Nd, Sr and stable isotope signatures of ancient methane-seep carbonates (Eocene, Washington, USA) as a record of incipient subduction at the Cascadia convergent margin

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Stratigraphic and structural context of the early evolution of the Cascadia convergent margin, following major subduction reconfiguration associated with accretion of the igneous Siletzia terrane at 50−45 Ma, remains insufficiently understood. Here, we have applied a novel approach that uses combined Nd, Sr and stable isotope analyses of ancient methane-seep carbonates to constrain the early hydrogeological regime of the Cascadia margin. Analyses included the oldest-known seep deposits of Cascadia, formed during mid-Eocene time (42.5−40.5 Ma). A combination of exceptionally high $\varepsilon_{\text{Nd}}$ and low $^{87}\text{Sr}/^{86}\text{Sr}$ signatures observed in these carbonates consistently point to former interactions between the seeping fluids and mafic, igneous constituents of the forearc basement. Moderately negative $\delta^{13}\text{C}_{\text{carbonate}}$ values imply thermogenic origin of hydrocarbons at three out of four studied seeps, with likely contribution of biogenic methane at a single, landward-most site. When combined with structural constraints, the recorded signals point to discharges of fluids originating from deep portions of the young subduction wedge, and their channeled ascent through the Siletzia terrane. The results document the presence of a fluid expulsion system indicative of active convergence prior to maturation of typical arc magmatism in the Cascades at 40 Ma. The exceptionally pronounced role of exotic, $^{143}\text{Nd}$-enriched, $^{87}\text{Sr}$- and $^{18}\text{O}$-depleted fluids recorded for early Cascadia reflects its distinctive structural architecture, including the relatively thin sedimentary cover of the young forearc, its extensional tectonics, and the near-trench position of the volcanic terrane that the descending plate-derived fluids must have migrated through prior to reaching the seafloor.