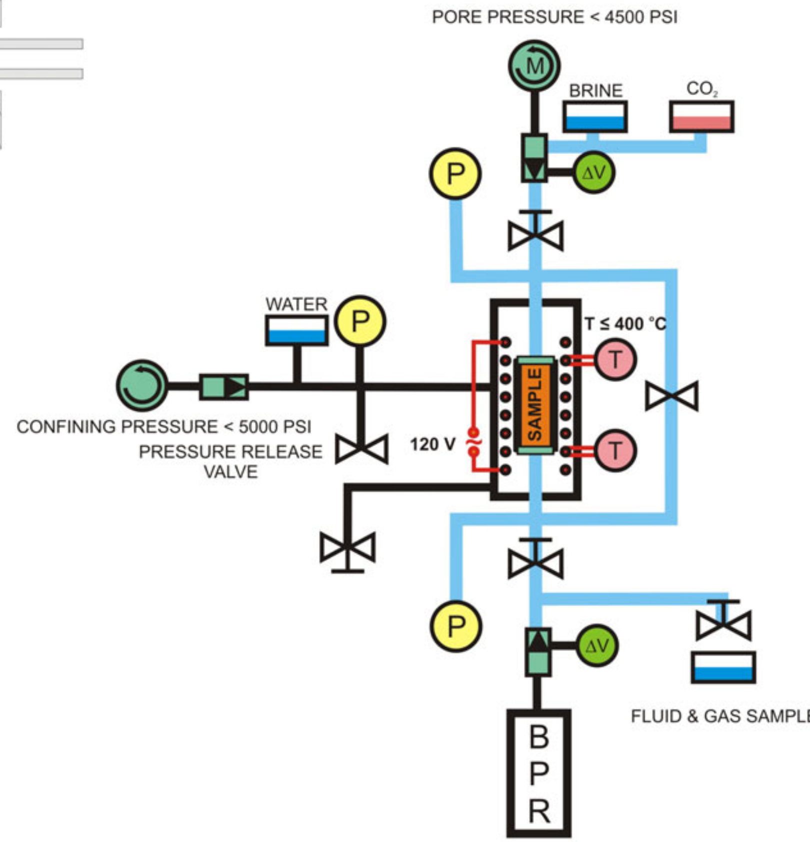
EXPERIMENTAL SETUP

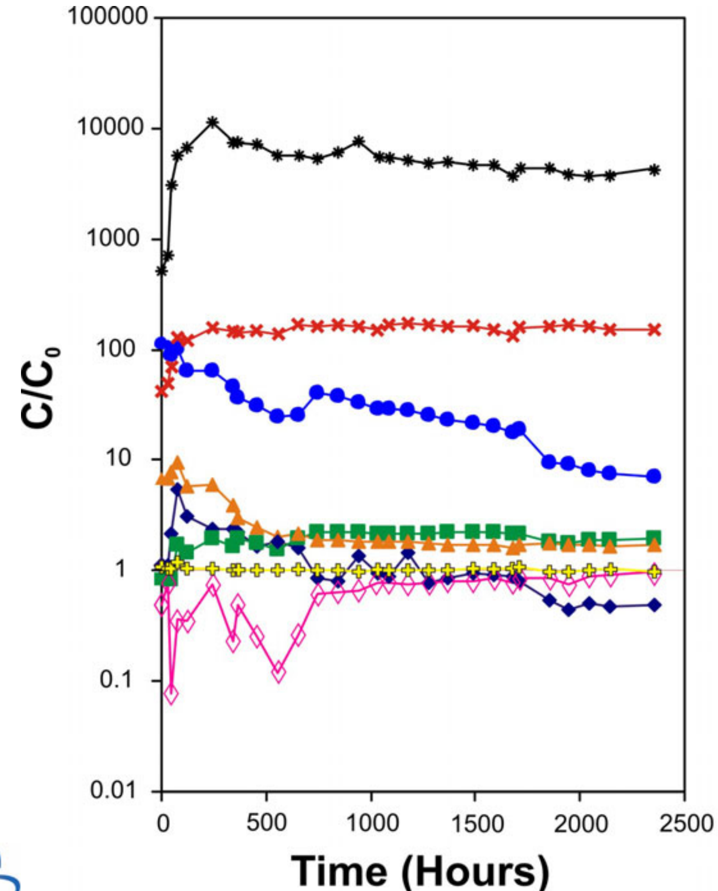




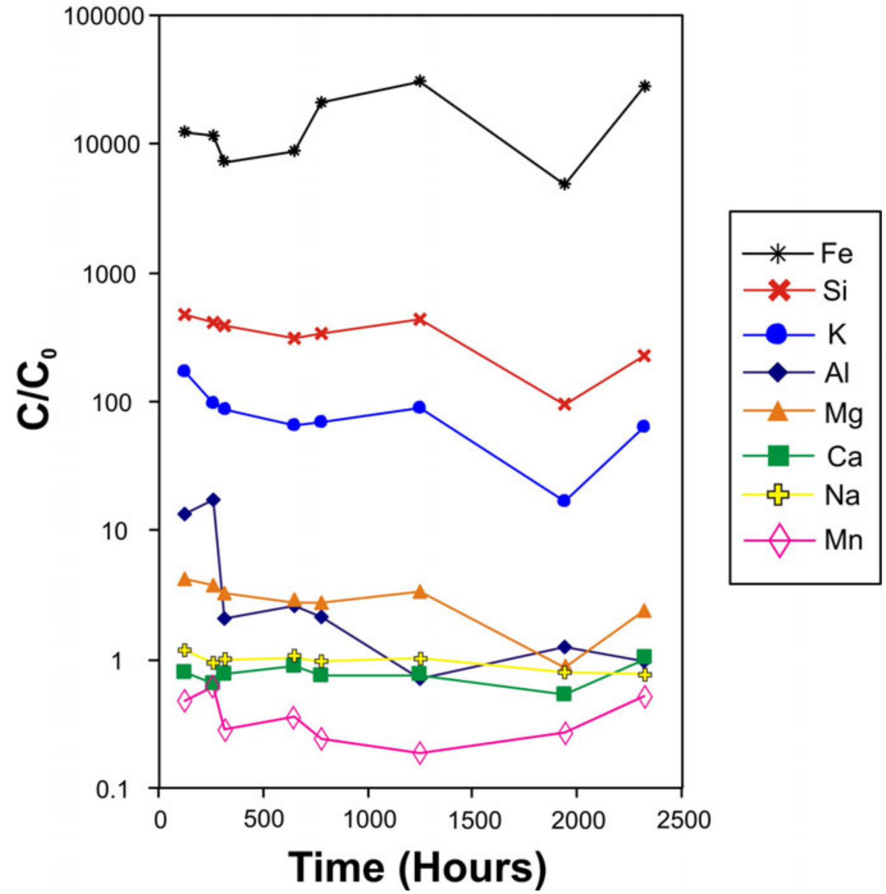
	EXPERIMENT I	EXPERIMENT II
TEMPERATURE	54 °C	200 °C
PRESSURE	2880 PSI	2880 PSI
DURATION	3263 HOURS	3263 HOURS
FLUIDS	$SCCO_2$& BRINE	$SCCO_2$& BRINE
ROCKS	LIMESTONE ILLITE-RICH SHALE	LIMESTONE ILLITE-RICH SHALE
FLOWRATE	$SCCO_2$: 4 µl min^{-1} BRINE: 8 µl min^{-1}	$SCCO_2$: 4 µl min^{-1} BRINE: 8 µl min^{-1}

FLUID CHEMISTRY

T=54 °C



T=200 °C



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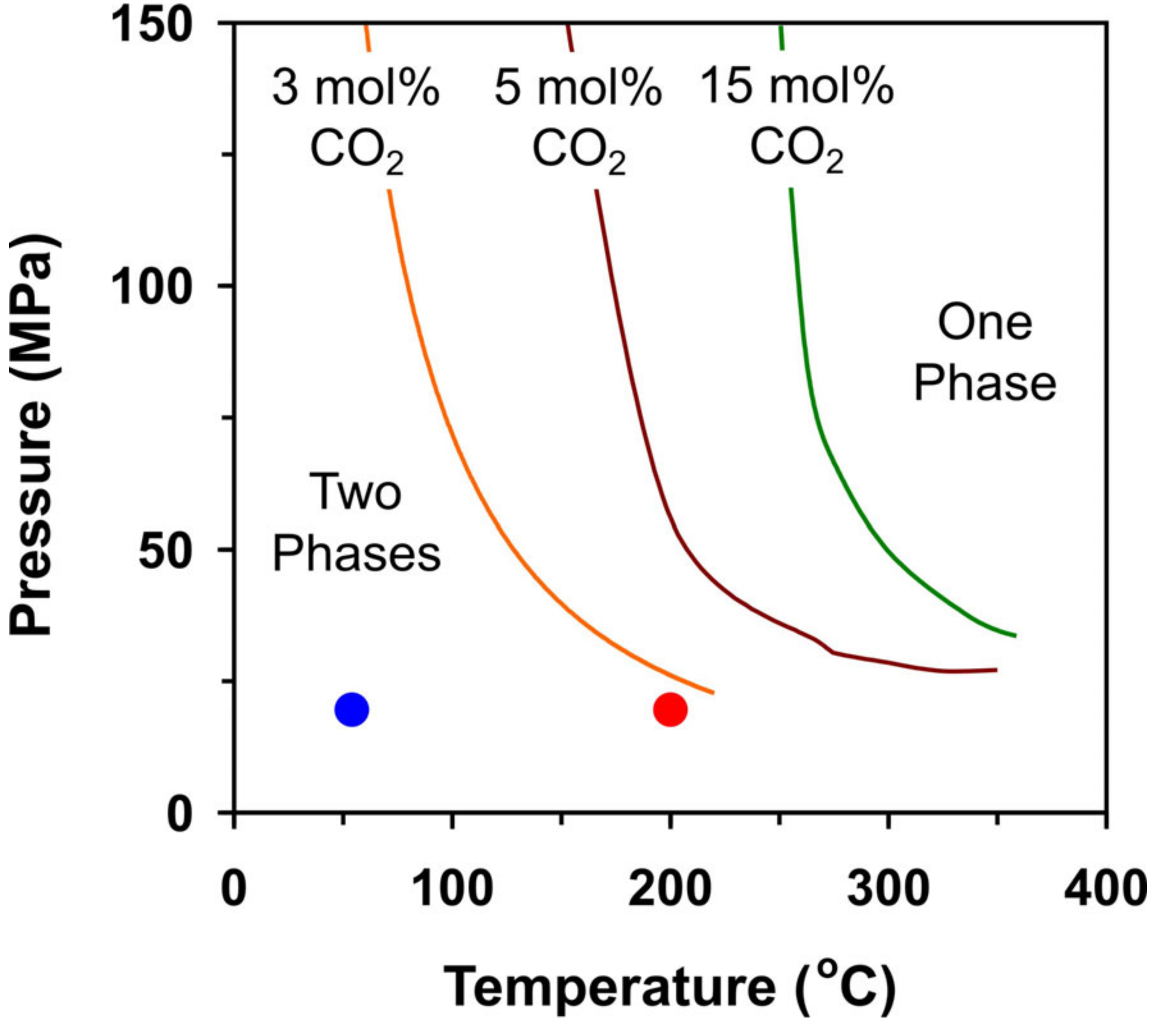
H_2O-CO_2 PHASE SPACE



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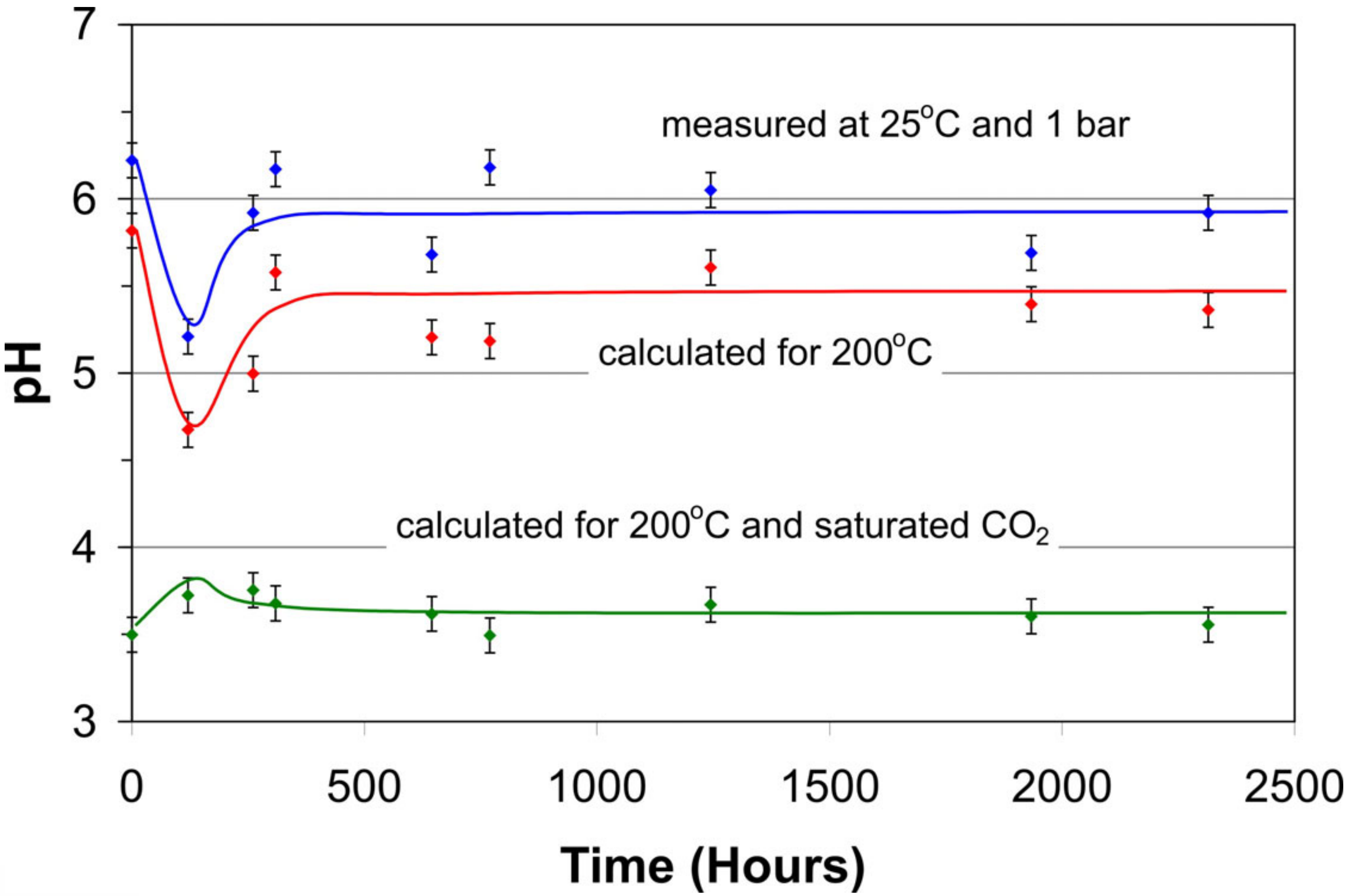
pH EVOLUTION OF BRINE (200ºC EXPERIMENT)



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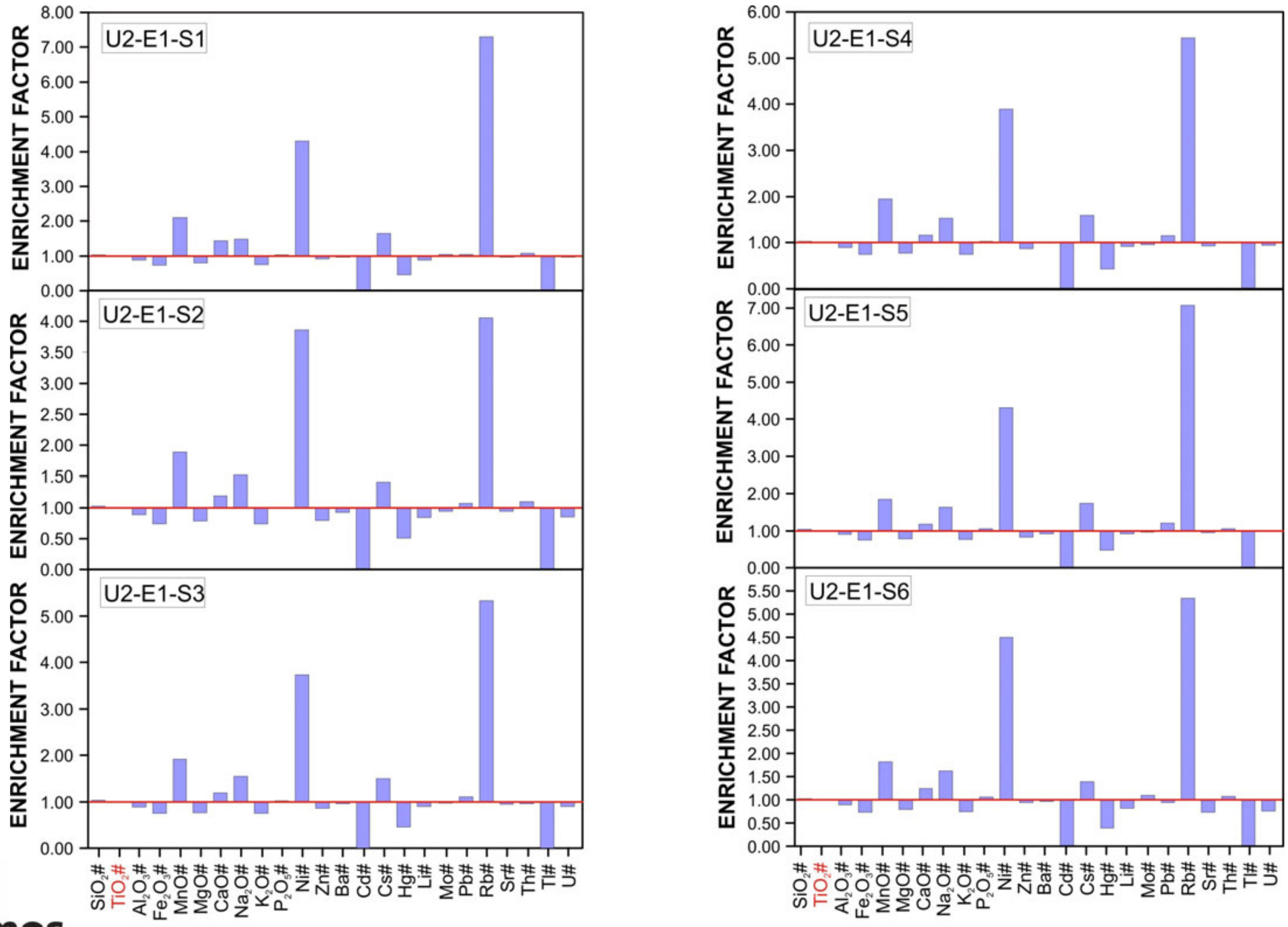
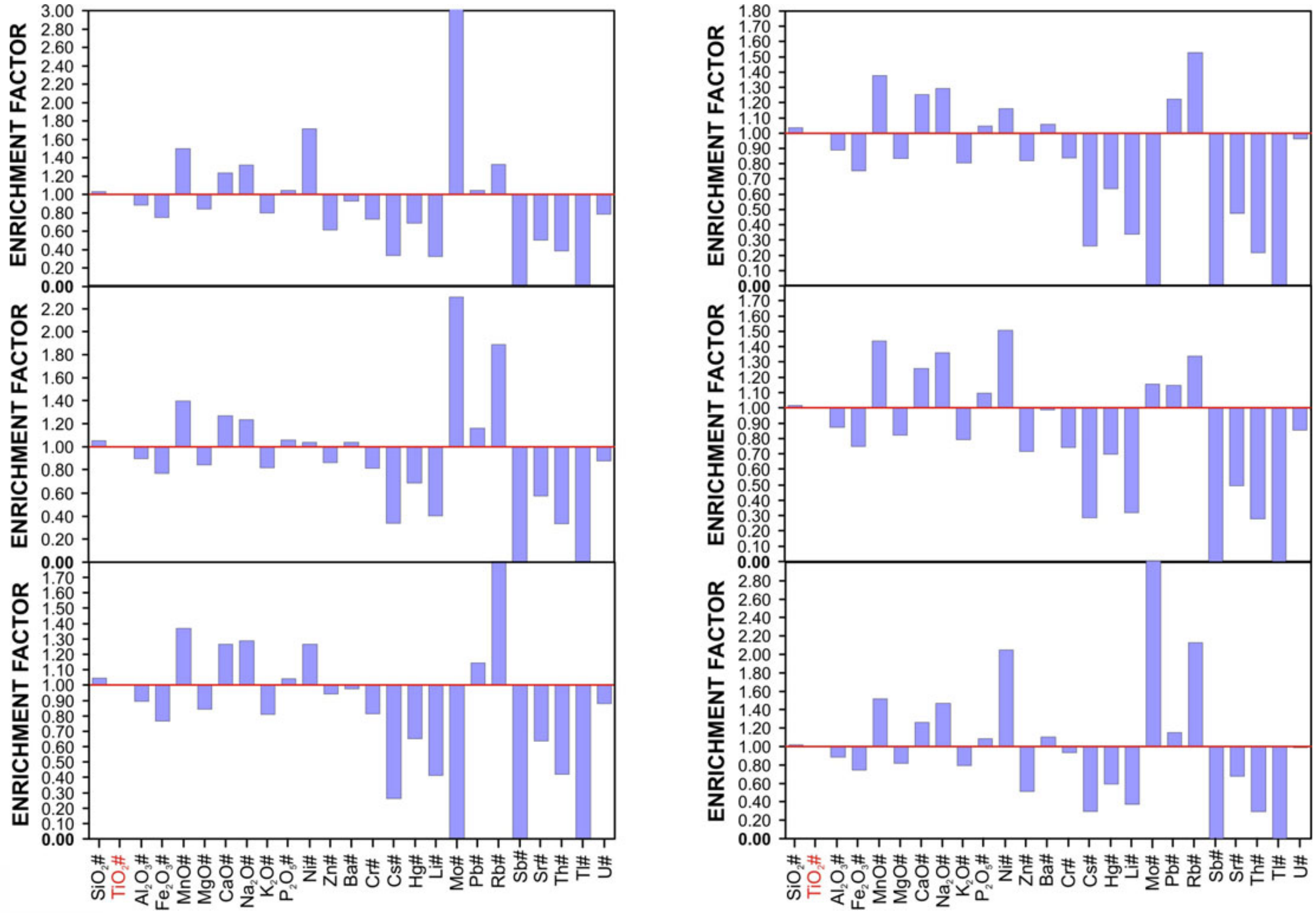
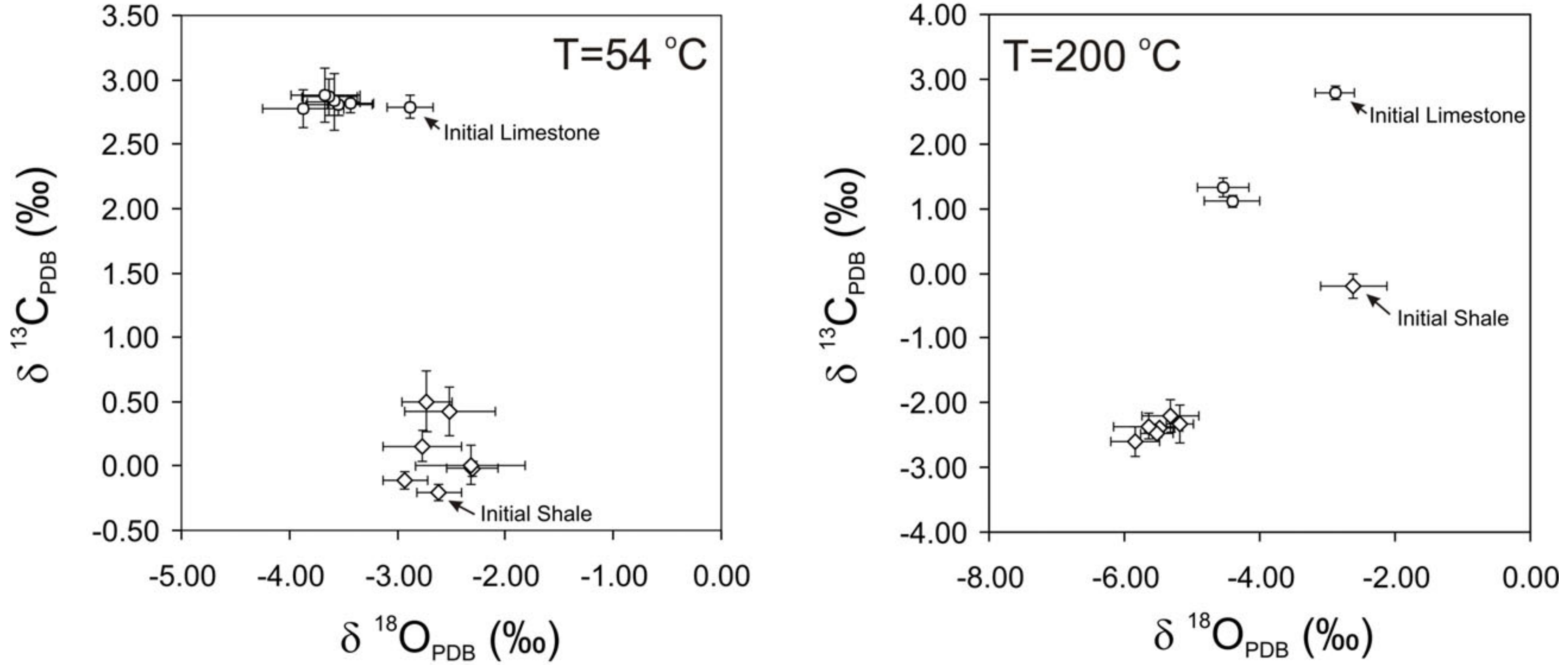
CHEMICAL CHANGES – ENRICHMENT FACTOR
54 ^{O}C EXPERIMENT $X=[A(X) / A(TiO_2)] / [L(X) / L(TiO_2)]$



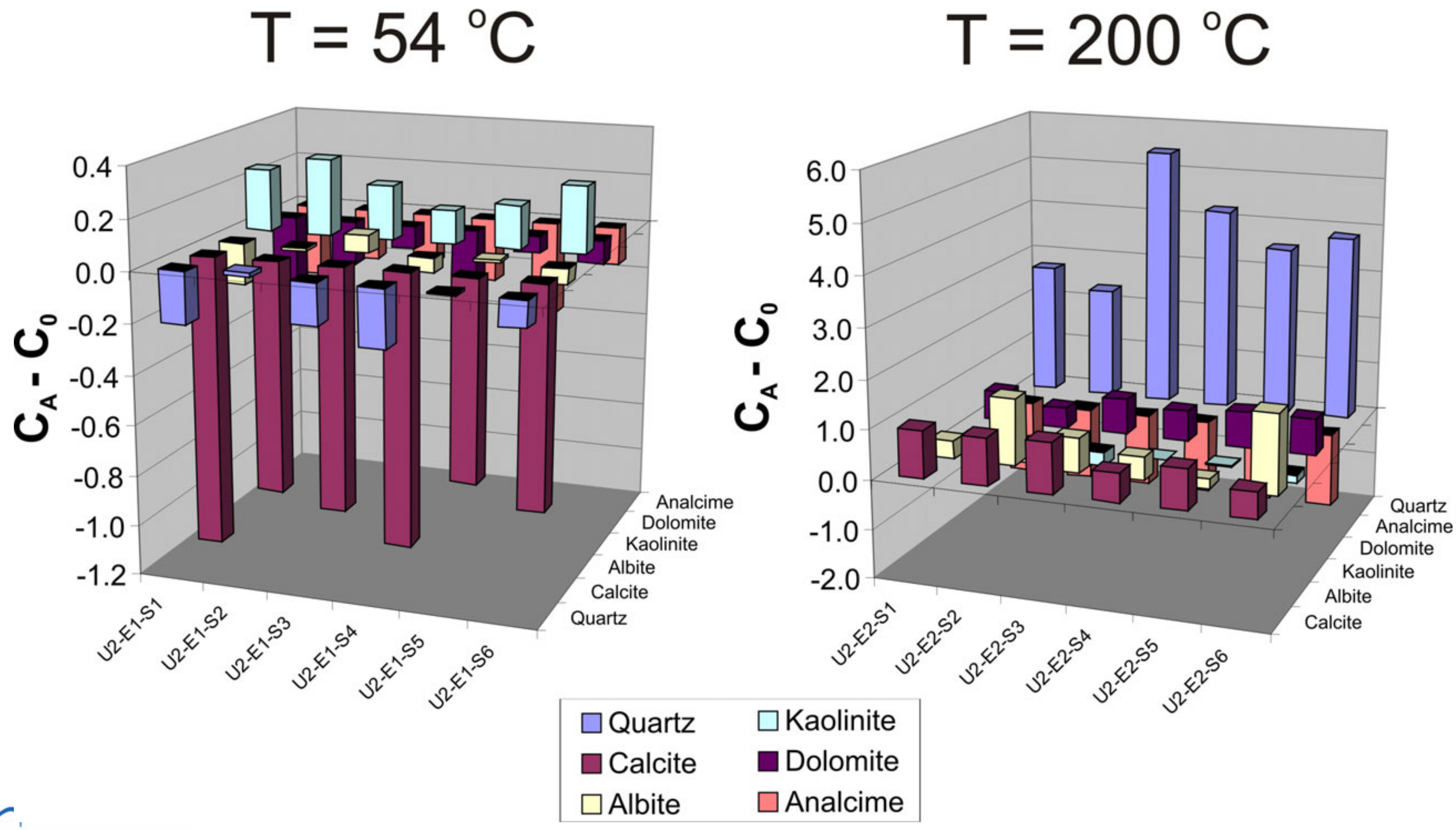
CHEMICAL CHANGES – ENRICHMENT FACTOR
200 ^{O}C EXPERIMENT $X=[A(X) / A(TiO_2)] / [L(X) / L(TiO_2)]$



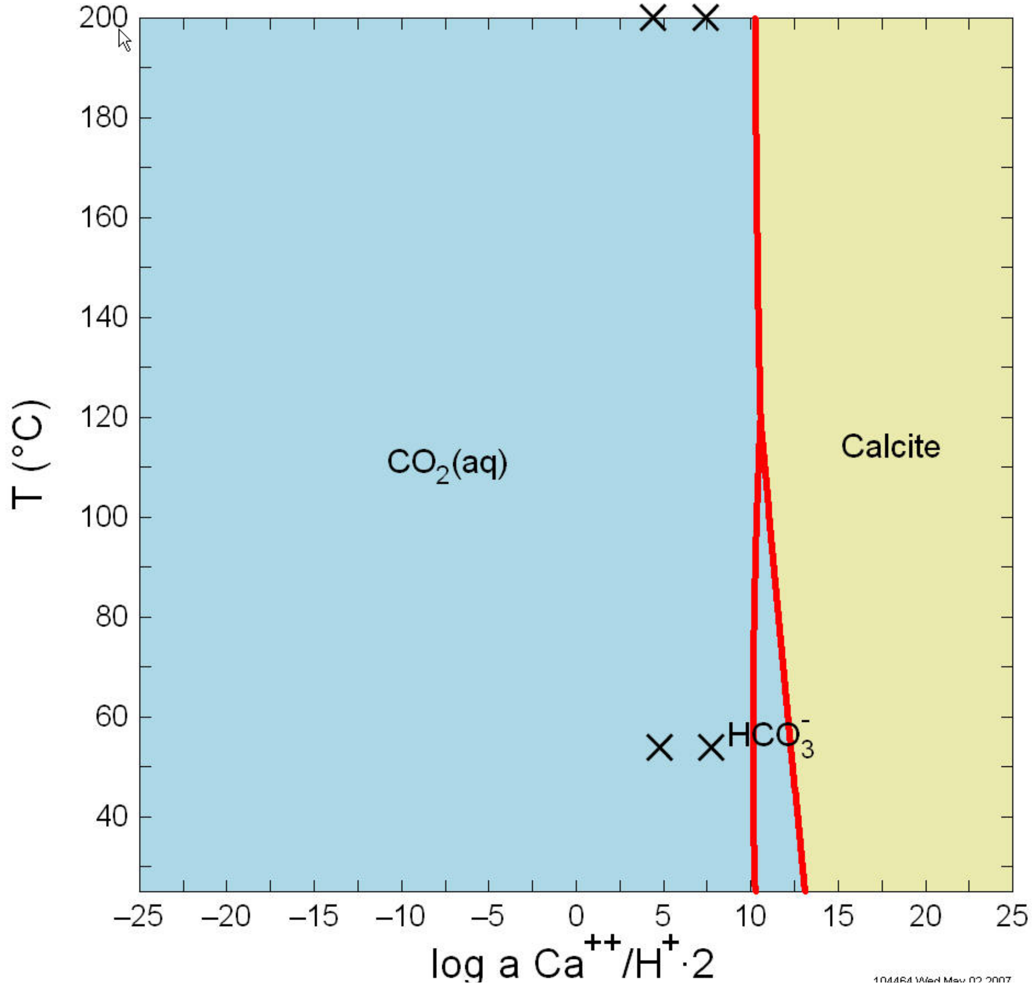
STABLE ISOTOPES



MINERALOGY


T = 54 °C
T = 200 °C
$C_A - C_0$
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
U2-E1-S1
U2-E1-S2
U2-E1-S3
U2-E1-S4
U2-E1-S5
U2-E1-S6
Analcime
Dolomite
Kaolinite
Albite
Calcite
Quartz
$C_A - C_0$
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
U2-E2-S1
U2-E2-S2
U2-E2-S3
U2-E2-S4
U2-E2-S5
U2-E2-S6
Quartz
Analcime
Dolomite
Kaolinite
Albite
Calcite
Quartz
Calcite
Albite
Kaolinite
Dolomite
Analcime

GEOCHEMICAL MODELING



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CONCLUSIONS

- The experiment performed at in-situ reservoir conditions (54 °C / 2880 psi) was dominated by the dissolution of rock-forming minerals such as calcite whereas calcite and quartz precipitated at elevated temperatures (200 °C / 2880 psi).

- The isotopic signature of $\delta^{13}C$ is not affected by the mechanism controlling the dissolution of carbonates at 54 °C but shows a strong change due to precipitation of calcite during the experiment performed at 200 °C.

- Carbon and oxygen isotopes have been shown to be sensitive to small amounts of carbonate precipitates.

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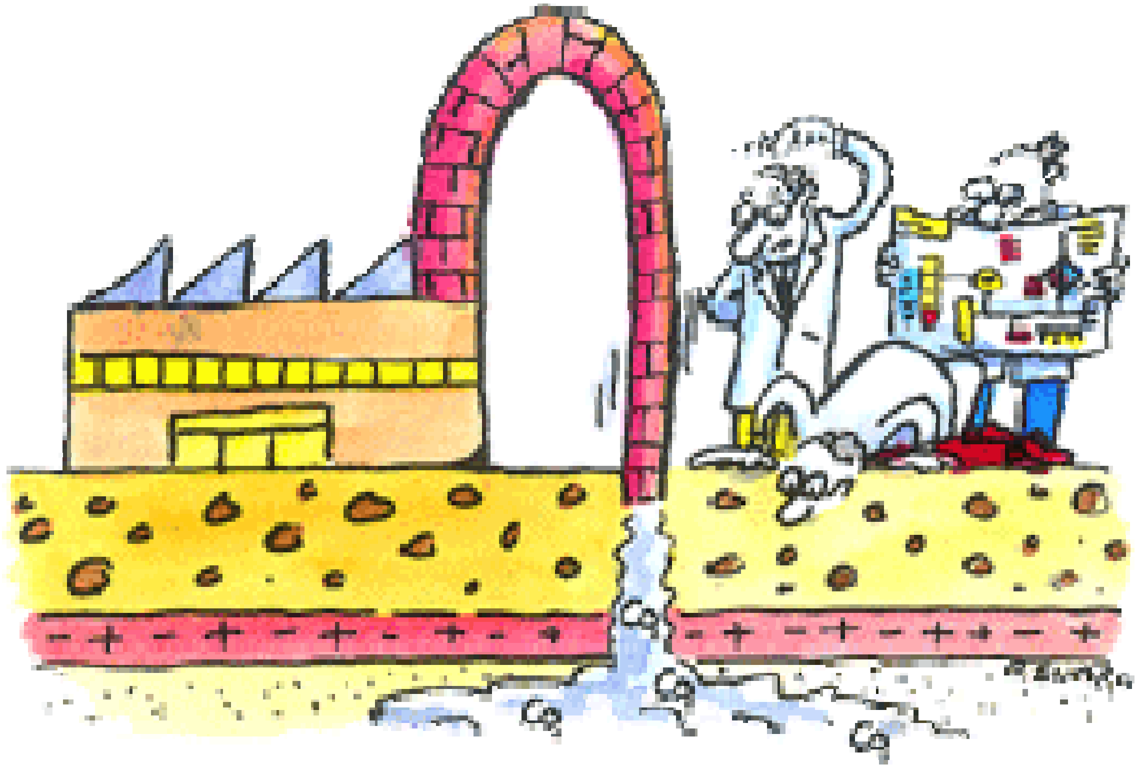

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Thank you very much for your attention!

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