Novel method to reconstruct paleopressure: a combined clumped isotope and fluid inclusion technique

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Reconstructing the pressure conditions under which diagenetic minerals were precipitated in subsurface can not only enhance our understanding about the burial and diagenetic history of studied rocks, but also bring insight into fundamental processes of mineral precipitation. This novel method is thus relevant for both industrial applications, such as reservoir characterization, as for fundamental research.

We have investigated several carbonate samples from Spain and Oman using both the clumped isotope and the fluid inclusion methods. Clumped isotopes can be used as a paleothermometer, providing a temperature of precipitation of a mineral independent of the stable oxygen isotopic composition of the parent fluid. Hence, both temperature and the stable oxygen isotopic composition of the fluid from which the mineral precipitated are extracted from clumped isotope analysis. The fluid inclusion technique, which is a common technique that has been used for decades, also provides an estimate of the precipitation temperature of a mineral, in addition to information on fluid chemistry and salinity. The estimation of the precipitation temperature of a mineral in this method is based on the temperature of homogenization during cooling-heating experiments. This homogenization temperature is measured at the equilibrium stage between the fluid and the gas bubble. However, at the time of trapping, usually a homogeneous fluid is trapped (and this is a requisite for deriving reliable homogenization temperatures) and a difference between the homogenization and the trapping temperature is expected because of the pressure at trapping conditions and the compressibility of the fluid. Isochores that can be reconstructed based on the density of the fluids, derived from fluid inclusion measurements, can then be combined with the independent temperature data from clumped isotopes, so that both the temperature and pressure conditions during precipitation of the analysed mineral can be reconstructed.

The proposed novel method can thus bring insight into a range of applications, such as prediction of overpressure conditions in the subsurface, fracturing processes, degassing upon pressure drop.

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Combined Lu-Hf and Sm-Nd garnet-geochronology of lower crustal rocks from Val Strona, Ivrea Zone, Italy

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The Ivrea Zone (IZ, N-Italy) is a key locality to study metamorphic processes in the lower and middle continental crust. The Val Strona section of the IZ is particularly suited to study the timing of metamorphic processes along an increasing temperature gradient, comprising a continuous assemblage of granulite to amphibolite facies rocks. Therefore, three metapelites and one metabasite from the Val Strona section were examined in a combined Lu-Hf and Sm-Nd study, covering both amphibolite-facies and granulite-facies conditions. The samples were also investigated in terms of their petrology and geochemistry, in order to reconstruct the P-T-t path of the IZ rocks. In particular, representative garnets were investigated via electron microprobe (EMP) and LA-ICP-MS, determining their distribution patterns of major and some trace elements (REE, HFSE).

The EMP and LA-ICP-MS profiles in all investigated garnets lack any prograde zonation for 2+ elements (e.g. Mn) and Sm-Nd, whereas for Lu-Hf some growth patterns are preserved. The Lu-Hf ages obtained for the amphibolite-facies metapelites therefore presumably reflect garnet growth (278 ± 3 Ma; MSWD 2.3 and 279 ± 0.9 Ma; MSWD: 0.31). In contrast, the younger Lu-Hf ages obtained for the granulite-facies metapelite (263 ± 0.5 Ma; MSWD 0.9) and for the metabasite (249.6 ± 1.3 Ma; MSWD 2.0) are interpreted to represent cooling ages and document later cooling of the deeper crustal section. All Sm-Nd ages obtained in our study are about 30 Myrs younger than the respective Lu-Hf ages. Hence, the Sm-Nd ages likely represent cooling ages and may indicate retrograde diffusion-controlled re-equilibration processes. In conclusion, the results of this study point to a polyphase metamorphic evolution of the Val Strona section.

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