The Global Chlorine Cycle: a Subduction Zone Perspective

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with lots of help from:
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Global Chlorine Cycle

Why Chlorine?

1) Hydrophilic
2) Large component of slab-derived fluids (wt% !)
3) Cl can affect the transport efficiency of trace elements and the water activity
   ("energy and resources should be highlighted in the new program")
Global Chlorine Cycle

Total Inputs = $4.5 \times 10^{12}$ g Cl/yr

3 - 5 $\times 10^{12}$ (3 - 22 $\times 10^{12}$)

Sediments
$1.6 \times 10^{12}$

AOC
$2.9 \times 10^{12}$

“serpentine is not included and must be considered as a potential source to arc magmas” (Straub and Layne, 2003)
SCD theme: Linkages between volatile release and the rheology of the plate boundary interface
-What is the role of serpentinization in weakening the incoming plate and the plate interface?
-Does serpentinization of the incoming plate significantly change its mechanical strength?
-Does serpentininite dehydration control the location of some intermediate depth seismicity?

SCD theme: Storage, transfer, and release of volatiles through subduction systems
-What is the role of serpentine in subduction and release of H₂O?
-To what extent is the incoming plate serpentinized?
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*Should we care or is it just a “green herring”? Geochemical fingerprint for serpentinites*
Chlorine in Serpentinites

Range from $<0.01$ to $>1$ wt\% Cl
($<100$ to $>10,000$ ppm Cl)

serpentine = $\sim 13$ wt\% water
seawater = $\sim 1.94$ wt\% Cl

$\sim 0.25$ wt\% Cl in serpentinites
(Anselmi et al., 2000)

$0.26 \pm 0.16$ wt\% Cl ($n = 86$)
(Sharp and Barnes, 2004)
Global Chlorine Cycle: including serpentinites

3 - 5 $\times 10^{12}$ (3 - 22 $\times 10^{12}$)

Total Inputs = $8.2 \times 10^{12}$ g Cl/yr

(Barnes and Straub, 2010; Ito et al., 1983; Jarrard, 2003; John et al., submitted; Sharp and Barnes, 2004; Straub and Layne, 2003; Wallace, 2005)

- highly saline fluid inclusions in Alpine eclogites (e.g., Selverstone et al., 1992; Scambelluri et al., 1997)
- deeply subducted serpentinites with ~150 ppm Cl (e.g., John et al., submitted; Scambelluri et al., 2004)
Chlorine Stable Isotopes

Pore fluids 0 to –8‰
Sediments -2.5 to 0‰
Altered oceanic crust –1.6 to –0.9‰
Serpentinites –1.8 to +0.5‰

\[
\delta^{37} \text{Cl} = \left( \frac{^{37}\text{Cl}}{^{35}\text{Cl}} \right)_{\text{sample}} - \left( \frac{^{37}\text{Cl}}{^{35}\text{Cl}} \right)_{\text{standard}} \times 1000
\]

(Arcuri and Brimhall, 2003; Barnes and Sharp, 2006; Barnes et al., 2008, 2009; Bonifacie et al., 2007, 2008; Godon et al., 2004; Hesse et al., 2000; John et al., 2010; Kaufmann et al., 1984; Layne et al., 2009; Ransom et al. 1995; Sharp et al., 2007; Spivack et al., 2002)
Izu-Bonin-Mariana

- sediments
- serpentine mud volcanoes
- arc volcanoes (gases/wells & ashes)
- cross-chain (basalts)
1) Serpentine seamounts → Cl from chrysotile-antigorite transition

Brearley et al. (submitted)
IBM Summary

1) Serpentine seamounts → Cl from chrysotile-antigorite transition

2) Arc volcanoes → sediments/AOC; Little variation along the length of the arc
1) Serpentine seamounts $\rightarrow$ Cl from chrysotile-antigorite transition
2) Arc volcanoes $\rightarrow$ sediments/AOC; Little variation along the length of the arc
3) Guguan cross-chain $\rightarrow$ antigorite breakdown/mantle?
Central America

Sediments
Gases; Ashes

- CA ashes/lavas
- IBM VF gases/wells
- IBM VF ashes/lavas
- marine pore waters
- sediments
- altered oceanic crust
- seafloor serpentinites
- MORB/upper mantle seawater

δ³⁷Cl (% vs SMOC)
Barnes et al. (2009), Eiler et al. (2005), Elkins et al. (2006), Fischer et al. (2002), Zimmer et al. (2004), M. Carr’s online database
Current and Future Directions

1) Defining/refining volatile (Cl, F, S, C) reservoirs & fluxes (concentrations & isotopic compositions) (including)

![Diagram showing δ^{37}Cl (%) vs SMOC with data points for different reservoirs: marine pore waters, eclogite-facies metasediments, seafloor sediments, altered oceanic crust, seafloor serpentinites, OIB, MORB/upper mantle, seawater.

![Graph showing Hole 735B data with meters below seafloor (m) vs Cl (wt%), δ^{37}Cl (%), and volume percent with an arrow pointing to Hydrothermal Amphibole Veins at T = 400-500°C.]
Current and Future Directions

1) Defining/refining volatile reservoirs & fluxes *(including exhumed margins)*
2) Expand forearc and back arc studies
3) Melt inclusions
4) Fractionation *experiments*