Archaeo-environmental characterization of the Arvernian gold mines of Auvergne (France)

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During the Iron Age, the Gaulish *Arverni* and *Lemovices* influence extended well beyond Auvergne (Central France), into the Mediterranean regions owing to extensive agricultural activities and silver mining. Recent discoveries showed that gold mining in the area of Haute-Combraille (Auvergne) may also has contributed to the wealth of these communities. Gold was possibly extracted as well during the first two centuries AD. at the onset of Roman occupation.

Our project (MINEDOR) aims to study from an interdisciplinary and diachronic point of view these ancient gold mines, traditionally attributed to the Gaulish period, discovered in large numbers at the fringes of the *Arverni* and *Lemovices* territories, in the area of Upper Combraille (Puy-de-Dôme). Our goals are 1) to accurately identify the mines through fieldwalking and aerial surveys, analysis of vertical aerial photographic coverage and localization by dual-frequency DGPS, 2) to assess their environmental impact using palaeoenvironmental (palynology, microfossils) and geochemical (heavy metals, trace elements, stable lead isotopes) analyses in wetlands, and 3) to date transient phases of exploitation.

Here we present high-resolution peat core analyses from the Haute-Combraille highlands (900-1000m) that allow to evidence gold mining operational phases since the Iron Age through vegetation cover changes and the release of lead (Pb) from mining activities. These new data highlight important features of the ancient economy of the Massif Central and the transient environmental impact of mining operation on watershed quality.

Advances in MC-TI-MS for precise and accurate Ca isotopic analysis

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Ca isotopes have proved to be powerful isotopic tracers in a number of disciplines within Geosciences, including Paleoceanography, Geochronology and Biogeochemistry, and Cosmochemistry, where minute anomalies relative to Earth are a key to deciphering the origin of Earth and the terrestrial planets. However, accurate and precise Ca isotope analysis is highly challenging, due to, both, the extreme range of relative Ca isotopic abundances - ^{40}Ca alone representing 97% of Ca isotopes - and the extreme mass dispersion of the Ca isotope array of 20%. These limiting features have prevented optimized multicollection (MC) analysis of all Ca isotopes, and introduced uncertainties due to ion beam instabilities and inferior counting statistics for the minor Ca isotopes. Precision and accuracy can be improved by optimizing sample loading and double spike techniques, but ultimately, there is a need for improved mass spectrometry performance in order to improve the state-of-the-art for Ca isotopic analysis.

The TRITON *Plus* offers new solutions to address these analytical challenges:

[1] An extended mass dispersion provides *simultaneous collection of all Ca isotopes*, without the requirement of applying a zoom to deflect the Ca ion beam. Peak-jumping mode is no longer required for Ca isotope analysis, thus saving acquisition time and limiting the potential detrimental effects of Ca ion-beam instabilities on precision and reproducibility.

[2] Different gain current amplifiers (10^{10}, 10^{11} and 10^{12} Ohm) can be combined. The 10^{12} Ohm amplifiers provide a factor of 2-3 improvement in the signal/noise ratio relative to a classical 10^{11} Ohm amplifier, and can be associated to the cup(s) collecting the minor Ca isotope(s). Additionally, a 10^{10} Ohm amplifier can be connected to the cup collecting ^{40}Ca, and hence increase the dynamic range by a factor of 100. Amplifier switching to any cup is supported by the tried and tested relay matrix already equipping TRITON instruments. The combination of these current amplifiers ultimately contributes to enhancing Ca isotope in-run precision through improved ion counting statistics and by application of more precise instrumental mass fractionation correction as the normalizing ratio ^{42}Ca/^{44}Ca can be determined at 10 times higher beam intensities.

[3] The new TRITON *Plus* Ca package consists of 2 special cups: an extended cup attached on the high mass side of the focal plane that accomodates acquisition of the heaviest Ca isotope (^{48}Ca); and an oversized cup on the low mass side of the focal plane for the high intensity ^{40}Ca beam.