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Nature and origin of the resistant carbonaceous polymorphs involved the fossilization of biogenic soil-aggregates

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The rare occurrence of organic-rich surface horizons in soil archives is widely accepted to resulting from their rapid degradation. We intend here to further elucidate how pedogenic signatures that initially formed at the soil surface could resist over long timescales to burial processes. We focus on the structural evolution of the biogenic soil aggregates that is controlled by the complex interaction of bioturbation, root colonization, microbial decomposition, chemical weathering and physical processes. The nature and origin of carbonaceous components that could possibly contribute to the long term preservation of biogenic soil-aggregates is particularly examined. The study is based on the comparison of pedogenic aggregated microfacies from present-day situations and the ones encountered in soil archives from contrasting edaphic conditions: Arctic Holocene soils from Spitsbergen, hyper-arid soils from the Moche valley (Peru), Holocene semi-arid Mediterranean soils from Northern Syria, late Pleistocene paleosols from lake Mungo (South Wales Australia) and late Pleistocene paleosols from the Ardeche valley (France). The assemblage and composition of biogenic soil-aggregated horizons has been characterized under the binocular microscope and in thin sections. The basic components have been separated by water sieving. A typology of carbonaceous polymorphs and associated composite materials has been established under the binocular. They have been characterized by SEM-EDS, Raman spectrometry, X-ray diffraction and TEM.
The comparative study shows that all the biogenic soil-aggregates from the soil archives contain a high amount of similar exotic components that contrast from the parent materials by their fresh aspect and their hydrophobic properties. This exotic assemblage comprises various types of aliphatic carbonaceous polymorphs (filaments, agglutinates, spherules) and aromatic ones (vitrous char, graphite), carbon cenospheres, fine grained sandstones and rock clasts which are all finely imbricated with phosphides, phosphates, sulphides, sulphates and native metals (Fe-Cr-Ni and Fe-Cr alloys, Ni, Al, Cu, Zn, Pb, As, Sn, Ag, Au, Bi). The 3D observations show that the carbonaceous filaments play a major role in the cohesion of the fine fraction. The carbonaceous components only start to decompose under HF attack and from 400°C heating. They do not display evidence of microbial degradation. The biogenic aggregates with high amount of carbonaceous polymorphs appear to have resisted to cryoturbation and to hard setting under water saturation. Biogenic micro-aggregates from present-day top soils only contain rare exotic components. In contrast to the ones of the soil archives, they display highly variable structural stability depending upon local edaphic conditions. The exotic assemblage of the stable biogenic micro-aggregates from the soil archives is shown to be similar to the range of terrestrial aerosols that are associated to meteor explosion (Courty et al., this volume). This suggests that the fossilized organic-rich surface horizons in soil archives would trace singular situations possibly marked by recurrent meteor explosion with high stratospheric aerosol production. Mechanisms explaining how the dual stratospheric/cosmic processes formed resistant carbon species from fossil combustible precursors yet remain to be investigated.
Courty, Benoît and Vaillant (2012). Possible interaction of meteor explosion with stratospheric aerosols on cloud nucleation based on 2011 observations. Geophysical Research Abstracts Vol. 14, EGU2012.