Geochemistry of Icy-World Interiors

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Intro

- Fluid-rock interaction in icy moons and dwarf planets
  - Product of internal heating
- Present day ratio of these materials, probable they were beginning materials

Enceladus. NASA

Ceres. Wikipedia

Purpose

- Interaction between fluid and rock
- Alterations to fluid and rock
- Indications of habitability to life forms
  - Oxidation of minerals provides food source for organisms

deepoceanfacts.com

Why I chose this topic

- Planetary studies have fascinated me
- Inspiration from GSA
- Little previous experience

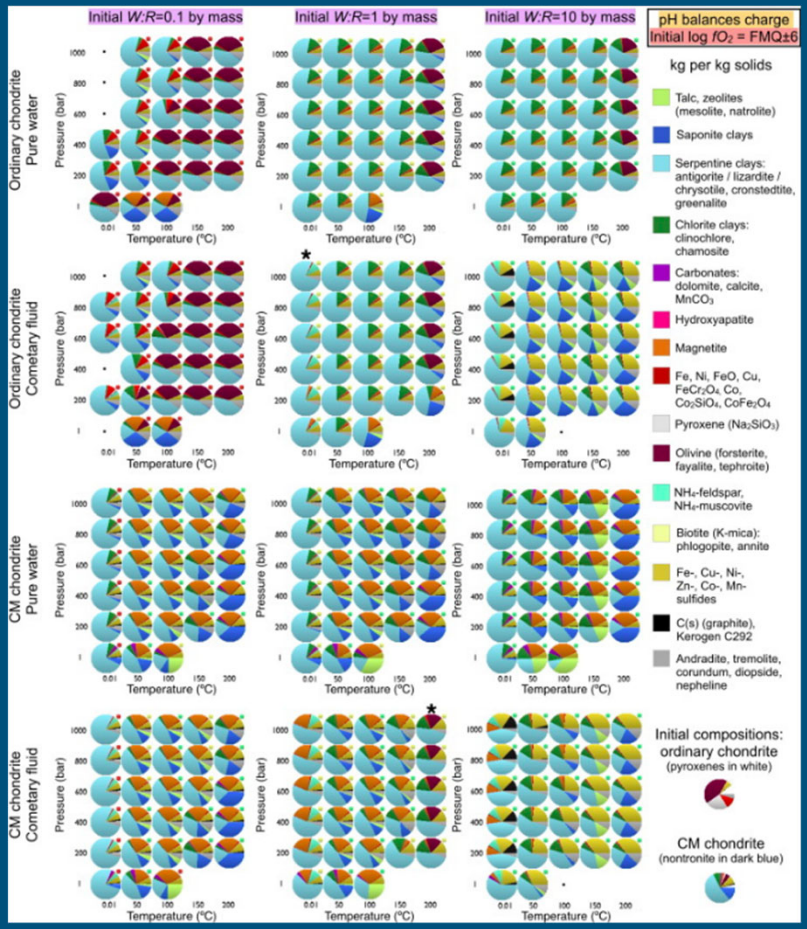
Source of Data

1. PHREEQc modeling using core.dat (Castillo-Rogez et al., 2017)

2 . Specific asteroid/chondrite composition (Agee et al., 2018)

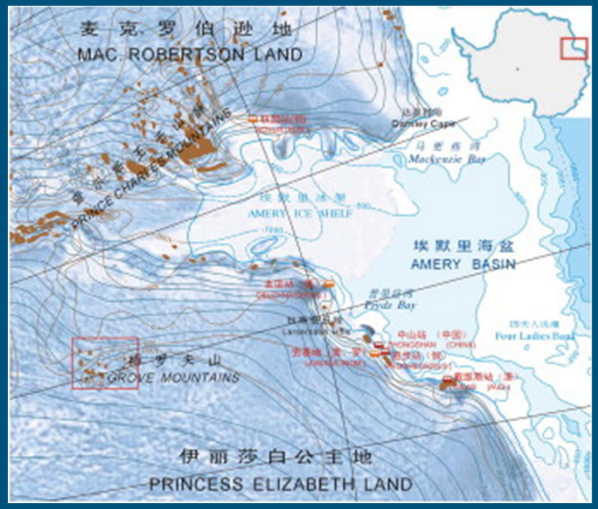
Previous Work (Castillo-Rogez et al., 2017)

- Took mineralogical concentrations of average chondrite
  - Equilibrate with pure water and cometary fluid
- Variables: water/rock ratios, temperature, pressure, pe



Previous Work (Agee et al., 2018)

- Samples are a chondrite known as Grove Mountains (GRV) 020043
  - Part of parent asteroid
  - Derived from protoplanetary disk or differentiated body
- Collected in Grove Mountains, Antarctica



Locality of sample. sciencedirect.com

Method of Modeling

- Ran core.dat on asteroid composition
  - Based upon proportions for 1 mole of rock material
  - Pure water and cometary fluid
    - Cometary fluid: 5 mol% C, 2 mol% N, 0.5 mol% S, and 520 ppm by mass Cl
  - Baseline: 0.01ºC, 0.01 atm, 10 kg of fluid
- Looked for changes in the fluid and rock
  - Changes in pH
  - Ionic strength comparisons (compare to earth systems as well)
  - Distribution of species

Results - Pure Water

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

                                    pH  =  11.845      Charge balance
                                    pe  = -12.708      Adjusted to redox equilibrium
                           Density (g/cm≥)  =   0.99960
                                Volume (L)  =   9.99051
                        Activity of water   =   1.000
                  Ionic strength (mol/kgw)  =   1.109e-03
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- Ionic Strength: synonymous with rivers and lakes (Faure, 1998)
- Distribution of Species
  - Cations and metals are free ions or bonding almost specifically with O, OH, or H

*Note: Due to proportionary rock composition of 1 mole, all minerals undersaturated and with relatively low molality

Results - Cometary Fluid

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

                                    pH  =    8.156      Charge balance
                                    pe  =   -9.364      Adjusted to redox equilibrium
                           Density (g/cm≥)  =    0.95886
                                Volume (L)  =   11.19859
                        Activity of water  =    0.929
                  Ionic strength (mol/kgw)  =    7.334e-01
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- Ionic Strength: Synonymous with seawater (Faure, 1998)
- Much more neutral solution
- Much more variation is distribution species
  - Notably those present in fluid: C, S, N, and Cl

Comparison

Pure Water After Equilibration

Species	Molality
OH-	8.593e-04
H+	1.480e-12
H2O	5.553e+01
Al	1.686e-07
AlO2-	1.686e-07
HAlO2	2.715e-12
AlOH+2	6.300e-23
Al+3	5.707e-29
Ca	1.381e-06
Ca+2	1.381e-06
Co(2)	9.597e-18
Co+2	9.597e-18
K	7.825e-06
K+	7.825e-06
Mg	1.008e-09
Mg+2	1.008e-09
Mo	1.102e-05
MoO4-2	1.102e-05
Na	1.103e-03
Na+	1.086e-03
NaHSiO3	1.699e-05
NaOH	1.624e-07

- Other notables:
  - More speciation, but less Fe in CF
  - Similar Na
  - Same compounds of Si, but difference ordering of which phase is more abundant
    - Greater molality in pure water

Cometary Fluid After Equilibration

Species	Molality
OH-	2.421e-07
H+	8.660e-09
H2O	5.553e+01
Al	2.141e-18
AlO2-	2.029e-18
HAlO2	1.113e-19
AlOH+2	3.040e-22
Al+3	2.652e-24
Ca	8.992e-03
Ca+2	8.985e-03
CaCl+	6.179e-06
CaCl2	6.023e-08
CaCO3	1.853e-33
CaCH3COO+	5.476e-35
CaSO4	3.454e-39
K	1.998e-03
K+	1.998e-03
KCl	2.192e-07
KCH3COO	1.079e-36
KSO4-	1.872e-40
Mg	3.747e-02
Mg+2	3.734e-02
MgCl+	1.377e-04
MgCO3	5.765e-33
MgCH3COO+	9.382e-34
MgSO4	2.222e-38

Conclusions

- Pure water was very basic
  - Few species in solution
- Cometary fluid equilibrated with a more diverse solution
  - Greater number of species
  - Basic solution, but more neutral than pure water
  - More to react with in initial solution
- Interaction of rock with cometary fluid leads to more alteration in icy world setting

References

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Questions?