EXAMPLES OF KINETICALLY CONTROLLED OXYGEN ISOTOPE MINERAL/FLUID EXCHANGE FROM REGIONAL- AND CONTACT METAMORPHIC ENVIRONMENTS

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The isotopic signature imposed on a rock during fluid/rock interaction depends on the mechanisms and relative rates of isotope transport and mineral/fluid isotopic exchange. Given isotope transport at finite rates and infinitely fast mineral/fluid isotopic exchange, local equilibrium will prevail during fluid/rock interaction and isotope fractionations between coexisting phases will depend on temperature exclusively. If isotope transport and mineral/fluid exchange occur at finite rates, then grain-scale disequilibrium may develop. In such cases, isotopic fractionations are not merely functions of the system temperature. Due to the effects of finite transport- and exchange rates, they may vary as a function of space and time, even if the temperature is constant throughout the system.

The Ventina Ophicarbonate Zone is a 10 to 400 meter wide ophicarbonate layer within massive serpentinites of the Malenco ultramafic body southeast of the Oligozene Bergell intrusive complex. In profiles across the ophicarbonate zone, the oxygen isotope compositions of calcite, antigorite and diopside become successively depleted towards the lithologic contacts. This trend is due to interaction of the ophicarbonate rocks with an isotopically light fluid derived from serpentine dehydration during contact metamorphism. It is interesting to note that the calcite-antigorite and calcite-diopside fractionations decrease systematically from internal positions towards the lithologic contacts. If this pattern were interpreted in terms of local equilibrium, this would indicate a temperature increase from 450 °C in the center of the ophicarbonate zone to 600 °C at the lithologic contacts. The profile is, however, oriented subparallel to the isograds of contact metamorphism and there is no petrographic evidence for such temperature variation across the ophicarbonate zone. The observed pattern rather indicates grain-scale isotopic disequilibrium during fluid/rock interaction resulting from differences in mineral/fluid exchange rates of the constituent minerals with the rates decreasing in the order calcite > antigorite > diopside.

In the Penninic Platta Nappe (eastern Switzerland) Late Jurassic to Cretaceous metasediments occur as several meter thick layers within volumetrically dominant metabasic lithologies. They include a sequence of pelagic limestones interbedded with shales (Palombini Formation). The Platta Nappe and the overlying Austroalpine units experienced lower greenschist facies metamorphic overprint during the Cretaceous. On outcrop scale, metasediment oxygen isotope ratios are systematically depleted towards the lithologic contacts with the surrounding metabasic rocks. This trend is ascribed to interaction of the metasediments with an isotopically light fluid buffered by the metabasic rocks. Calcite and quartz isotopic compositions show systematic variations over 6 per mill across the metasediment layer and the calcite-quartz fractionations decrease successively towards the lithologic contacts. Given local equilibrium during fluid/rock interaction, the observed pattern would indicate a temperature variation over 150 °C on a 10 m scale, which is improbable to occur in a regional metamorphic terrain. The isotope signature rather suggests grain-scale isotopic disequilibrium during fluid/rock interaction that resulted from differential calcite/fluid and quartz/fluid isotopic exchange rates.

In both cases, the contact metamorphic Ventina Ophicarbonate Zone and the regional metamorphic Platta Nappe, the observed isotope signature suggests that isotopic mineral/fluid exchange was slow relative to isotope transport and that the isotope pattern was significantly influenced by the kinetics of mineral/fluid exchange.

FLUIDBEWEGUNG IM KAP-FALTENGÜRTEL UND IM KAROO-BECKEN, SÜDAFRIKA

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In der Kap Province, etwa 300 km nordöstlich von Kapstadt, Süd Afrika, verläuft ein Gebirgszug parallel zur Küste. Durch diese Faltungszone sowie das daran nördlich anschließende Karoo Becken wurden zwei Nord-Süd-Profile gelegt und nach Zeugen von Fluidbewegungen vom Gebirge in Richtung des Beckens untersucht. Dazu wurden strukturgeologische Beurteilungen mit den Ergebnissen von Messungen stabiler Isotope beziehungsweise Flüssigkeitseinschlüssen kombiniert. Das besondere Interesse an den Fluiden wurde durch die Entdeckung von Uranerzvorkommen im nördlichen Bereich des Arbeitsgebietes ausgelöst. Es sollten (1) die Bedingungen unter denen die Fluide existierte und (2) deren Herkunft erforscht werden, sowie (3) ein möglicher Zusammenhang zwischen den Erzvorkommen und der Fluid Migration geprüft werden.

Geologisch baut sich die schwach metamorphe Faltungszone aus den sedimentären Abfolgen des Pan Afrikanischen Kango Basements, der paleozoischen Cape- und Karoo-Hauptgruppen, bis hin zu den frühtriassischen Sedimenten der Beaufort Gruppe auf. Das Alter der Sedimente und deren Deformation nimmt gegen Norden hin ab. Die Querprofile durch das Gebirge in das Karoo Becken stellen daher eine stratigraphische Altersabfolge dar. In den gefalteten Gesteinen der Cape- und Karoo-Sedimente konnten vier verschiedene Generationen von Gängen identifiziert werden, die alle mit der Kap-Gebirgsbildung im ausklingenden Perm, vor etwa 250 ± 20 Ma im Zusammenhang stehen. Quarz und Kalzit sind die häufigsten Gangminerale.