Seafloor eruption and hydrothermal fluid chemistry

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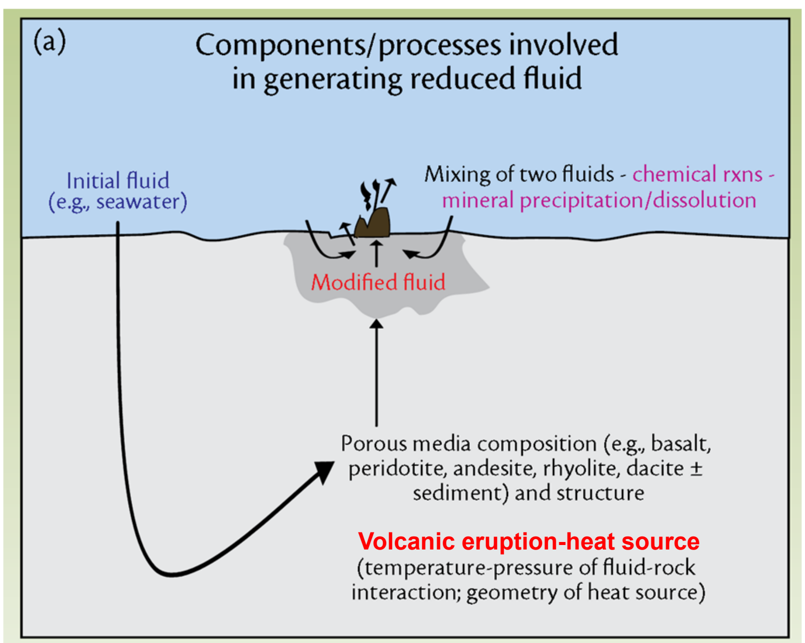


Tivey (2007)

Outline

- What can chemical compositions of fluids tell us?
- Sampling methods
- Generic hydrothermal vent system
  - Generic answers to the question → eruption event
- Data interpretation
  - Mixing curve
  - Time series→ changes after eruption
  - Phase separation
- Future study

What can chemical compositions of fluids tell us?

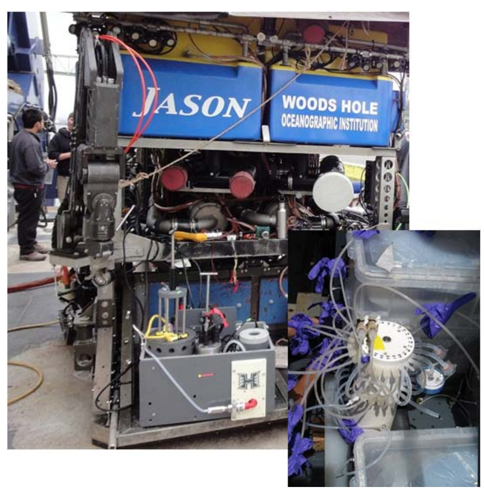
- **Sample quality**
- **Elemental cycle**
  - **Major sink**
  - **Major source**
- **Biology**
  - **Nutrients**
  - **Chemical energy**
  - **pH**
- **Geology**
  - **Water-rock ratio**
  - **Reaction temperature**
  - **Reaction depth**

Fluid sampling-1

CTD- Rosette
Niskin/Go-Flo water sampler

Fluid sampling-2

UH-GeoMicrobe Sled
“long-term monitoring”



UH-MPS system
“Large volume fluid & particle sampling”

Fluid sampling-3

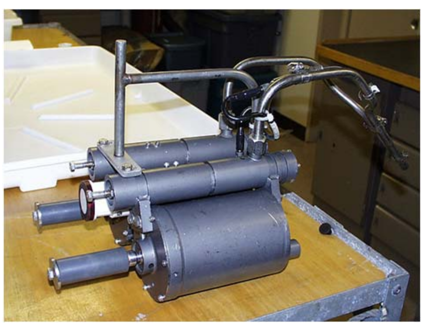
MBARY-”OSMO”
Long term, very small volume fluid

PMEL-”Beast”
~300mL fluid and particle sampling

http://www.pmel.noaa.gov/vents/nemo1998/science-news.html

http://www.pmel.noaa.gov/vents/nemo2006/logbook/images/sep04img2.html

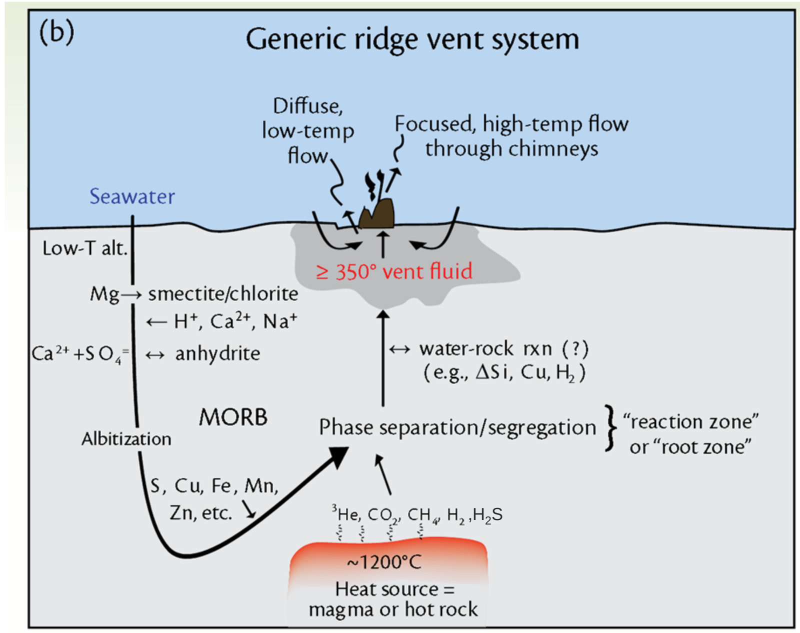
Fluid sampling-4



- Ti Major

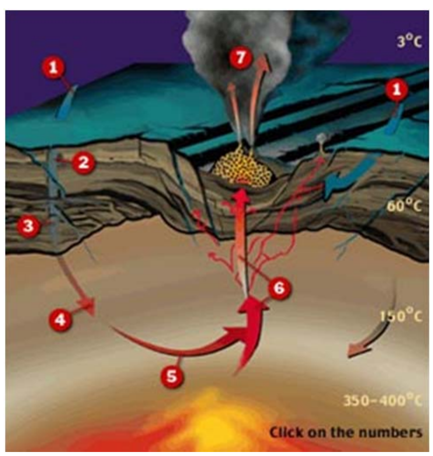
- Gas tight sampler

http://oceanexplorer.noaa.gov/explorations/05lostcity/background/sampling/media/gastights3.html



Tivey (2007)

Hydrothermal vents → plumes



- http://www.divediscover.whoi.edu/vents/vent-chemistry.html#

What can chemical compositions tell?

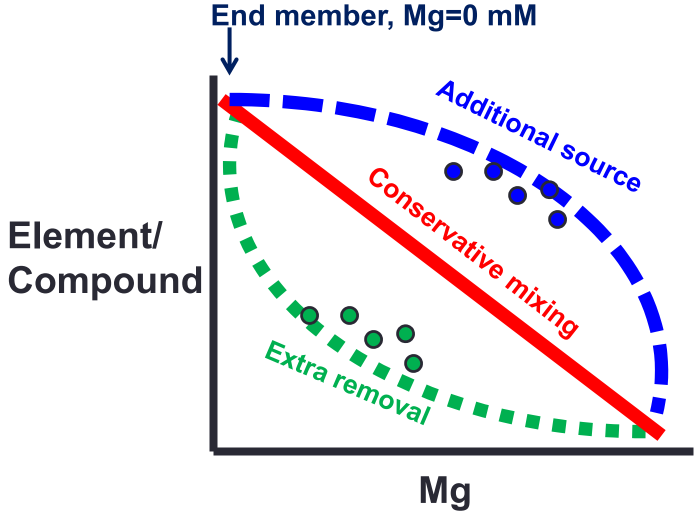
- $[Mg^{2+}]$ → sample integrity
- $[Cl^{-}]$ → phase separation → reaction depth
- $[SO_4^{2+}]$ → biological activity (sulfate reduction) & mineral precipitation
- $[H_2S]$ → biological activity (sulfate reduction)
- $[NH_3]$ → biological activity (sulfate reduction)
- $[Fe^{2+}]$, $[Mn^{2+}]$,[Si], $[Li^{+}]$→ water/rock reaction
- $[Li^{+}]$ → water-rock ratio

Redox status

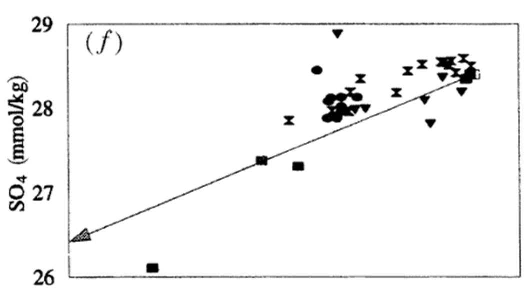
- **Red**uction-**Ox**idation state

	Reduced species (e-donors)	Oxidized species (e-acceptors)
# Electron	Rich	Depleted
S	H_2S	SO_4^{2-}
C	CH_4	CO_2
N	NH_3	NO_3^-
Fe	Fe^{2+}	Fe^{3+} : Fe-oxide, brownish particles

Mixing curve

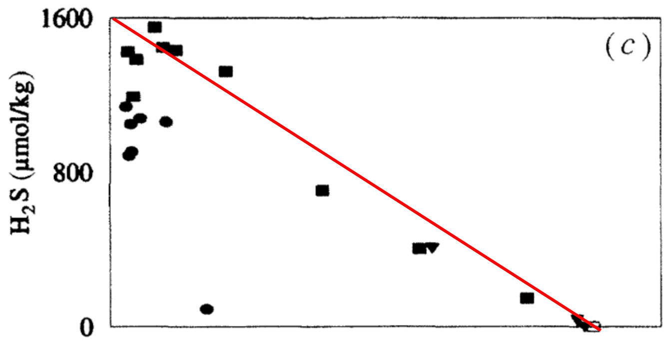


SO_4^{2-} v.s. Mg^{2+}



- Straight line – conservative mixing line
- Data **__above__** the line → **addition** of SO_4^{2-}
  - Oxidation of sulfide to form sulfate
  - Dissolution of sulfate bearing mineral

H_2S v.s. Mg^{2+}

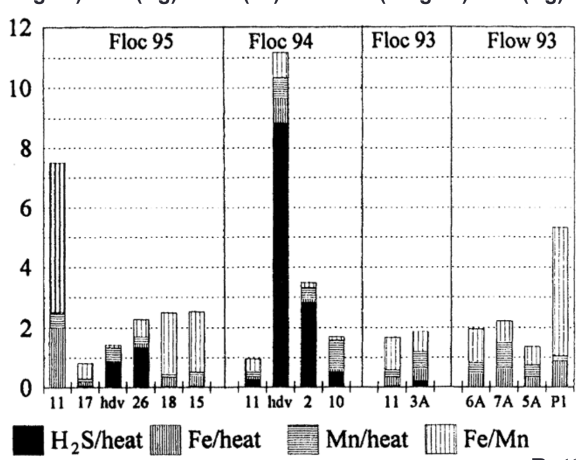


- Straight line – conservative mixing line
- Data **below** the line → **removal** of H_2S
  - Oxidation of sulfide
  - Precipitation of sulfide bearing mineral

Element/Heat

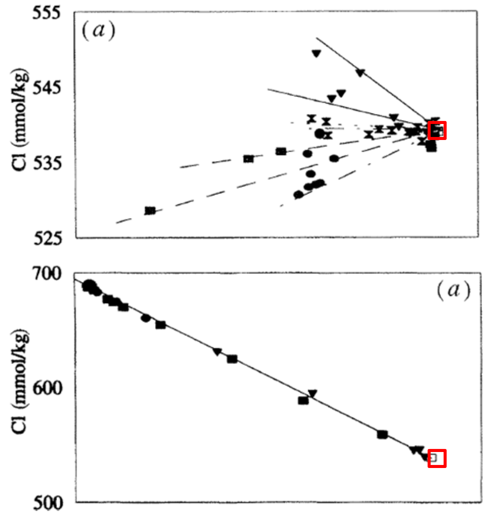
- **Heat is calculated as**

$$H_{(J)} = C_{(J/Kg/°C)} \cdot M_{(Kg)} \cdot \Delta T_{(°C)} = 4200_{(J/Kg/°C)} \cdot M_{(Kg)} \cdot \Delta T_{(°C)}$$



Butterfield (1997)

Cl^- v.s. Mg^{2+}

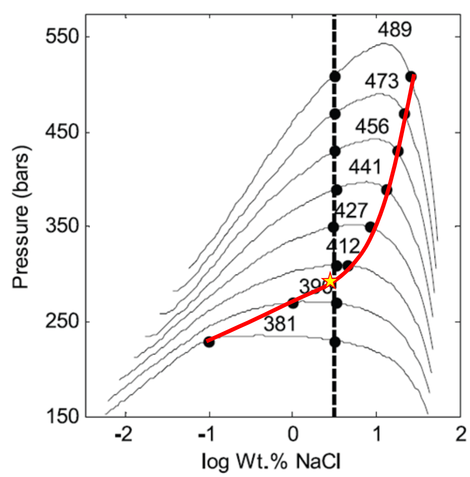


- Flow and Floc vents (low T diffuse)
- Source vents (high T)

Butterfield (1997)

Phase separation

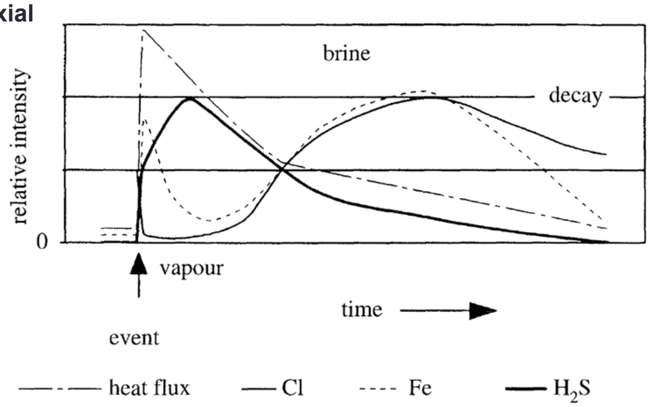
- **T, P below critical point** ☆ **(407^{0}C, 298 bars)**
  - **Sub-critical**
  - **Boil of H_2O**
  - **Form low [Cl] vapor**
- **T, P above critical point**
  - **Super-critical**
  - **Condensation of H_2O**
  - **Form high [Cl] brine**



Larson et al. (2009)

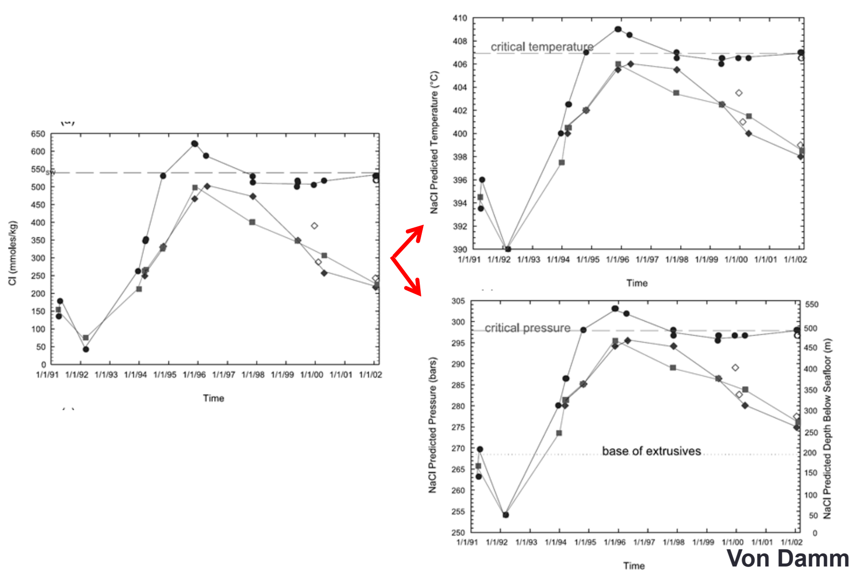
Vapor dominate → brine dominate

- Endeavor Main Field
- N. Cleft segment
- Co-Axial



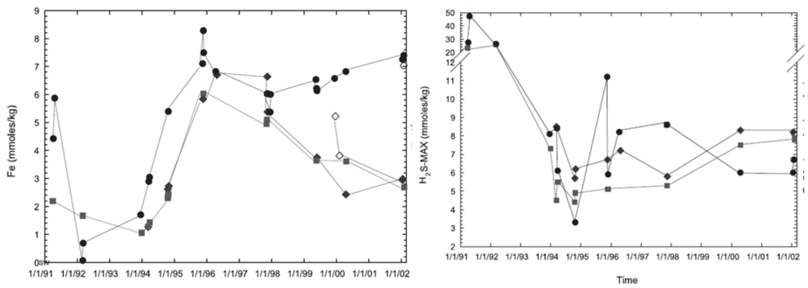
Butterfield (1997)

[Cl⁻] v.s. time after eruption

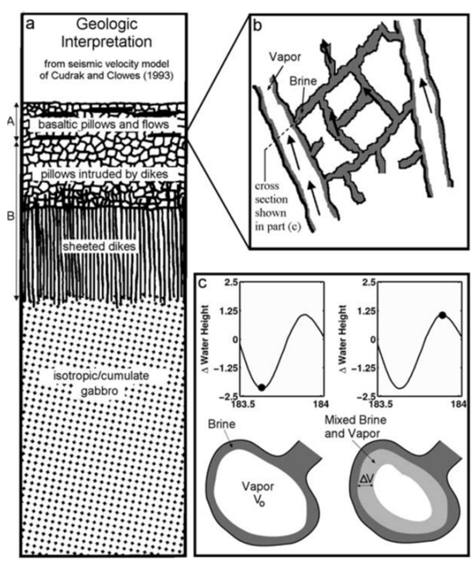


Von Damm (2004)

East Pacific Rise: 9⁰50’N



Von Damm (2004)



Larson et al. (2009)

Future study

- Precisely/accurately measure the flux → heat budget
- Look for “finger-print” signature b.w. vents and plumes
- Compare the fluid data with the “precipitates”
- Time-series sampling at various sites to test the phase separation hypothesis.