Geophysical Research Abstracts, Vol. 7, 04621, 2005
SRef-ID: 1607-7962/gra/EGU05-A-04621

The record of interaction between the 4-kyr BP hot impact-melt and surface soils in vesicular glass slabs from Southern France

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Evidence for similar flow-glass debris associated with a heated soil surface has been recognized as the widespread traces of the 4-kyr BP impact in Southern France. Initiation of thermal alteration by dispersion of an ejecta cloud throughout distal areas from the impact zone is intriguing. Glass products were suggested by us to result from pulverisation at the ground of a gas-rich hot fluid bed produced by impact melting of mineral and organic terrestrial sources.

This study aims to determine the exact mechanisms of interaction between the impact melt and the ground surface. Vesicular glass slabs (5-20 cm) and related host soils are compared from three sites with distinctive parent materials in Southern France. Optical and analytical electron microscopy (SEM, TEM, EDS and WDS microprobe), reflected X-ray diffraction, Raman microspectrometry, ICP-MS analysis and isotope mass spectrometry (C, O, S, Fe) were performed to characterize the intrusive phases and the transformed host matrix.

The vesicular glass bodies share in common a budding morphology formed of imbricated micro-facies that contrast with the original matrix. Dark brown flow-glass with devitrified domains fill grain boundaries and pore spaces. Its texture, micro-scale chemical heterogeneities, occurrence of ballen-cristobalite, melted-zircons, shock-dissociated ilmenite, pure metal blebs, and nano-scale micro-spheroidal pattern are typical of a polymict impactite. These features, which are similar at the three sites, characterise the intrusive fluid phase derived from the impact ejecta melted at temperature above 1700˚C. Its pattern and presence as spheroid (50-300 μm) clusters filling degassing vesicles suggest incorporation as liquid droplets. The host matrix attached to the flow-glass displays clay vitrification, carbonate amorphisation by decarbonatation, selective melting at grain boundaries and local recristallisation of diverse minerals (silicates, carbonate, silico-phoshates). Mineral alteration and neoformation indicate thermal transformation at temperature around 750˚-800˚C. The wide compositional range of the glass phases and neoformed minerals is consistent with mixing between the intrusive fluid and the local fine mass. Metal droplets and clusters of carbon-rich micro-spheroids sprinkle degassing vesicles of the flow glass and heated host materials. The carbonaceous compounds consist of nano-sized diamonds, graphitic carbon, amorphous carbon, and polycyclic aromatic hydrocarbons (PAHs) species. Their low δ^{13}C value identifies their organic origin. The anomalous isotopically light carbonates in the heated matrix suggest thermal decomposition of the local carbonates due to incorporation of the volatile carbonaceous liquids and carbonate re-crystallization from the melt-derived carbon. The contrast between sporadic coarse vesicular glass bodies and abundant impact-ejecta debris (glass beads, metal particles, carbonaceous grains) throughout the heated surface is proposed to result from the local fall of solidified melt masses transported and incorporated into the gas-rich hot fluid-bed.