

## Accelerator-mass-spectrometry: Where are we now and where will we be in 10 years?

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In the years since the discovery of cosmic-ray-produced  $^3\text{He}$  in iron meteorites, *in-situ*-produced cosmogenic nuclides are now routinely measured in meteorites, lunar surface materials, terrestrial surface materials, and very likely, martian surface material. In the near future it is anticipated that they will be measured in materials returned to Earth by spacecraft, including those returning samples from asteroids, Mars, and remarkably a sample of the solar wind. This expansion of applications has been and continues to be enabled by advances in measurement capabilities.

The most commonly utilized *in-situ*-produced cosmogenic nuclides are  $^{10}\text{Be}$ ,  $^{14}\text{C}$ ,  $^{26}\text{Al}$ , and  $^{36}\text{Cl}$ ; these nuclides are measured in both extra-terrestrial and terrestrial materials.  $^{41}\text{Ca}$ ,  $^{53}\text{Mn}$ , and  $^{59}\text{Ni}$  have been measured in extra-terrestrial materials however, their measurement is not routine. For both the prosaic and exotic, improvements in ionization or detection processes could potentially lead to improvements in sensitivity, precision, and accordingly capability. For example, terrestrial applications of the  $^{10}\text{Be}$ - $^{26}\text{Al}$  pair are often limited by the error of the  $^{26}\text{Al}$  measurement.  $^{26}\text{Al}$  is extracted from the ion source as  $^{26}\text{Al}^+$ , an inefficient process.  $^{26}\text{AlO}^+$  is produced more efficiently. Lamentably,  $^{26}\text{MgO}^+$  is produced as well, and  $dE/dx$  techniques alone cannot resolve  $^{26}\text{Al}^+$  from  $^{26}\text{Mg}^+$ . The addition of a gas-filled-magnet to the detector allows the separation of these isobars. Other radionuclides suffer from isobaric interferences as well, e.g.  $^{36}\text{Cl}$ ,  $^{41}\text{Ca}$ ,  $^{53}\text{Mg}$ , and  $^{59}\text{Ni}$  and improvements in isobar rejection, such as is possible with a gas-filled-magnet, will likely lead to the routine application of these radionuclides to problems of geologic interest, terrestrial and extra-terrestrial. The effect upon sensitivity and precision of likely improvements in AMS techniques will be reviewed and the impacts on the nature of geologic problems that could potentially be investigated will be explored.

## Constraints on diffusion rates in garnet from natural occurrences

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Application to metamorphic problems of experimental data on intracrystalline diffusion in garnet is hindered by the need for long extrapolations to lower temperatures and pressures, and by the marked – yet so-far poorly understood – dependence of rates on the host garnet's composition. Measurement and numerical simulation of the development of stranded diffusion profiles at the periphery of partially resorbed garnet crystals in well-constrained natural occurrences can be combined with existing experimental data to yield tighter constraints on low-temperature diffusion rates of Mg, Fe, Mn, and Ca, and a first-order correction for the effects of garnet composition.

Diffusion during polymetamorphism in the Llano Uplift of central Texas (USA) has produced concentration gradients for major elements in the rims of partially resorbed garnet crystals. During resorption, elements that are preferentially partitioned into the relict garnet (e.g., Mn) build up at the rim, whereas elements that are preferentially partitioned into the reaction products develop concentration profiles that decrease outward. In either case, the steepness of the profile in the relict garnet depends upon the relative rates of the resorption reaction and the intracrystalline diffusion that results from it. A numerical model simulating this coupled resorption-diffusion process (Carlson, 2002) retrieves optimal values for diffusion coefficients by means of a fitting procedure that maximizes congruence between measured and calculated concentration gradients.

Preliminary results from analysis of profiles in 14 Ca-bearing mafic garnets, resorbed at temperatures of ~625-475 °C and 0.3 GPa pressure, yield diffusion rates that are in good agreement with down-temperature extrapolation of the experimental data of Chakraborty and Ganguly (1992) for Mn in almandine-spessartine diffusion couples, but that are significantly higher than extrapolated values for Fe, Mg, and Ca. Using a linear increase in  $\ln D^*$  with garnet cell-edge length to account for variations in diffusivity for garnets of different composition provides a first-order compositional correction. The actual dependence of rate on cell-edge length is complex and non-linear, however, so more sophisticated approaches to computing diffusivities as a function of composition must be developed as the database expands.

### References

- Carlson W.D., (2002), *Am. Min.* **87**, 185-204.  
Chakraborty S., and Ganguly, J., (1992), *Contrib. Min. Pet.* **111**, 74-86.