Ber. Inst. Erdwiss. K.-F.-Univ. Graz	ISSN 1608-8166	Band 9	Graz 2004

STABLE ISOTOPIC (C,O) COMPOSITION OF QUATERNARY TALUS BRECCIAS (NORTHERN CALCAREOUS ALPS, AUSTRIA): IMPLICATIONS FOR DIAGENESIS

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The stable isotope signatures (C, O) of carbonate talus breccias from the Northern Calcareous Alps (NCA) show distinct clusters of host rock, matrix and of meteoric phreatic cements. The investigated breccias consist of clasts of Mesozoic limestones, lithified by calcite cements precipitated in vadose and phreatic meteoric environments. Alternatively, or in addition, the breccias contain a primary matrix or an infiltrated, secondary matrix of calcisiltite to calcimicrite; the secondary matrices are characterized by sedimentary lamination. Many of the talus breccias are overlain by Würmian lodgement till.

The investigated talus breccias show a diagenetic pathway that, aside lithification of the fine-grained matrices, is characterized by (1) isopachous to mammillary crusts of micritic cement (locally with microbialite fabrics), followed by (2) isopachous fringes of phenocrystalline skalenoedric calcite cements. Locally, repetitive phases of dissolution of cement and/or of matrices followed by precipitation of micritic and/or phenocrystalline cements are indicated. No features of marked corrosion of clasts, however, were identified.

$\delta^{18}O_{(VPDB)}$ and $\delta^{13}C$ values allow to estimate the isotopic composition, the origin and the temperature range of diagenetic fluids involved in cementation. About 1000 isotope samples from 17 different locations were analyzed. All rock samples were brushed, soaked and washed with distilled water; isotope samples were excavated with a dental drill. Upon isotope sampling, we distinguished between meteoric cements, primary or secondary matrix, and host rock.

Host rock: The host rock signals, with means of $\delta^{13}C$ = 2,6 ‰ and $\delta^{18}O$ = -5,2 ‰, are typical for fully lithified marine limestones.

Phenocrystalline meteoric calcite cements: The d13C of the breccia cements varies between -10,4‰ to +3,9 ‰, whereas $\delta^{18}O$ is characterized by values between -11,7 ‰ and -6,1 ‰, with a distinct maximum of -9,6‰. Within a sample, however, the isotope ratios of C and O covary, although the variation of the $\delta^{18}O$ is smaller. In view on the 14,3 ‰ range of the $\delta^{13}C$ values and the coupled, but smaller, variation of the $\delta^{18}O$ values, a meteoric origin of the cements in indicated (e.g. ALLEN & MATTHEWS, 1982; LOHMANN, 1988). The $\delta^{13}C$ values of the cements cluster between -10‰ to -7‰. The carbon isotope value in the meteoric cements could have originated from different sources such as atmospheric CO_2 (about -8,0‰), from soil/calcrete organic matter decay ($\delta^{13}C \geq$ -20‰), and/or from meteoric dissolution of basal moraines that, in many cases, overlie the talus breccias. Carbonate precipitated in surface or shallow diagenetic settings with an open-system exchange with atmospheric CO_2 has an isotopic composition reflecting the signature of air-CO_2 (RAHIMPOUR-BONAB & BONE, 2001). Calcite precipitated in open-system equilibrium with soil-gas CO_2 is limited to $\delta^{13}C$ values of about -15 ‰ (RIGHTMIRE & HANSHAW, 1973). Together, the evidence suggests an overriding meteoric signal within the cements, whereas host rock buffering and contribution of soil CO_2 are tentatively considered of subordinate significance.

Matrices: In the matrices, the $\delta^{13}C$ ranges from -6,2 ‰ to 6,6 ‰ (mean 0,6 ‰), and $\delta^{18}O$ values range from -11,2 ‰ to -2,1 ‰ (mean -8,0 ‰). For all samples, the mean $\delta^{13}C$ values of the matrices are both more variable and plot closer to the host rock signature than the $\delta^{18}O$ ratios. The $\delta^{13}C$ values thus may be more host-rock buffered than the $\delta^{18}O$ values. Further investigations for understanding matrix isotopic composition are necessary and will be done in future.

Geographic latitude (approximated as 47° for all samples), altitude, and temperature are primary factors controlling the isotopic composition of meteoric cement (HAYS & GROSSMAN, 1991). With respect to the present-day altitude effect, for Austria, HUMER et al. (1995) indicated an average decrease of -0,16 ‰ d18O per 100 meter increase in altitude (see also MOSER & RAUERT, 1980). My own calculations based on the $\delta^{18}O$ values from the measured meteoric calcites in the breccias resulted in an altitude gradient of -0,11 ‰ per 100 meters. The similarity of the figures of the present altitude effect and that calculated for the talus breccias supports that the isotope signal of the cements is mainly determined by meteoric-derived pore fluids.

Relative temperature estimations (see e.g. DANSGAARD, 1964; ROZANSKI et al., 1992) result in a 4°-5°C temperature range covered by the total of the measured $\delta^{18}O$ values. For the minimum $\delta^{18}O$ value (-11,7 ‰) of the breccia cements, palaeotemperatures calculated according to HAYS & GROSSMAN (1991) yielded a temperature range between 3°C and 33°C; the mean $\delta^{18}O$ value (-9,58 ‰) resulted in a range of 5,1°C to 30,4°C. As compared with recent temperatures (HUMER et al., 1995), values above about 10°C are unrealistic for the altitudes and geographic position of the sampled talus breccias.

Together, the isotope evidence suggests that cementation proceeded within meteoric-derived waters (rain, snowmelt), whereas carbonate precipitation in association with subglacial melt waters is considered improbable. Apart from a first characterization of C,O-isotope signatures of Alpine Quaternary lithified talus, our data imply that relatively long-lived, meteoric-derived phreatic groundwater bodies are common at least within the deeper portions of many talus accumulations. Moreover, the mentioned repetitive changes between dissolution and meteoric-vadose and phreatic cementation record distinct fluctuations of groundwater table that, perhaps, may occur over long intervals of time. Because, by volume, talus is the most significant type of sediment storage in high-mountainous areas such as the NCA (SCHROTT et al., 2004), talus slopes probably represent a significant and hitherto little considered groundwater reservoir.

FWF project P 16114-NO6 is acknowledged for financial support.

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