Light Carbon Stable Isotopes in Aragonite Veins, Lopez Island, WA: Evidence for Deep Life?

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Abstract

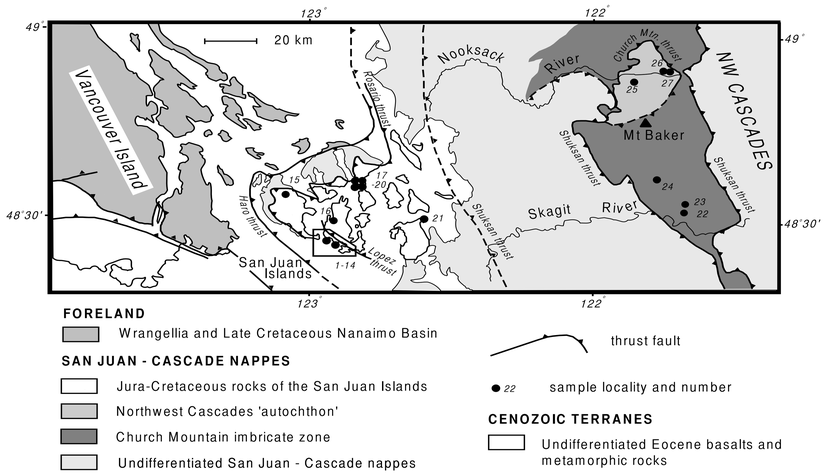
The San Juan Islands in NW Washington State preserve a record of very low temperature-high pressure metamorphism, which formed by structural burial and rapid exhumation between 100 and 84 Ma (Brandon et al., 1988). Aragonite is widespread in the metamorphic assemblages, occuring both by vein deposition and recrystallization of limestones (Vance, 1968). Maximum metamorphic conditions are constrained to about 100 - 200 and 500 MPa, equivalent to depths of 10 to 20 km.

We investigated an outcrop, about 50 m long, on Davis Head, southern Lopez Island. The outcrop lies within an 3 km-thick fault zone, the Lopez Structural Complex, that juxtaposes pillow basalts over mudstones. Basalts are middle-Cretaceous in age and have OIB trace-element composition (Brandon et al., 1988).Structural relationships in this region clearly show that large-scale faulting occurred first, followed by high-pressure metamorphism, and then the development of a pressure-solution cleavage.The aragonite veins at Davis Head show variable deformation, indicationg that they were emplaced during cleavage formation. Aragonite is the primary carbonate phase, but it has been variably retrograded to calcite by a solid-solid transformation.

An unpublished study by Feehan (1997) found that aragonite veins at Davis Head contain anomalously light concentrations of carbon isotopes, with a range of 0 to -50 per mil. Such light values are commonly attributed to carbon associated with biogeniclly produced methane. We found carbon-isotopic values ranging from +1 to -30 per mil, confirming Feehan's results. Isotopes in the carbonate anion do not re-equilibrate during a solid-solid transformation, suggesting these values are original.

We propose that the aragonite veins were formed by oxidation of methane. The degree of oxidation varied across the outcrop, as indicated by the wide range of carbon isotopic values with little variation in oxygen isotopes. If correct, the lightest carbon values represent the isotopic composition of the methane. At low surface pressures, bacterial life is known to remain active to temperatures of ~122 C. High pressures tend to stabilize biomolecules, so bacterial life should extend to higher temperatures within the Earth's interior. We suggest that the Lopez Island aragonite veins are evidence of this deep life.

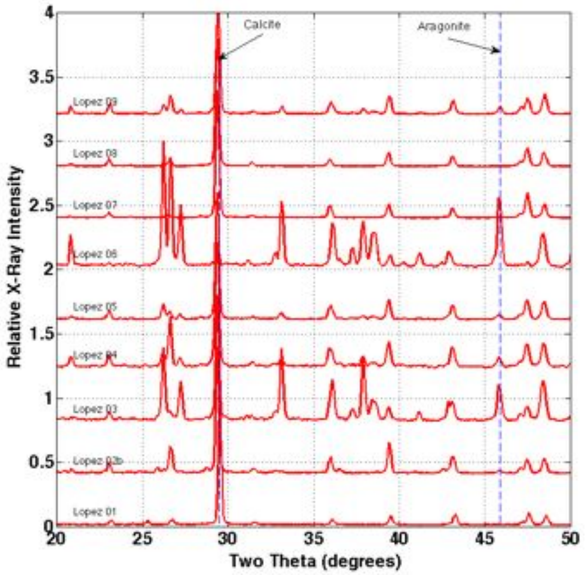
Beach outcrop at Davis Head, Lopez Island, WA, at which veins with anomalusly light carbon stable isotopes were identified.



(1) We collected eighteen samples from across the ~50m outcrop at Davis Head, selecting a wide range of vein types.

Sample #5 in situ: thick vein at low angle to outcrop surface.

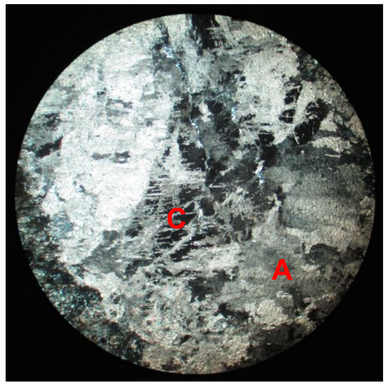
Sample #6 in situ: crosscutting veins with differing amounts of deformation



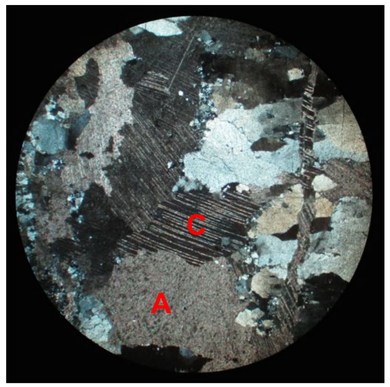
(2) Calcite/aragonite ratios within each vein were assessed visually by optical analysis of thin sections under cross-polarized light and quantitatively by Powder X-Ray Diffraction.

X-Ray Diffraction Emission Spectra for saples 1-9, showing peaks associated wtih calcite and aragonite. The maximum percent of total carbonate that was aragonite was ~90% (in Sample #6).

$$X_C = X_A \frac{A_C}{A_A \times 3.5} \equiv X_C = X_A \times Y$$

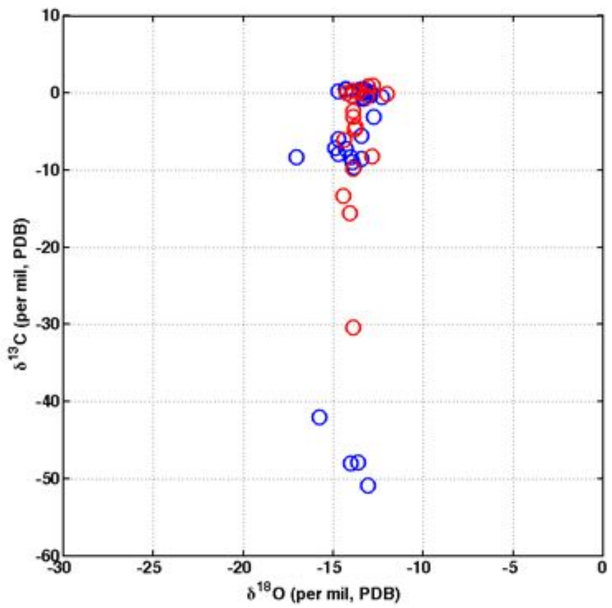


Portion of thin section of Sample #1 under cross-polarized light.



Portion of thin section of Sample #5 under cross-polarized light.

(3) Vein material from each sample was powdered and analyzed for $\delta^{13}C$ and $\delta^{18}O$. While oxygen stable isotopes had a small range, carbon isotopes varied considerably, from +1.0 to -50.9 per mil PDB.



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