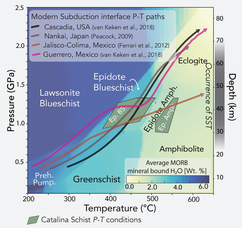
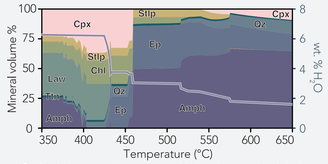
The geologic record of hydration and dehydration in the subducting slab: Epidote minerals record alteration and metamorphism before and during subduction

Peter C. Lindquist[1], Cailey B. Condit[1], William F. Hoover[1], Victor E. Guevara[2]
[1]*University of Washington*, [2]*Amherst College*
Contact: plindqui@uw.edu

The fingerprint of metamorphic dehydration in subduction zones



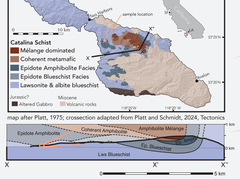
The breakdown of hydrous minerals like lawsonite and chlorite are expected to release significant volumes of water from subducting basalts. These fluids influence the rheology of the plate interface (e.g., promoting slow slip and tremor). Epidote is a common product of the predicted dehydration reactions.

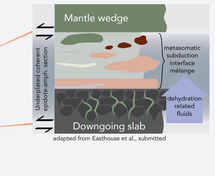


Predicted mineralogy and water content of hydrated metabasalts subducting at Guerrero, Mexico. Adapted from Lindquist et al., 2023, G-Cubed.

We analyze epidote in metabasalts from the Catalina Schist to (1) explore the use of epidote as a tracer of prograde subduction processes and (2) look for evidence of dehdration reactions in the subducted rock record.

The Catalina Schist represents an exhumed Cretaceous subduction complex, composed of tectonic slices of oceanic crust that were subducted and underplated to North America. The epidote-amphibolite facies unit experienced peak P-T conditions of 0.8–1.3 GPa and 500–560°C, representative of conditions at ~35 km depth in modern warm subduction zones, around 105 Ma.





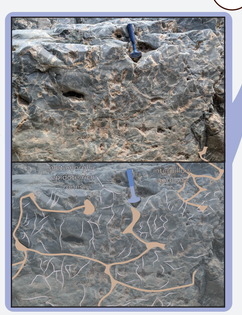
Records of seafloor alteration

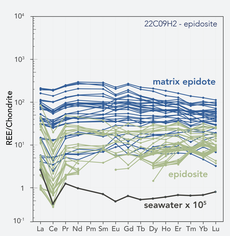
0

Pillow and hyaloclastite breccia textures are preserved in parts of the epidote amphibolite metabasalts.

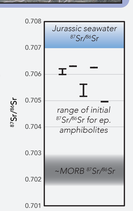
Networks of interpillow material are commonly epidote rich and we interpret these as having been altered to epidosite.

Strongly negative Ce anomalies in epidote from these zones are indicative of interaction with seawater.



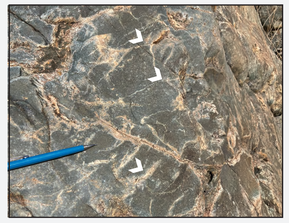


Bulk-rock Sr isotope measurements provide another indication of intial seawater-rock interactions, and suggest potentially large water/rock ratios prior to subduction.



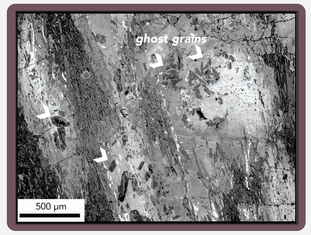
Epidote-rich networks preserve early metamorphism

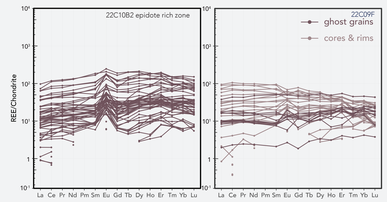
1 2



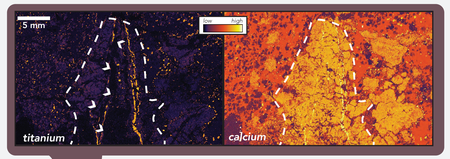
Distinct from interpillow epidosite networks, we interpret wispy, epirote-rich vein-like features as forming during prograde metamorphism during subduction.

"Ghost grains" in the cores of epidote crystals likely represent replacement of pumpellyite based on crystal shapes and geochemistry. REE patterns in these ghost grains are comparable to those measured in pumpellyite from other metabasalts.





While metamorphic epidote-rich zones lack discrete vein-like boundaries, elemental X-ray maps reveal discrete Ti-poor zones within these. These may represent zones of transient porosity produced during pumpellyite breakdown.

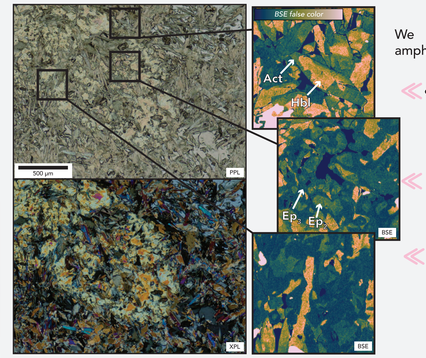


Metamorphic epidote-rich zones may represent self-organized dehydration features that developed as a result of intial compositional heterogeneity.

Porphyroblastic epidote records pro- and retrograde metamorphism

3 4 5

While metamorphic epidote networks preserve ~intial growth, epidote porphyroblasts react with surrounding matrix and exhibit complex textures and compositions that track progressive metamorphism.

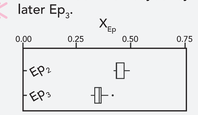


We identify two generations of amphibole and epidote:

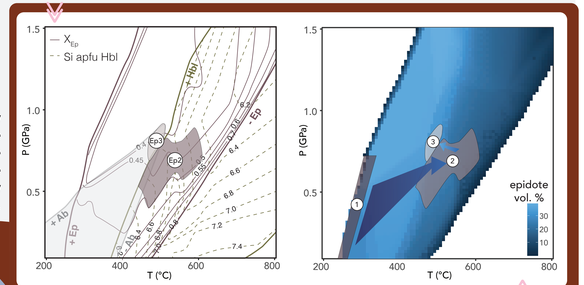
- Both hornblende and actinolite are present in the matrix and within porphyroblast structures. Hornblende is commonly rimmed by actinolite.

cores of more Fe-rich epidote (Ep_2) are embedded within more Al-rich epidote (Ep_3).

Hornblende is embayed by the later Ep_3.



Pairing these textures and mineral compositions with phase equilibrium modeling with PerpleX constrains a range of *P-T* conditions for the growth of the two generations of minerals.



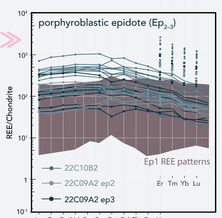
The Ep_2 field is defined by epidote compositions and the Si-content of hornblende. The Ep_3 field is defined by epidote compositions, and the stability of actinolite and albite.

The abundance of epidote is predicted to decrease with increase temperature, which helps explain the presence of Ep_2 as relic cores that are then overgrown by Ep_3.

Epidote 2 therefore represents the composition of epidote at ~peak *P-T* conditions, while growth of more Al-rich epidote 3 with actinolite suggests retrograde cooling.

- REE patterns for epidote porphyroblasts (both Ep_2 and Ep_3) are enriched in LREEs relative to epidote-rich networks (Ep_1).

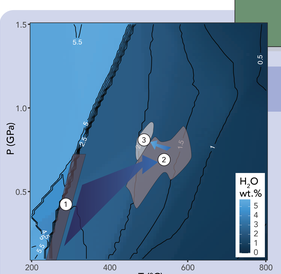
- With progressive metamorphism, epidote porphyroblasts likely preferentially incorporated more LREE from other reacting phases while the epidote-rich networks do not communicate as much with the matrix.



H_2O fluxes

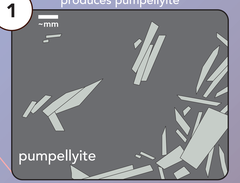
Phase equilibrium modeling also predicts the conditions at which pumpellyite would have broken down to produce epidote (1) and allows us to estimate how much H2O this reaction would produce.

This transition is associated with a release of ~94 kg H_2O/m^3 of basalt, which, to first order, could result in fluxes of 10^4–10^5 kg H_2O/m^2/Myr in the region of such dehydration in a generic sudbuction zone.



0 initially hydrated MORB

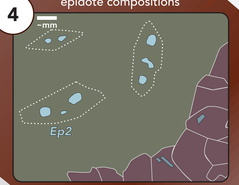
1 low grade metamorphism produces pumpellyite



2 pumpellyite reacts to form epidote and release H_2O

3

4 Ep2 represents near-peak epidote compositions



5

epidosites record hydration of oceanic crust prior to subduction

Pumpellyite to epidote dehydration reactions result in a pulse of water release around 250–300°C

epidote growth reaches a peak around 400°C

with increasing *T* to peak conditions the volume % epidote decreases and epidote befomes more Fe-rich

refrigeration following underplating restabilizes more epidote (Ep_3)

Sharing is encouraged