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High-Frequency Geochemical Time Series Across Scales: Using miniRUEDI to Probe Subsurface Responses to Seismicity

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The relationship between subsurface geochemical variability of fluids and seismic activity remains poorly understood, largely due to the lack of systematic, long-term and high-frequency geochemical observations. Many reported observations between geochemical anomalies and earthquakes rely on isolated events or short monitoring periods in large-scale field observations, limiting the ability to assess the relationship between observed anomalies and the physical mechanisms underlying them [1].

Here, we present how a portable mass spectrometer (*miniRUEDI,* [2]) enables continuous monitoring of multiple gas species in fluids across a range of spatial and temporal scales. We illustrate the versatility of the instrument through three complementary applications. (1) Small scale laboratory rock-deformation experiments demonstrate how high-resolution gas measurements capture the temporal evolution of liberated gases during progressive loading and prior to macroscopic failure. (2) Deployment in the Bedretto Underground Laboratory shows how dissolved gases in groundwater can be monitored on-site during controlled, induced seismicity in a natural rock mass at the decameter-hectometer scale. (3) Long-term field observations in an Alpine hydrothermal system provide multi-year time series of dissolved gases, allowing the exploration of potential links between natural seismicity and subsurface geochemical dynamics.

These three examples highlight how systematic, high-frequency gas monitoring can move seismo-geochemical studies beyond event-based observations toward systematic, process-oriented analysis. The miniRUEDI thus provides a robust experimental basis for investigating how mechanical perturbations of the subsurface may be reflected in fluid geochemistry, from controlled laboratory conditions to complex natural and engineered systems.

[1] Toutain et Baubron (1999), *Tectonophysics, **304**, 1-27*

[2] Brennwald et al. (2016), *ES&T, **50**, 13455-13463*