Exploring micro-scale stable isotope variations using femtosecond laser ablation MC-ICP-MS

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We present advancements in micro-scale analyses of non-traditional stable isotopes using a second generation custom build femtosecond laser ablation system coupled to a multicollector ICP mass spectrometer.

The heart of our laser ablation system is based on the latest generation Ti-Saphire regenerative amplifier system *Spectra Physics Solstice*, which produces 100 fs infrared (IR) laser pulses with up to 3.7 mJ/pulse. Non-linear optics are used to convert the fundamental IR wavelength into the UV with a wavelength of 196 nm and an adjustable pulse energy of up to of 0.1 mJ/pulse. The system provides full control on laser parameters, such as spot size, energy density, pulse width, repetition rate (continuous from 1 to 1000 Hz) and beam shape. The spot size can be varied from 10 to 100 μm in diameter with energy densities on the sample between 0.1 and 50 J/cm^2.

The laser beam is delivered to the sample (thin sections or polished blocks contained in a He-flushed sample cell) through a fully automated and computer controlled microscope stage, modified with UV optical components to focus the laser beam and visualise the sample surface. Special emphasis in the construction was given to high quality optical imaging of the sample, while maintaining an optimum laser beam quality.

A custom-designed software allows integrated control on laser parameters, sample positioning and observation, as well as fully automated analyses through a synchronised operation with a *Thermo Neptune* MC-ICP-MS, equipped with a *Neptune Plus Jet Interface* for increased sensitivity.

We will present results on optimized analytical conditions for stable isotopes measurments of Fe, Si, and Mg at the micro scale in various matrices, such as minerals, glasses, and soils.

Climate change and the KISS principle

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Mineral carbonation is the logical answer to rising CO_2 levels. The CO_2 is captured in a safe and sustainable way and returned to the rock record as solid carbonates. The recipe is simple and straightforward:

-select an abundant material that weathers easily (olivine or serpentine)

-mine and mill this material

-spread it in a favorable climate for weathering

Instead of leaving it at that, and follow the KISS principle (Keep It Simple, Stupid), most researchers try to develop techniques to speed up the carbonation. This costs extra energy and money. This is a major reason why the storage of CO_2 in abandoned oil and gas fields, or in saline aquifers is still the favored mitigation strategy. Mineral carbonation has been overlooked, mainly because researchers have made it too complicated in their attempts to speed up the reaction.

There is no need to speed up the reaction, as olivine grains of 100 μm weather and capture CO_2 in a few years in a suitable climate. Extrapolation of abiotic experiments suggests that weathering is not fast enough. Outside the laboratory the role of biotic factors like mycorrhizal fungi on land or lugworms on tidal flats has been demonstrated, which speed up the weathering reaction by factors of ten to almost one thousand. Crushed serpentinite mine tailings in British Columbia are known to weather fifty times faster than basaltic tuffs in even the most favorable climate for weathering.

For the global C-cycle it makes no difference where the CO_2 is captured, as the atmosphere is a well mixed reservoir on the timescale of a few months. Capturing and storing of CO_2 from flue gases is too expensive. The separation step alone costs already considerably more than straightforward enhanced weathering.

The strategy for enhanced weathering relies upon olivine mined in the wet tropics. This material is milled and the grains are spread over the surrounding area. The whole operation (mining, milling and transport) will cost around 10 Euro/ton of captured CO_2. Negative effects on the environment are unlikely.