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Clumped Isotope Compositions of Marbles from the Backbone Range of Taiwan

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Clumped isotope composition of carbonates provides a way to retrieve temperature conditions in ancient systems without the knowledge of the isotopic compositions of co-existing phases. This technique has been extensively applied to low-temperature geologic processes in the past decade. However, application of this new thermometer to high-temperature geologic processes is limited due to poor understanding of the clumped isotope behavior under such environments, as well as the lack of proper calibrations at high temperatures. In this study, we present clumped isotope compositions of marbles from the Backbone Range of Taiwan. These marbles have experienced greenschist-facies metamorphism. The possible implications of their clumped isotope compositions are discussed.

Taiwan is located at the junction of the Eurasia and the Philippine Sea plates. The formation of the Taiwan island is due to the still ongoing collision/accretion of the Luzon arc with the eastern margin of South China, starting from the Mio–Pliocene. The present geologic architecture of Taiwan mainly resulted from rock exhumation due to this ongoing tectonics, although the basement rock, i.e., the Tailuko belt of the Tananao Metamorphic Complex, has also experienced Mesozoic tectonic processes. Following the present tectonic unit division (Ho, 1986), the northern part of the Backbone Range (Fig. 1) of Taiwan is composed of the prehnite-pumpellyite facies Lushan Formation of Miocene age, the prehnite-pumpellyite facies to greenschist facies Pilushan Formation of Eocene age and the greenschist facies to amphibolite facies Tailuko belt of the Tananao Metamorphic Complex of pre-Tertiary age. The metamorphic grade increases eastward and roughly correlates with the age of these rock units.

Selected marble samples from both thin marble layers and massive marbles of the Backbone Range (Table 1 and Fig. 1) were analyzed for their bulk stable isotopes and clumped isotope compositions ($\Delta47$). $\Delta47$ (expressed in ARF, Absolute Reference Frame) of these samples ranges from 0.350 to 0.484 per mil (Table 2). The corresponding estimated temperatures range from 95 to 205°C (Table 2 and Fig. 1), following the calibration by Guo et al. (2009). The calculated O-isotope compositions of the co-existing fluid phase ranges from -1.9 to +10.7 per mil (Table 1), based on the calibration of O'Neil et al. (1969). The resulting temperature estimates are lower than and do not correlate with the observed metamorphic grade trend of the Backbone Range. The results may thus indicate temperatures of the last dynamic open-system recrystallization of marbles due to tectonic movements, especially for those samples near marble-country rock contact. Calculated negative O-isotope composition of the presumed co-existing fluid phase might demonstrate that meteoric water has percolated downward to a depth of at least 3-4 km, probably along lithological contacts, during rock exhumation. On the other hand, calculated high O-isotope composition of the fluid phase might have resulted from extensive interaction of such fluid with rocks during percolation or different origins. Note that the higher temperature estimates, mainly from samples located at interior part of massive marbles, may alternatively signify closed-system cooling/closure temperatures during rock exhumation. If the latter proposition holds, such samples may provide valuable information on the cooling/exhumation rate of the whole mountain belt. In summary, the present study demonstrates that clumped isotope composition of marbles indeed has the potential revealing key process characteristics during mountain building.