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Shock-induced deformation of Shergottites: shock-pressures and perturbations of magmatic ages on Mars

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Shergottites and Chassignites practiced major deformation effects whose nature, magnitude and relevance were controversially evaluated and disputatively debated. Our studies of many shocked shergottites present, contrary to numerous previous reports, ample evidence for pervasive shock-induced melting amounting of at least 23 vol.% of the original labradorite, finding of several high-pressure polymorphs and pressure-induced dissociation reactions. Our results cast considerable doubt on using the refractive index (R. I.) of maskelynite, in estimating magnitudes of peak-shock pressure in shergottites or ordinary chondrites because R. I. of maskelynite was first established after quenching of the feldspar liquid to maskelynite glass followed by glass dilation after decompression and first at the closure temperature of relaxation. This procedure widely practiced in the past 38 years, revealed unrealistic high-pressure estimates discrepant with the high-pressure mineral inventory in shergottites and with results obtained by robust static experiments. Shergottites contain the silica high-pressure polymorphs seifertite, a monoclinic ultra dense polymorph of silica, stishovite, a dense liquidus assemblage consisting of stishovite + Na-hexa-aluminosilicate (Na-CAS) and both K-lingunite and Ca-lingunite. Applying individual high-pressure silica polymorphs alone like stishovite, previously practiced to estimate the equilibrium shock pressure, is inadequate due to the considerable shift of their upper pressure bounds intrinsically induced by spatially variable absorptions of minor oxides like Al_2O_3, Na_2O, FeO, MgO and TiO_2. This revealed variable pressure estimates within the same shergottite subjected to the same peak-shock pressure. Occurrence of Na-CAS + stishovite, lack of $NaAlSiO_4$ Ca-ferrite structured polymorph or jadeite indicates that the peak-shock pressures barely exceeded 22 GPa. We present convincing evidence to discard the claim that the shock-induced high-pressure inventory in shergottites and ordinary chondrites resulted from local shock spikes in excess of 80 GPa and during the decompression stage. Such scenario calls for a series of incomplete and quenched retrograde reactions starting with Mg-silicate perovskite + magnesiowustite if formed above 80 GPa followed by majorite-pyropess + magnesiowustite below 23 GPa and 2000 degree, ringwoodite above 16 GPa, respectively and finally polycrystalline olivine at ambient pressure. Such incomplete retrograde reactions were never encountered in any shergottite, chassignite or shocked ordinary chondrite so far. Olivine-ringwoodite phase transformation commences with the coherent mechanism producing ringwoodite lamellae with their (111) parallel to the (100) plane of olivine followed by the incoherent mechanism due to build up of strain in the parental olivine. Application of experimentally obtained kinetic parameters of the olivine-ringwoodite phase transitions reveal duration of the natural events for at least several seconds thus refuting the claimed decompression mechanism.

The shock-induced pervasive melting of labradorite and partial melting of clinopyroxene strongly suggests partial to complete resetting of the Ar-Ar, Rb-Sr, Sm-Nd, Lu-Hf, and Hf-W radiometric systems. This also casts considerable doubt on the radiometric ages shorter than 575 Ma reported in the past 38 years to be the igneous crystallization ages. These short ages resulted from partial or total shock-induced age resetting.