

## Fluid composition and carbon isotope evolution in the Borrowdale graphite deposit (United Kingdom)

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Graphite was discovered at the Borrowdale volcanic-hosted deposit (Cumbria, UK) by mid 16th century. The graphite deposit occupies about a 400 m length of a conjugate set of normal faults and is hosted by andesitic rocks of the upper Ordovician Borrowdale Volcanic Group, and by a probably coeval hypabyssal dioritic intrusion. The volcanic rocks are underlain by the low-grade metapelites of the Skiddaw Group. Graphite in the Borrowdale deposit occurs as: i) nodular masses (up to 1 m in diameter) in pipe-like bodies along fault intersections (1 x 3 m in cross-section and up to more than 100 m in length), ii) fault-veins in the volcanic rocks, usually associated with chlorite, and iii) as replacements (disseminations) within the volcanic host rocks. Graphite morphologies include flakes (>90 vol%), cryptocrystalline (colloform) aggregates, and spherulites. The textural sequence of graphite morphologies (spherulites → cryptocrystalline → flakes) suggests precipitation from fluids with progressively lower supersaturation in carbon.

Fluid inclusions were studied in quartz fragments associated with graphite in the pipes. Microthermometric and Raman data allowed the recognition of four types of inclusions. The composition trend of these fluid inclusion assemblages shows an overall fluid evolution characterized by: 1) depletion in volatiles, i.e. the carbonic species are transferred to the solid state as graphite, and 2) progressive decrease in the  $XCO_2/(XCO_2+XCH_4)$  ratio. Bulk carbon isotope ratios of graphite nodules and microscale SIMS study of the different graphite morphologies show light  $\delta^{13}C$  values (-34.7 to -23.4 ‰) compatible with the assimilation of biogenically-derived carbon from the Skiddaw metapelites. Within the main mineralized breccia pipe-like bodies, cryptocrystalline graphite is lighter than flaky graphite, which is consistent with the progressive loss of  $CO_2$  in the mineralizing fluids. Late graphite-chlorite veins contain isotopically heavier spherulitic graphite than flaky graphite. This agrees with  $CH_4$ -enriched fluids at this stage of the mineralizing process.

## Metabolic and thermal properties of soils from the Atacama desert

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Calorimetry was applied to study the metabolic and thermal properties of 11 soil samples collected in different sites in the Atacama desert. The heat of combustion of the carbon-containing matter was calculated by differential scanning calorimetry [1] and isothermal calorimetry was used to measure the microbial metabolism and to quantify the biomass [2, 3]. The data given by the calorimetric methods were compared to other soil properties determined by elemental analysis as C, N, H content, and pH.

Results showed that the heat of combustion of the organic matter was directly related to the C content of the samples. There was measurable organic matter in 9 of the 11 samples. Biomass was not detected in 5 of the 11 samples. The quantity of biomass of the soils ranged from  $77 \pm 8$  to  $379 \pm 32 \mu\text{g C-g}^{-1}$ . There was microbial activation in 6 of the eleven samples after addition of glucose and water. The detected metabolism was heterotrophic. The activated microbial population was able to grow using the glucose added as C source at microbial growth rates ranging from  $0.093 \pm 0.004$  to  $0.455 \pm 0.004 \text{ h}^{-1}$ . These rates were directly correlated with the capacity of the soils to degrade the glucose added. The C conversion metabolic efficiency of these soils was determined by thermodynamic models [4] and varied from 0.55 to 0.74. That is the C quantity that is kept in soil by the biomass. The metabolic C efficiency, the C content and N content of the soils were all of them a direct function of the altitude of the locations where the samples were collected (from 300 to 4500 meters). Therefore, altitude and indirectly, temperature, appeared to be the main factors ruling the survival of the soil biomass and the C sequestration in the soils from the Atacama desert.

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[3] Sparling (1983) *J. Soil. Sci.* **34**, 381-390. [4] Barros & Feijóo (2003) *Biophys. Chem.* **104**, 561-572.