An attempt to use mean crystallite size of calcite for indicating metamorphic grade as examplified by metamorphic carbonate rocks from NE-Hungary

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A great variety of low-T metasedimentary rocks are devoid of metamorphic facies indicating mineral assemblages. Instead, they contain common mineral assemblages that are stable over wide P-T fields. The structural and related chemical changes in certain phyllosilicates proved to be reliable empirical indicators for expressing differences in metamorphic grades (zones). Illite and chlorite “crystallinity” (called Kübler, etc.) indices have been widely used to determine diagenetic and metamorpic (anchi- and epi-) zones mostly in pelitic and marly lithologies.

The present study intends to reveal whether there is any relationship between the structural and chemical changes of carbonate minerals (mostly calcite) in metamorphic rocks and the increasing metamorphic grade (increasing temperature). For this purpose such metamorphosed (recrystallized) limestones and marbles were selected from NE-Hungary, the metamorphic zones of which and their intercalated metapelitic environments have been fairly well known by earlier phyllosilicate “crystallinity” studies (Szendrő Mts.: epizonal, Uppony Mts.: epi-anchizonal, Árkai, 1983, 1991).

Petrographic and cathodoluminescence microscopy and stable isotope measurements were used to characterize the textural and chemical features of carbonatic metamorphic rocks. In addition, X-ray powder diffractometric single line (Voigt) profile analysis was also applied in order to determine changes in mean crystallite size of calcite (i.e., in average size of domains that scatter coherently the X-rays).

The mean crystallite size values of calcite range between 300 and 400 Å in the bulk rock samples. The crystallite size seems to be similar in the rocks originated from different (laguna, reef and deep marine basin) sedimentary environments. Certain carbonate generations (lenses and layers parallel to cleavage planes and veinlets formed before and after deformation), however, have lower (120 to 220 Å) average crystallite size than the bulk rocks. There is no unequivocal correlation between stable isotope composition and crystallite size, different carbonate generations and bulk rocks have nearly similar range of $\delta^{13}C$ and $\delta^{18}O$ values.

Further chemical and structural (microprobe and TEM) analyses are planned to reveal eventual correlations between crystalchemistry, structure and crystallite size of carbonate minerals.

References

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High-precision ^{26}Al-^{26}Mg dating of early Solar System processes

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The short-lived ^{26}Al to ^{26}Mg chronometer ($t_{1/2} = 0.73$ Myr) has been used to date Al-rich minerals in refractory inclusions and chondrules from chondritic meteorites, as well as feldspar from basaltic meteorites. Here, we explore the prospects of precisely *and* accurately resolving (and using) very small ($\leq$ 40 ppm) excesses and deficits in the abundance of ^{26}Mg in meteorites to date Al/Mg fractionation events associated with planetary differentiation in the first few Myr of the Solar System. Increases in Al/Mg ratios relative to chondritic (i.e., bulk planetesimal) values resulted from formation of basaltic magmas (Al/Mg = 1-3). Conversely, formation of essentially Al-free material resulted from olivine crystallization (pallasite olivine), formation of pyroxene cumulates (aubrites, diogenites) and partial melting (ureilites). The excesses and deficits that can be expected from these early Al/Mg fractionation events means it will be necessary to resolve δ^{26}Mg* anomalies with precision and accuracy $< \pm 10$ ppm (2σ) to potentially utilize the ^{26}Al-^{26}Mg chronometer to identify and date these processes.

Using a Nu Plasma MC-ICPMS, we have developed procedures that allow measurement of δ^{26}Mg* anomalies (the offset of a sample’s mass-bias-corrected ^{26}Mg/^{24}Mg ratio compared to the mean of bracketing standards) in single analyses with precisions as low as ±12 ppm (2 se), which incorporates the uncertainties from the bracketing standards. Accuracy of data is verified by analysis of matrix-matched standards and, in some cases, by analysis of standards doped with ^{26}Mg spike to create anomalies of known size. After anion and/or cation exchange chemistry, samples are analysed multiple times by MC-ICPMS in pseudo-high-resolution mode enabling resolution of molecular interferences (e.g., $^{12}C_2^+$, $^{12}C^{14}N^+$) from Mg.

We have reanalyzed meteorites where small δ^{26}Mg* excesses (angrites, eucrites) and deficits (pallasite olivines, ureilites, aubrites) have previously been reported, and used to constrain rapid timescales of planetesimal melting, differentiation and accretion in the young Solar System. These previous measurements were not made using high-resolution techniques and were characterized by somewhat larger analytical uncertainties than the present study. Further, we have also measured Mg isotopes in step-leaching fractions of C1 chondrites where large (ε to %) anomalies in neutron-rich isotopes of elements like Cr have been reported. Our new results place important constraints on the prospects of using high-precision Mg isotope measurements to date a wide range of meteoritic material and early Solar System processes.