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Tracing carbon sources in the lower continental crust (Ivrea-Verbano Zone, Italy)

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Carbon (C) isotopes in high-grade metamorphic sequences offer valuable insights into C-cycling, fluid interactions, and metamorphic processes. In the Ivrea-Verbano Zone, a classic lower crustal section in the Southern Alps, graphite (Gr) and calcite (Cc) are key C reservoirs, hosted in diverse metasediments such as Gr-bearing kinzigites, calcsilicate rocks, and marbles. As part of the ICDP-funded DIVE project (**D**rilling the **I**vrea-**V**erbano Zon**e**), this study examines the chemical and isotopic composition of Gr and Cc to better understand the origin and evolution of C in deeply buried sediments. Samples were collected from borehole 5071_1_B in Ornavasso (~7.5kbar, ~750°C), and outcrops nearby.

C-isotope compositions range from -11.8 to -13.8 ‰ for Gr ($\delta^{13}C_{Gr}$) in the kinzigites and -0.7 to -5.6 ‰ in calcsilicate rocks ($\delta^{13}C_{Cc}$), which also have $\delta^{18}O_{Cc}$ values between 11.0 and 15.0 ‰ (VSMOW). Marbles from the borehole have $\delta^{13}C$- and $\delta^{18}O$-values of -8.2 and 12.5 ‰, respectively, while marbles from nearby outcrops have a broader range of -0.7 to 1.2 ‰ for $\delta^{13}C_{Cc}$ and 13.6 to 22.6 for $\delta^{18}O_{Cc}$.

The trends in $\delta^{13}C$ and $\delta^{18}O$ values suggest that the compositions are related to a combination of sedimentary and metasomatic processes. The isotopic composition of Cc in calcsilicate rocks supports the interpretation of a mixed source, involving calcareous sediments associated with the marbles and a contribution of a mafic lithology, such as lava flows, as previously suggested by Baker (1990). Gr $\delta^{13}C$ values are between those of pure organic matter and carbonate-derived C, supporting a biogenic, non-carbonate origin of C within clastic sediments. Subsequent isotopic exchange likely occurred due to either a loss of methane-rich fluids during diagenesis and low-grade metamorphism and/or interaction with a CO_2-rich extraneous fluid, possibly sourced from the marbles. Both processes, first proposed by Baker (1988), would result in the observed shift toward higher $\delta^{13}C$ values.

Overall, our findings indicate a complex history of C-cycling in the Ivrea-Verbano Zone, shaped by sedimentary precursors and metamorphic fluid-rock interactions during solution-precipitation mechanisms in the presence of CH_4- and/or CO_2-bearing aqueous fluids or hydrous melts.

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