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Stable isotope evidence for fluid alteration of carbonates during Cretaceous compression and extension in the Graz Paleozoic (Eastern Alps)

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Following Early Cretaceous nappe stacking, the Eastern Alps were affected by late-orogenic extension during the Late Cretaceous. In the eastern segment of this range, a Late Cretaceous detachment separates carbonates of a very low to low-grade metamorphic cover (Graz Paleozoic, GP) above a low to high-grade metamorphic basement. Because there is ample evidence for fluid movement during thrusting and extension, stable carbon and oxygen isotope ratios are used to trace the obvious relation between deformation and contiguous fluid flow. Isotope alteration of limestones and shales is recorded in a well-documented Lower Cretaceous thrust zone within the GP (Kugelstein Section). In a Late Cretaceous extensional detachment at the base of the GP (St. Radegund Thrust), carbonates have been altered by migrating fluids parallel to the foliation. To characterize the altering fluids isotopically, carbonate samples were taken along several profiles across both detachments.

Measured δ^{18}O and δ^{13}C values along the profiles are compared to theoretically calculated curves. The curves are based on the isotope mass balance calculations of Zheng & Hoefs (1993). The alteration model for an open system, where the fluid´s isotopic composition is externally controlled, is applicable. The extent of isotopic exchange is dependent on the initial δ^{18}O inital and δ^{13}C inital values of the involved limestone as well as the fluid´s isotopic composition and temperature. In addition, the fluid-rock ratios, time and the grain contact surfaces are relevant. For the calculations, the fractionation factors for the systems Calcite - HCO_3- (Ohmoto & Rye 1979) and Calcite - H2O (Friedman & O‘Neill 1977) as well as the isotope values of the unaltered Schöckl limestone close to the migration paths are used. The fractionation factors for calcite approximate the dolomite fractionation factors. Fluid inclusion data of Krenn (2001) provides information about HCO_3-molalities. The values of δ^{18}O final, δ^{13}C final and the fluid temperature are estimated by fitting the theoretical curve to the sample profiles.

The results suggest a pinned boundary fluid flow during Early Cretaceous thrusting and subsequent late-orogenic extension. Both are characterized by the analytical results. Notably, despite the large distance between the sample locations, the similar characteristics of the alteration fluids argue for a large-scale pervasive fluid flow supplied by a carbonate reservoir during thrusting. In contrast, reduced organic matter must have been associated with the extensional fluids.