

Hydrothermal systems

- Where hydrothermal vent systems exist
- How fluid flows through vents
- Reactions that take place during hydrothermal activity
- Tracing hydrothermal activity using He

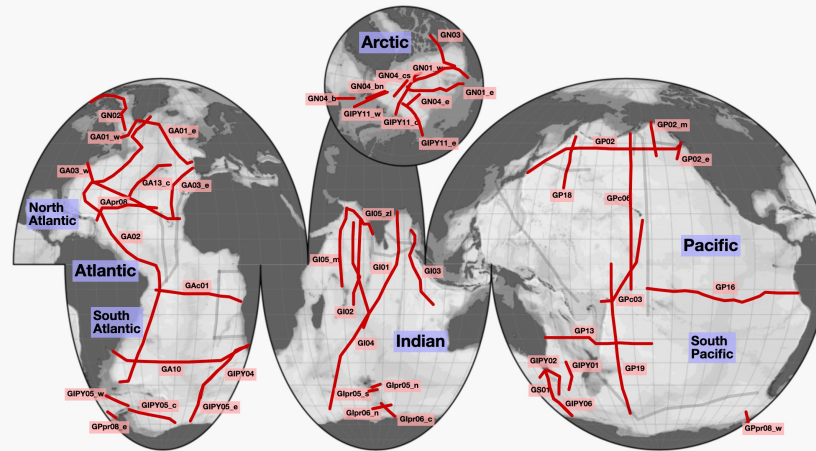
Trace element resource - eGeotraces

IDP2021_v1

Reiner Schlitzer, Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany

Select a data group and tracer, then click on a red section or blue basin label to view the tracer distribution along the section or as rotating 3D scene in the basin. Use the links at the bottom of the section and 3D scene pages to access original publications associated with the data or view other tracer plots along other sections or in other basins.

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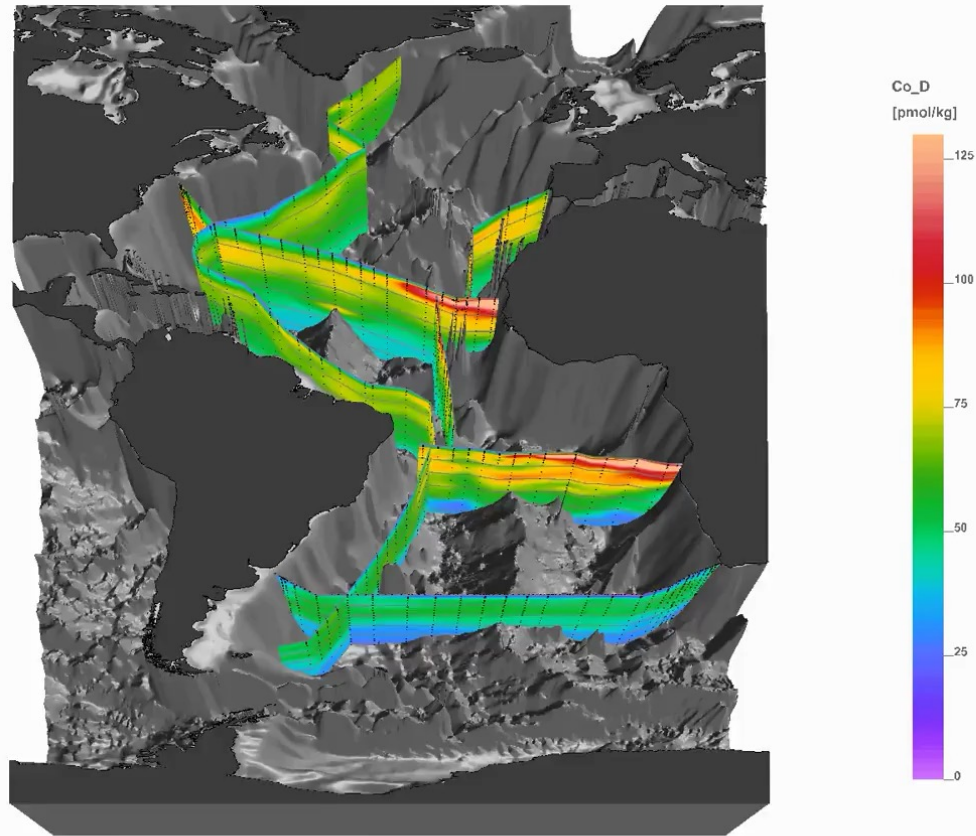
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HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

[Imprint](#)

- <https://www.egeotrases.org/>

Dissolved Cobalt, Atlantic cruises

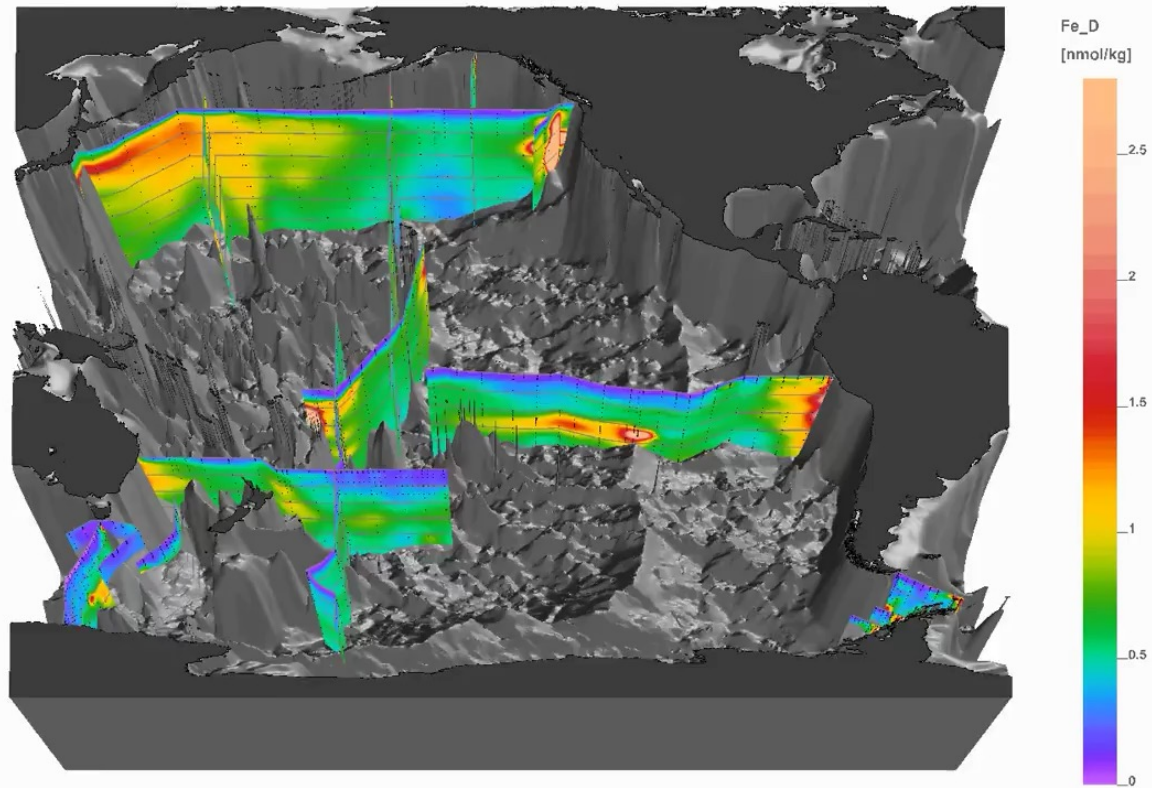
Basin-scale videos
available at website, or
individual section plots /
data



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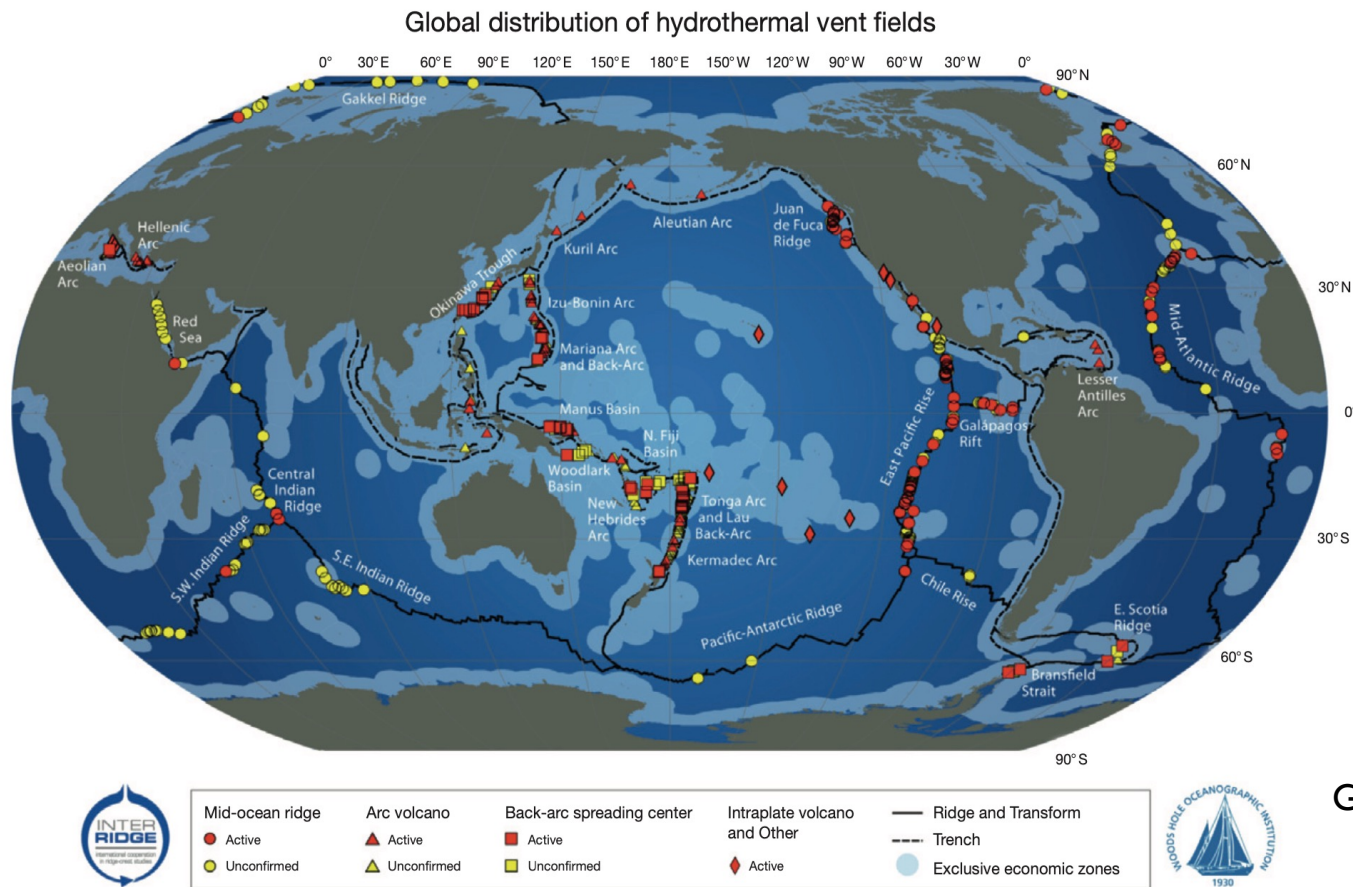
v2024

Dissolved Fe, Pacific



- What sources do you notice?

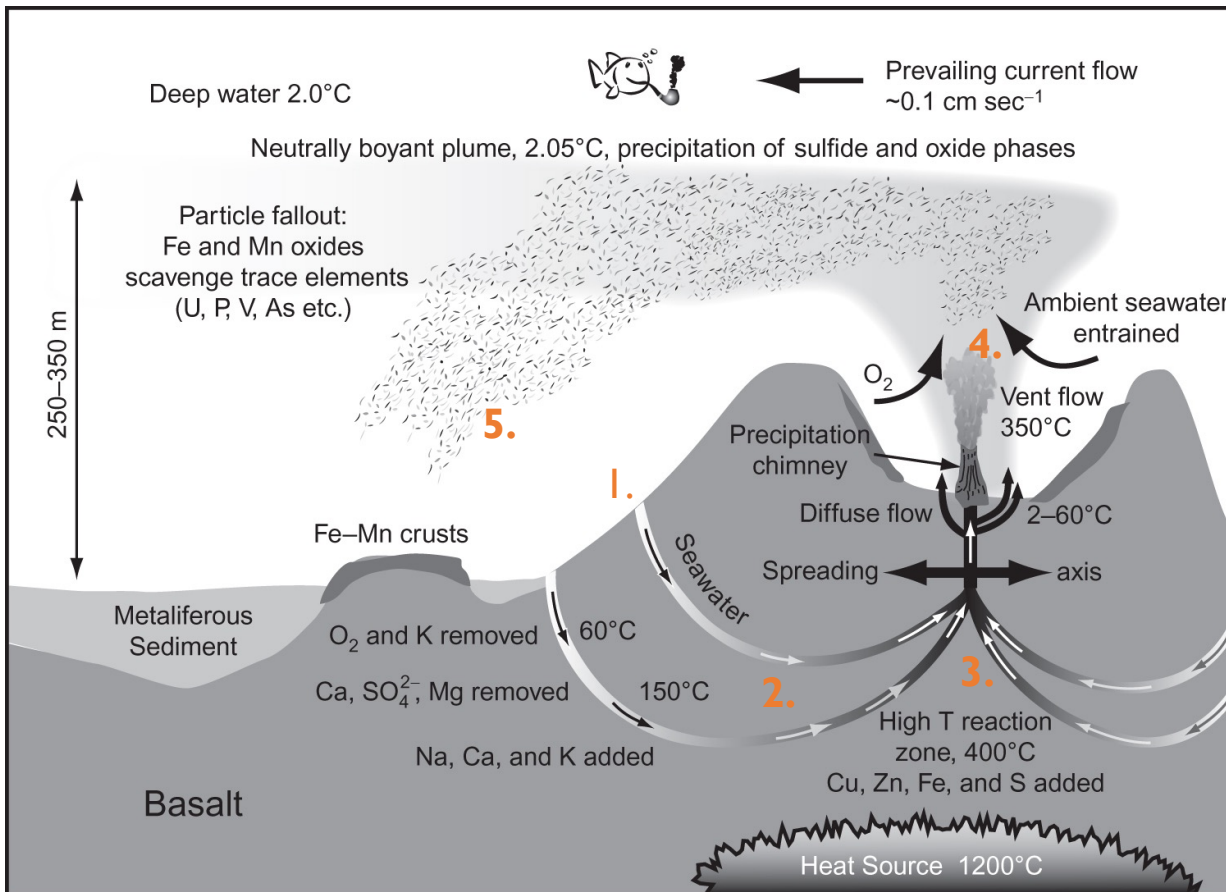
Ridge Crest / arc systems and (known) hydrothermal vents



German & Seyfried, 2014

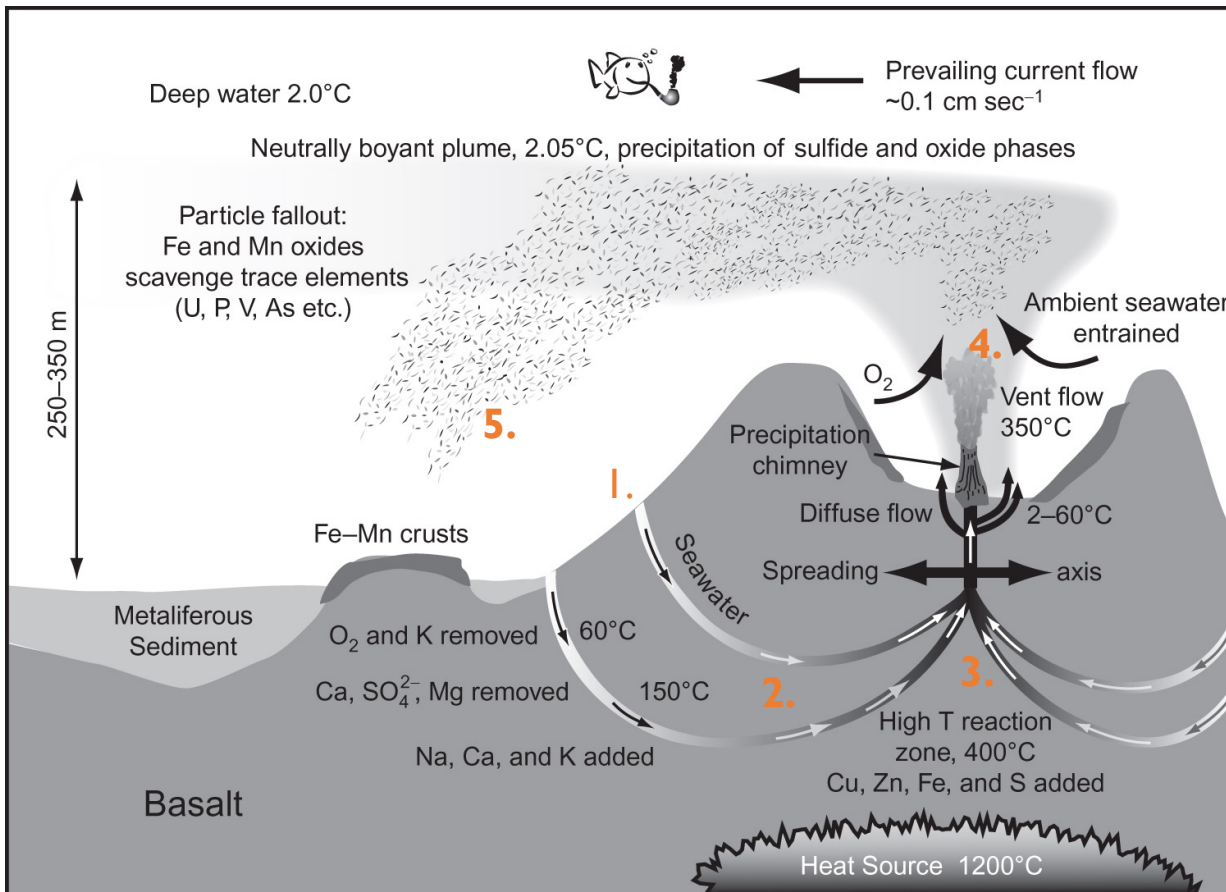
v2024

Hydrothermal schematic



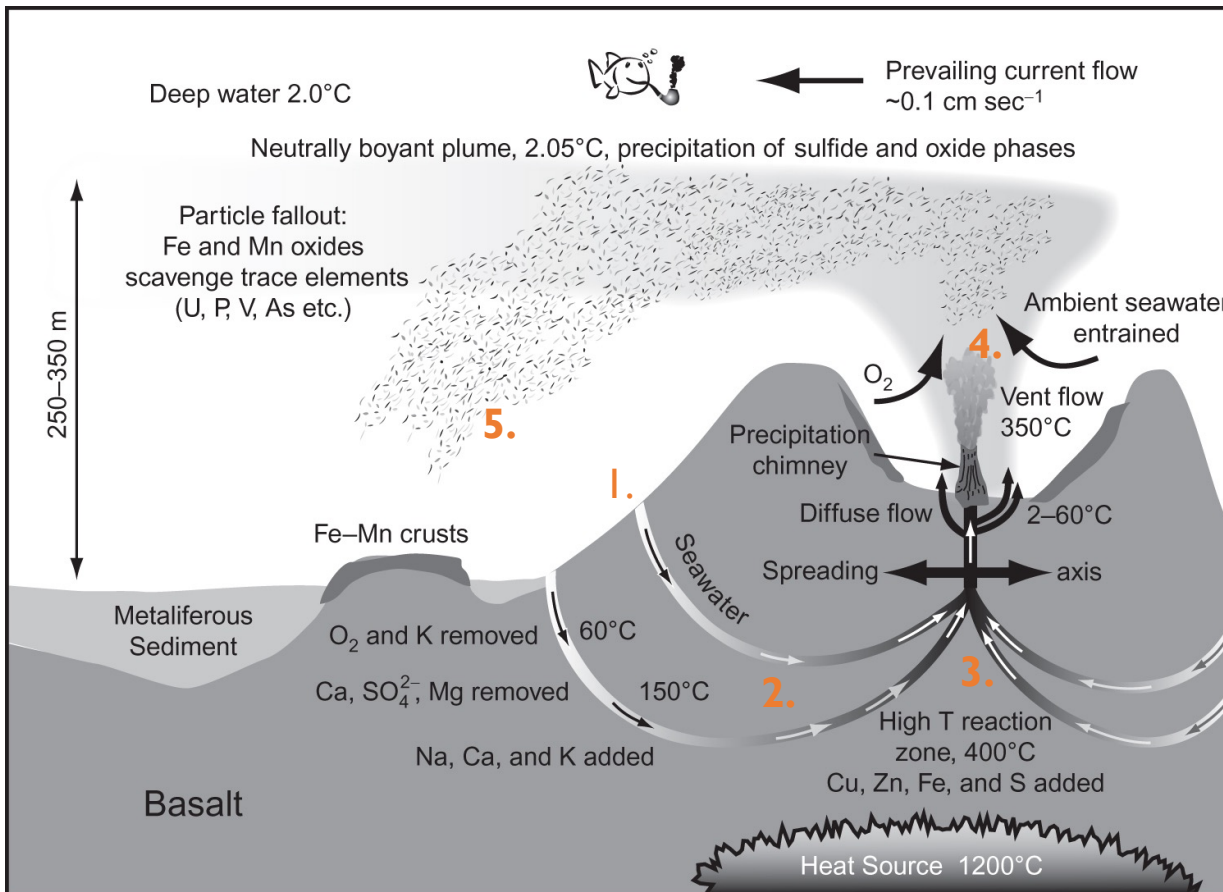
- I. Seawater flows into fractured basalt
 - 2C, oxygenated

Hydrothermal schematic



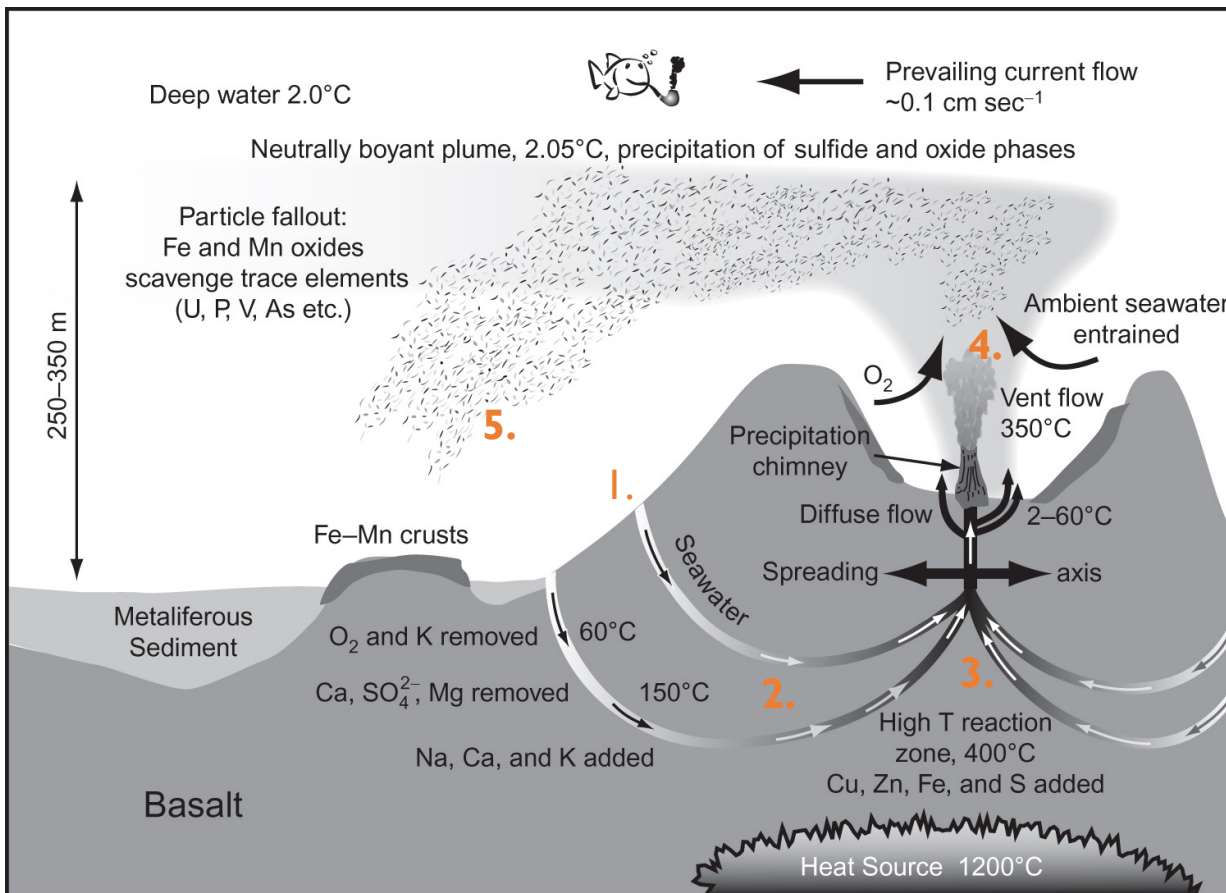
1. Seawater flows into fractured basalt
 - 2C, oxygenated
2. Water percolates into crust, some heating

Hydrothermal schematic



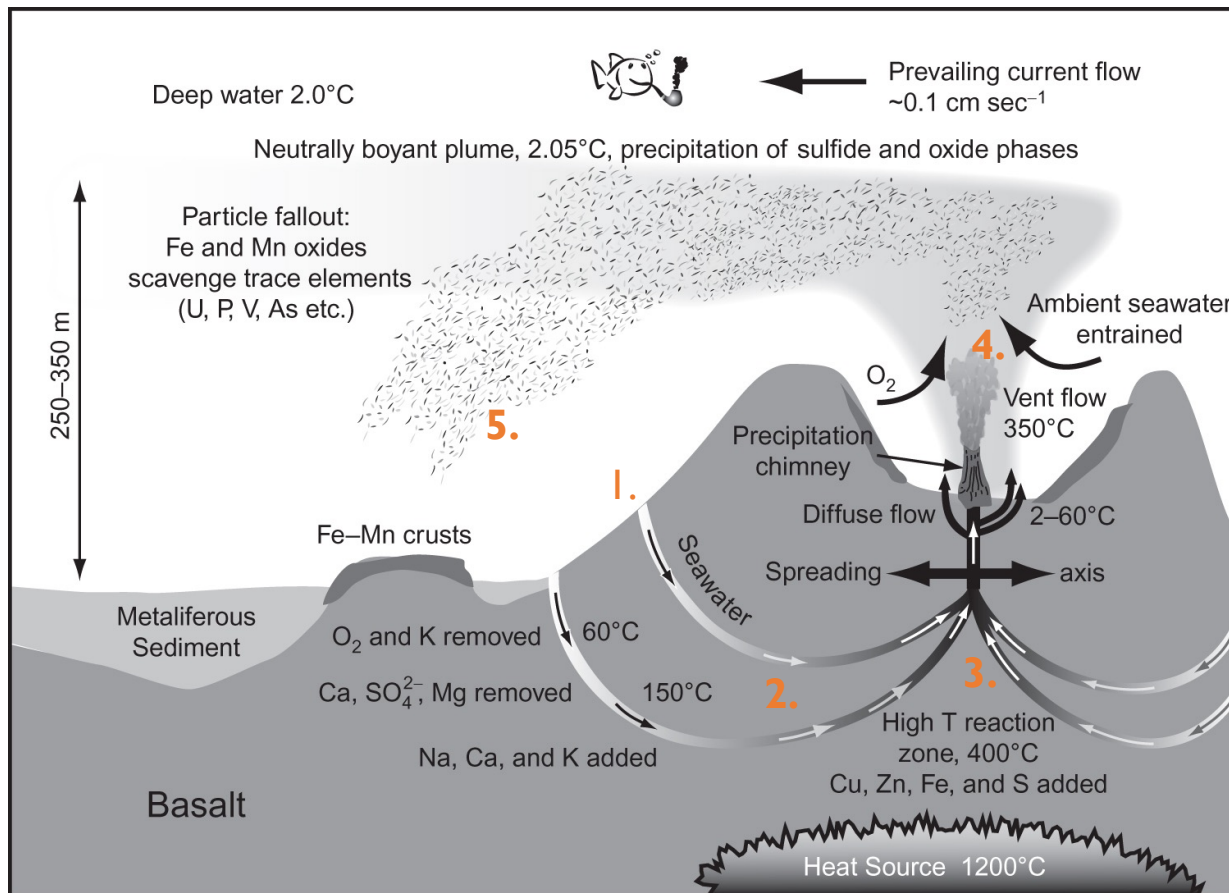
1. Seawater flows into fractured basalt
 - 2C, oxygenated
2. Water percolates into crust, some heating
3. Strong heating, dissolving of volatiles
 - SO₂ (will combine with water to make H₂SO₄), HCl, HF - all strong acids, CO₂ (H₂CO₃)
 - Will mobilize rock material (metal concentrations increase)
 - O₂ decreases to anoxia (reduced material comes out and oxidized (Fe²⁺ + O₂ → Fe³⁺))

Hydrothermal schematic



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4. Buoyant hydrothermal plume
 - Rapid entrainment / dilution until neutrally buoyant
 - Huge redox gradients

Hydrothermal schematic



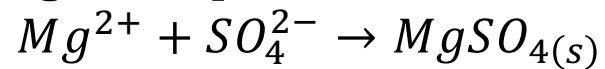
1. Seawater flows into fractured basalt
 - 2C, oxygenated
2. Water percolates into crust, some heating
3. Strong heating, dissolving of volatiles
 - SO_2 (will combine with water to make H_2SO_4), HCl , HF - all strong acids, CO_2 (H_2CO_3)
 - Will mobilize rock material (metal concentrations increase)
 - O_2 decreases to anoxia (reduced material comes out and oxidized ($\text{Fe}^{2+} + \text{O}_2 \rightarrow \text{Fe}^{3+}$))
4. Buoyant hydrothermal plume
 - Rapid entrainment / dilution until neutrally buoyant
 - Huge redox gradients
5. Precipitation of metaliferous sediments

Hydrothermal vent, East Pacific Rise

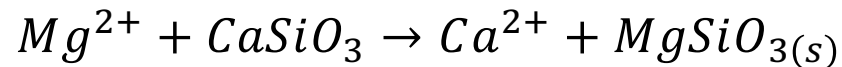


Black smoker reactions

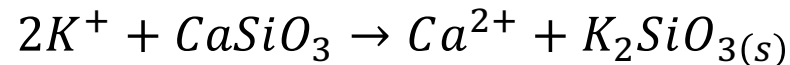
- High temperature reactions:



(53mM) (28 mM) – sulfate runs out first
~25mM Mg^{2+} left



Mg^{2+} consumed to ~ 0 mM



Both of these salts are normally very stable, so these are major sinks of these ions in seawater. Also major source of Ca^{2+}

- Production of H^+ can also create acidic waters

Mackenzie and Garrels 1966 ... from Day 2

<i>Major ion</i>		SO_4^{2-}	Ca^{2+}	Cl^-	Na^+	Mg^{2+}	K^+	H_4SiO_4	HCO_3^-
<i>Mass removed in 10^8 y (10^{18} mol)</i>		429	1238	821	861	477	143	589	3573
Mineral formed	Moles Removed	<i>Amount of ion remaining after reaction</i>							
Pyrite, FeS_2	215 ^a	214	1238	821	861	477	143	589	3573
Anhydrite, CaSO_4	214 ^a	0	1024	821	861	477	143	589	3573
Calcium Carb., CaCO_3	1024		0	821	861	477	143	589	1525
Sodium Chloride, NaCl	821			0	40	477	143	589	1525
Opal, SiO_2	630 ^b				40	477	143	0	1525

^a Assume half of the SO_4 is removed by pyrite formation and half by CaSO_4 formation

^b The biogenic opal (SiO_2) burial is taken from Tregeur and DeLaRocha, 2013

(b) Formation reactions:

Pyrite: $\text{SO}_4^{2-} + 2\text{CH}_2\text{O}(s) \rightleftharpoons \text{S}^{2-} + 2\text{CO}_2 + \text{H}_2\text{O}$ followed by $\text{Fe}^{2+} + \text{S}^{2-} + \text{S}^0 \rightleftharpoons \text{FeS}_2$

Anhydrite: $\text{Ca}^{2+} + \text{SO}_4^{2-} \rightleftharpoons \text{CaSO}_4(s)$

Calcium Carbonate: $\text{Ca}^{2+} + 2\text{HCO}_3^- \rightleftharpoons \text{CaCO}_3(s) + \text{CO}_2 + \text{H}_2\text{O}$

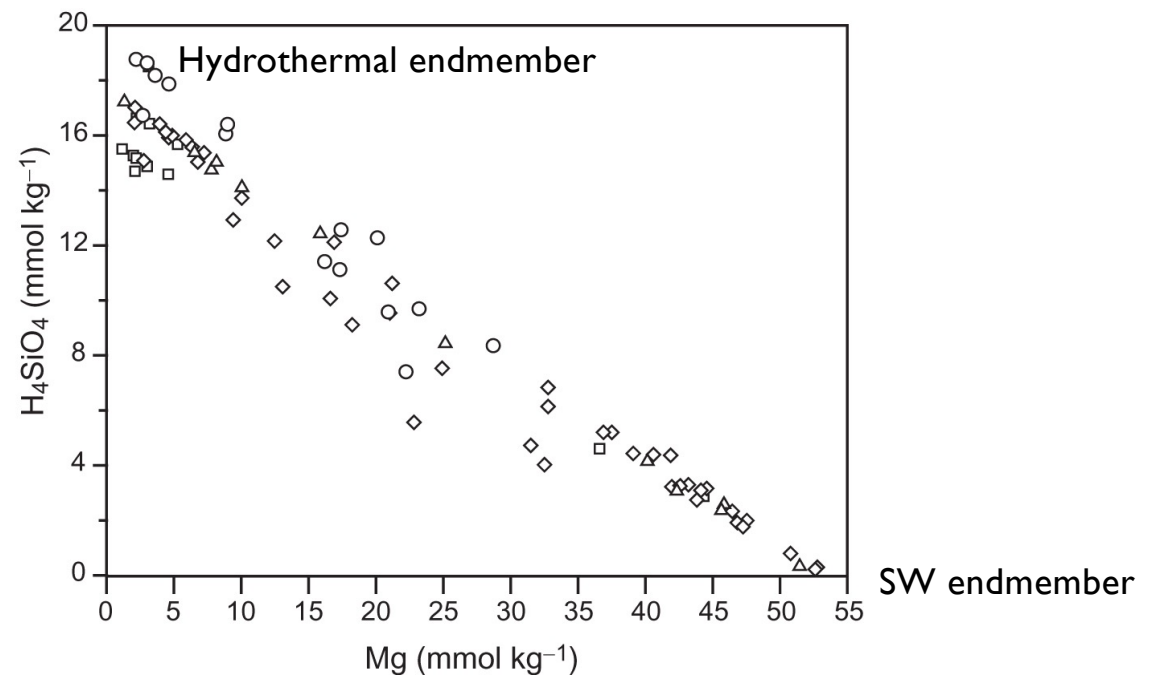
Sodium Chloride: $\text{Na}^+ + \text{Cl}^- \rightleftharpoons \text{NaCl}(s)$

Opal: $\text{H}_4\text{SiO}_4 \rightleftharpoons \text{SiO}_2(s) + 2\text{H}_2\text{O}$

How do you sample hydrothermal waters?



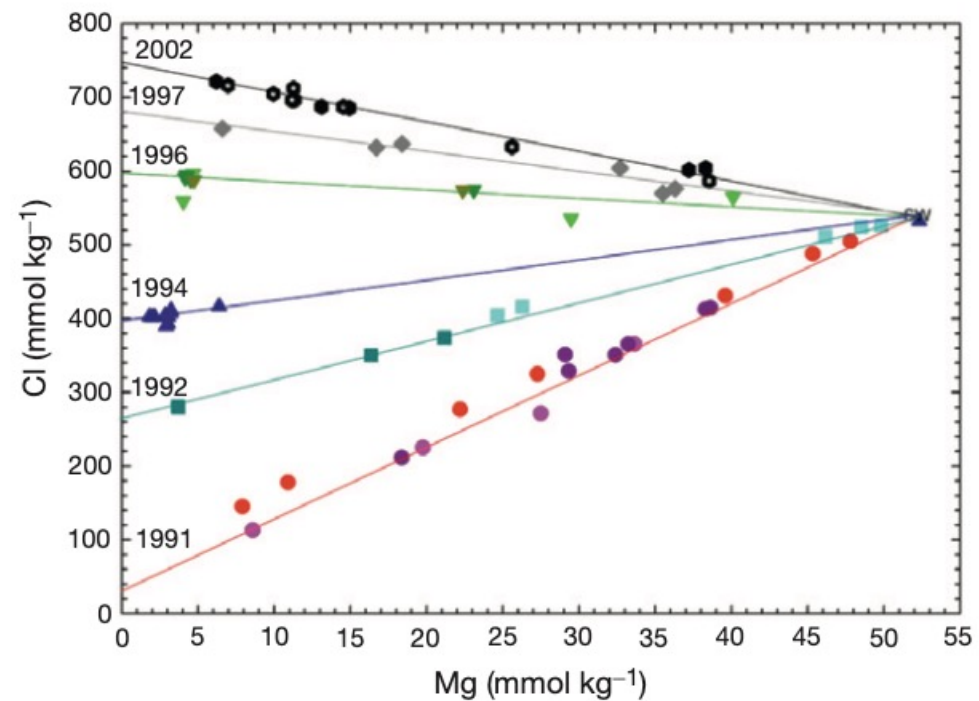
- How do you know if you're actually measuring the correct water?



How do you sample hydrothermal waters?



- Vent composition / flow can change over time



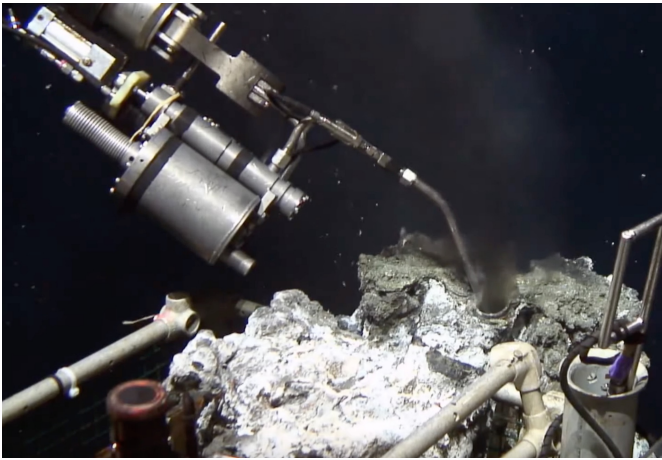
Von Damm (2000) and German & Seyfried, 2014

Elemental impacts from hydrothermal vents

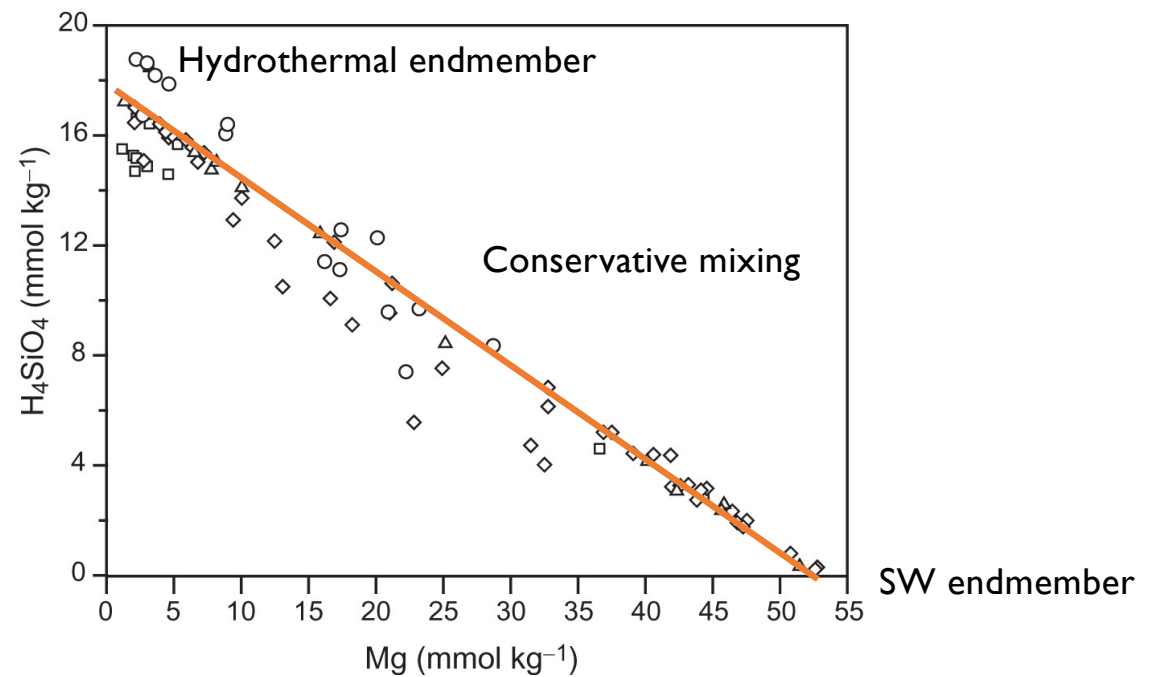
Periodic table of the elements																							
IA																	IIIA	IVA	VA	VIA	VIIA	VIIIA	
H	He																	B	C	N	O	F	Ne
Li	Be																	Al	Si	P	S	Cl	Ar
Na	Mg	IIIB	IVB	VB	VIB	VIIB	VIIIB	VIIIB	VIIIB	IB	IIB	Ga	Ge	As	Se	Br	Kr						
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	In	Sn	Sb	Te	I	Xe						
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	Tl	Pb	Bi	Po	At	Rn						
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg												
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub												

Enriched with respect to seawater on a Cl-normalized basis
Depleted with respect to seawater on a Cl-normalized basis
Enriched and depleted

How do you sample hydrothermal waters?



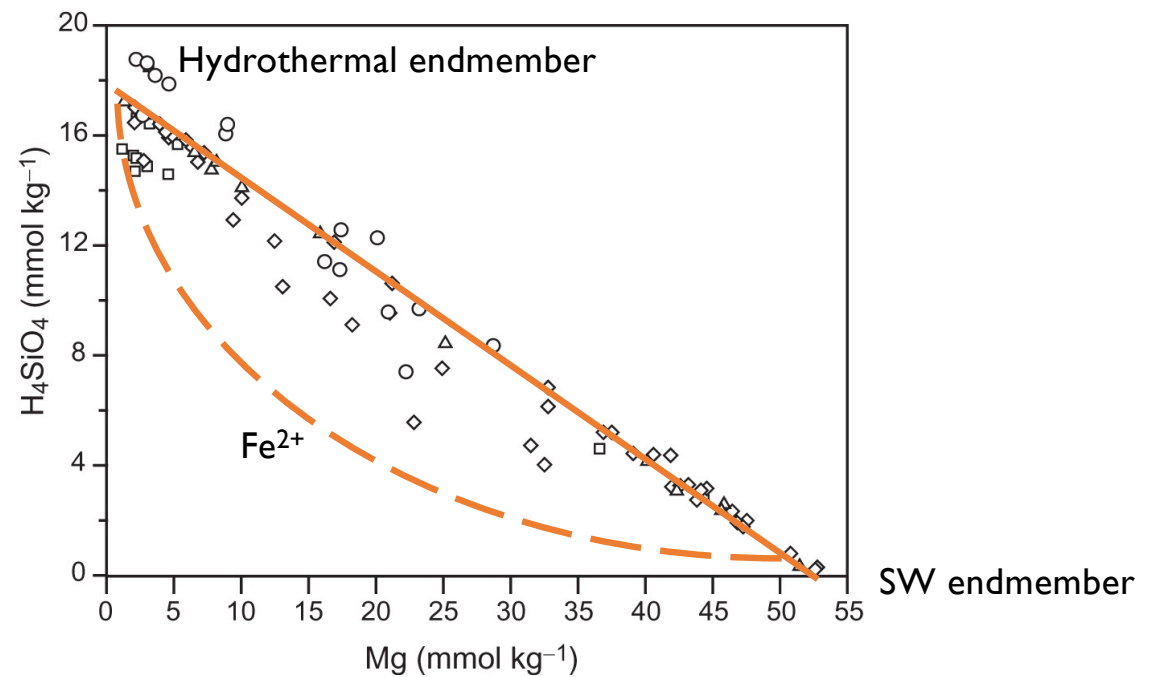
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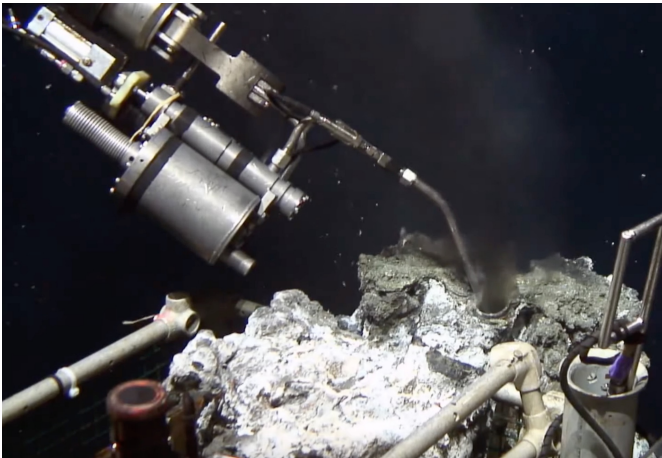
Reactions as hydrothermal waters mix



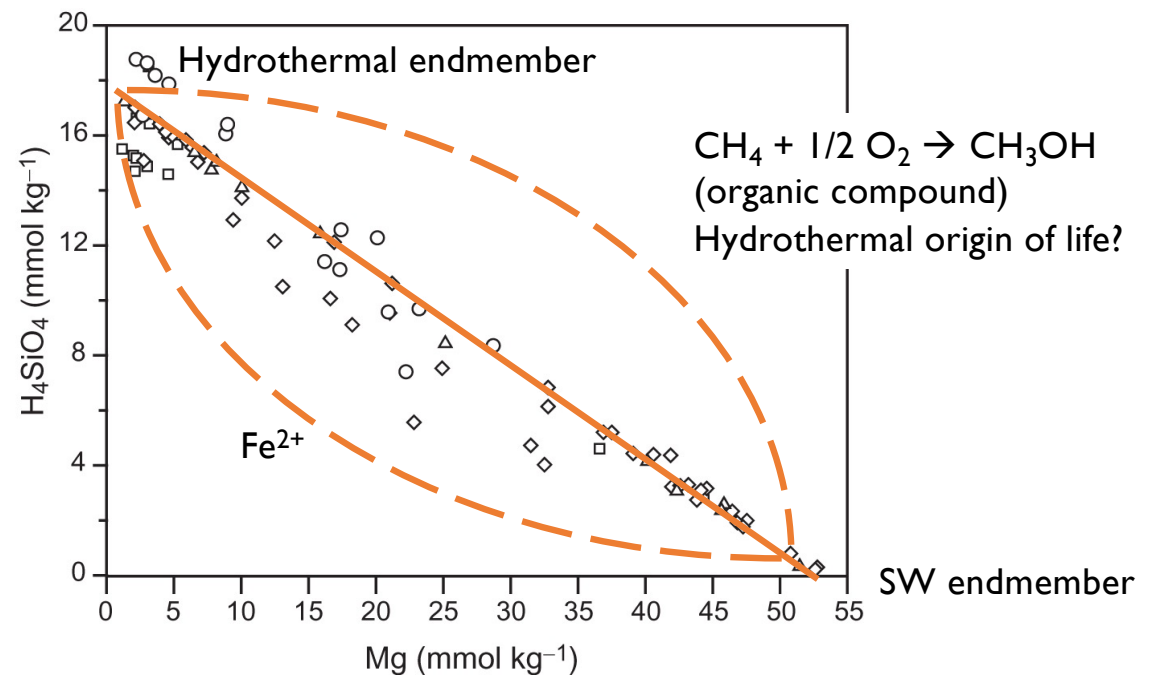
- What if your measurements follow a different shape?



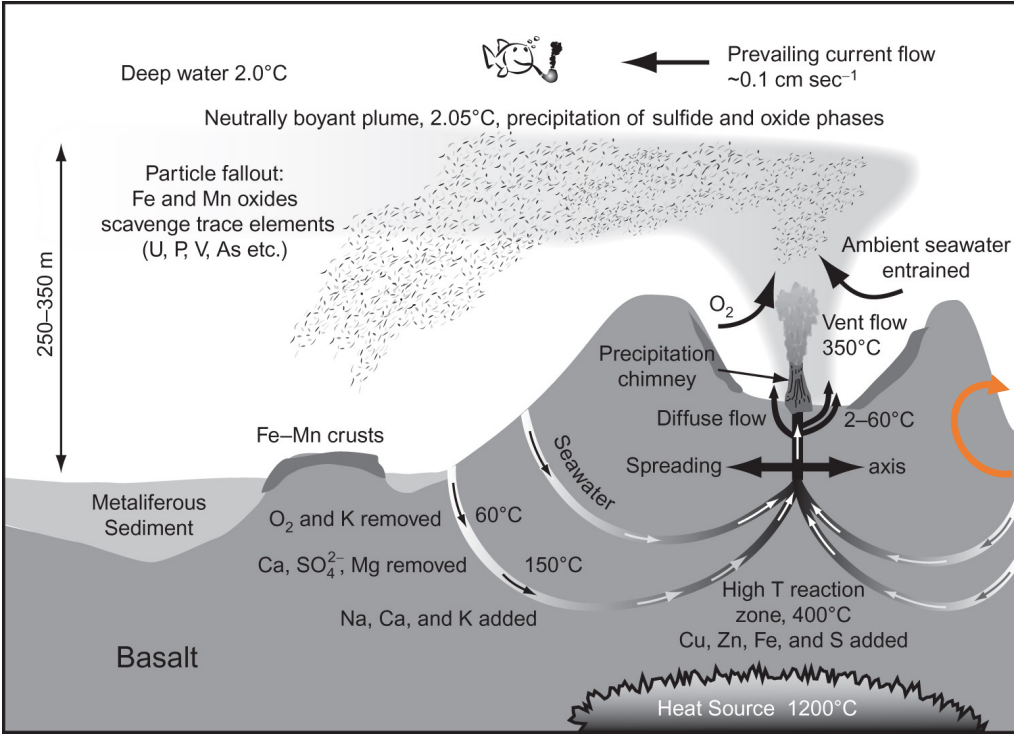
Reactions as hydrothermal waters mix



- What if your measurements follow a different shape?



White smokers: Off axis



- If you are too far from the magma source, may still have high heat but no volatiles
- $H_2O + H^+ + MgSilicates$ or $FeSilicates$ (olivine)
 - Consumes acid, so pH rises (becomes more basic)
 - Can form Silicate, $CaSO_4$, or $CaCO_3$
 - Remember that when the pH is very high, most of DIC is $CO_3^{2-} \rightarrow$ so Carbonates can precipitate

White smokers: Off axis

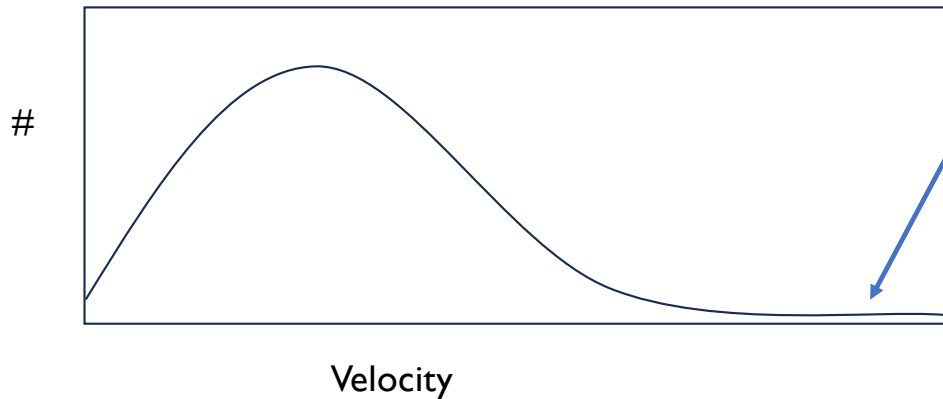


Lost City

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How do we know where hydrothermal vents exist?

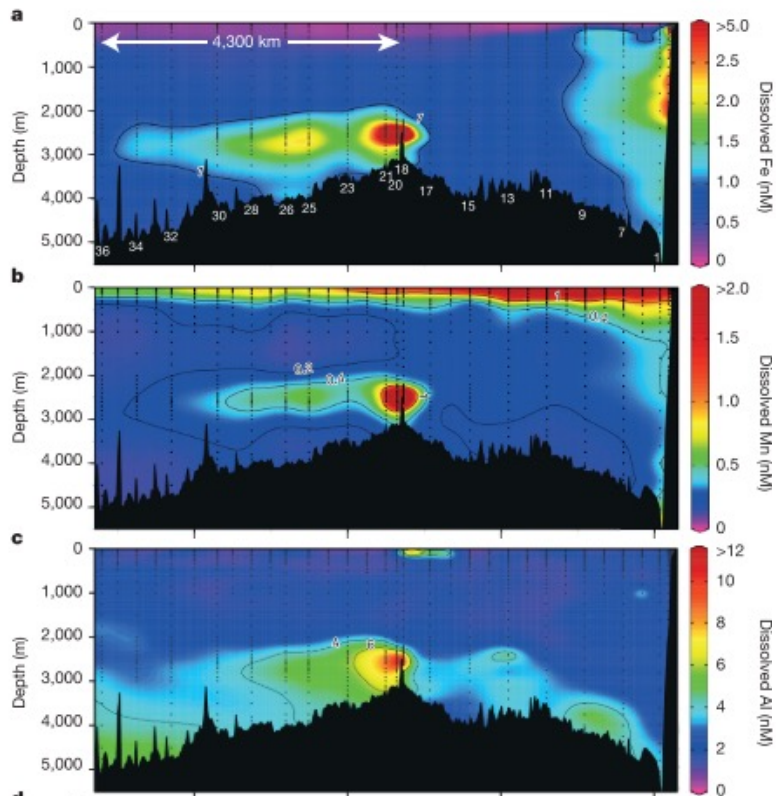
- Helium in the atmosphere – 5 ppm
 - Two isotopes ^3He & ^4He



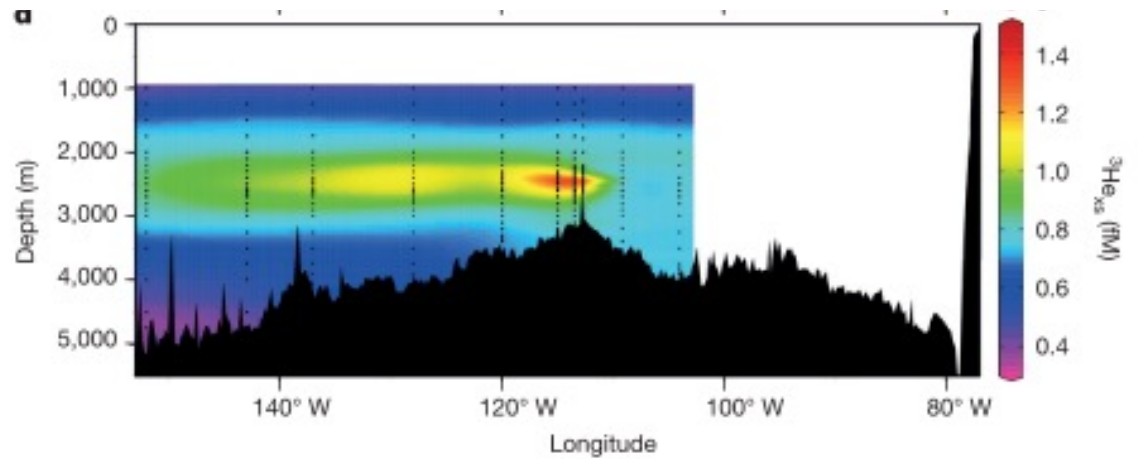
Some small fraction
reaches escape velocity,
leaves the atmosphere

- ^4He generated through radioactive decay in the crust
 - $^{238}\text{U} \rightarrow ^{206}\text{Pb} + 8x\ ^4\text{He}$
- ^3He released from hydrothermal vents – not generated by anything on earth (all ^3He from formation of earth)

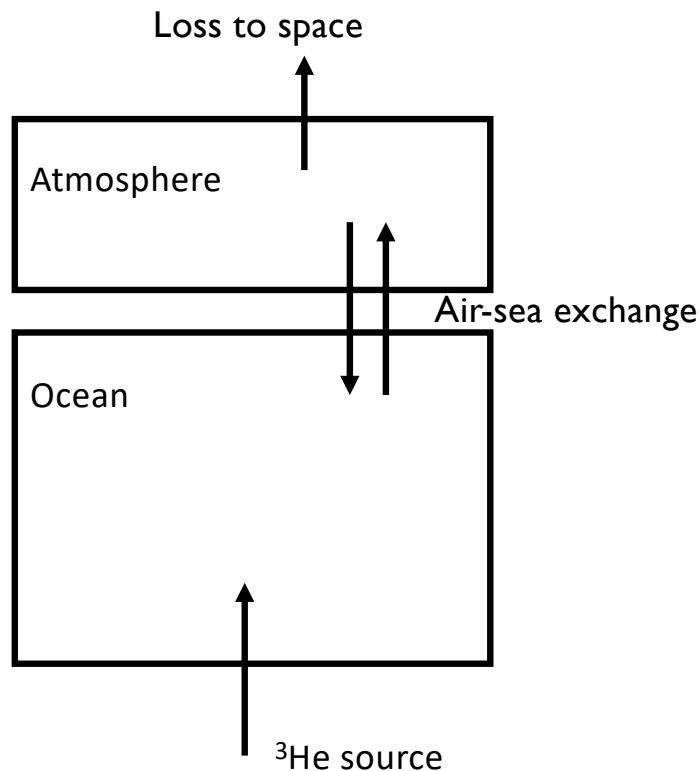
How do we know where hydrothermal vents exist?



- ^3He released from hydrothermal vents – acts as a tracer of hydrothermal release



How much hydrothermal venting is occurring?

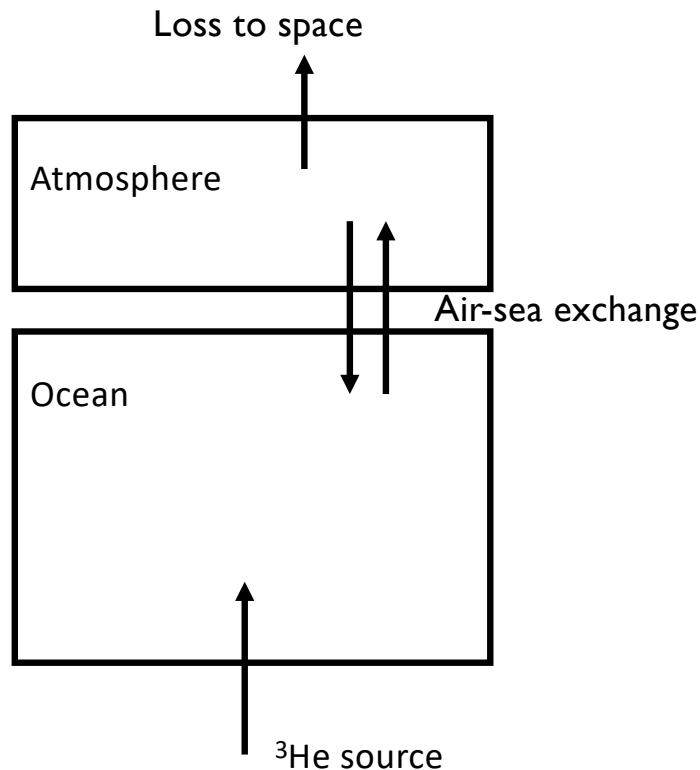


- Calculate an inventory of ^3He in an ocean basin
- Ocean overturning (~ 1000 years)

$$\frac{\Sigma ^3\text{He}}{\tau_{ocean}} = \text{venting supply}$$

$\sim 500\text{-}1000 \text{ mol } ^3\text{He}/\text{yr}$

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Can use ^3He to then scale other non-conservative tracers

Ex. Hydrothermal Fe flux (J_{Fe})

$$J_{\text{Fe,HT}} = J_{^3\text{He}} * \text{Fe}/^3\text{He}$$