SHOCK-PRODUCED SIDERITE IN IIE IRON METEORITE ELGA: A SECONDARY MINERAL OF EXTRATERRESTRIAL ORIGIN.

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Introduction: Meteorite Elga relates to differentiated IIE irons formed by impact-induced metal-silicate melting and mixing [1, 2, and ref. therein]. Elga is composed of a $Fe_{0.92}Ni_{0.08}$ matrix with rounded silicate inclusions of 1 – 15 mm in size which contain pyroxene and apatite grains embedded into SiO_2-rich glass of rhyolite-like composition and usually connected by silicate veins or cracks [3, 4]. Some portions of Elga exhibit shock effects evidence of two impacts separated in time [5]. The former one resulted in the appearance of articulated siderite-bearing Sch-Ox rims developed around silicate inclusions and along the cracks in metal matrix. The latter shock event manifests itself by fragmentation and brecciation of these rims, and by injection of melted phosphide and oxide matter from the silicate/FeNi boundary into the silicate inclusions. The observations are consistent with the model of the melt pockets generation during a passage of the shock wave through a pore space in solid matter [6, 7]. Siderite has been found in all shock-produced zones [5]. The early (primary) siderite occurs in schreibersite-oxide rim. Therefore a mechanism of stratified Sch-Ox rim formation is a key to understanding the mechanism and origin of siderite in Elga.

Results: SEM, FIB/TEM, EMPA and Raman spectroscopy were used to study shock-transformed regions in Elga. The Sch-Ox rims of 20 – 50 μm in thickness around silicate inclusions are stratified into shreibersite and oxide layers, with the $(Fe_{0.77}Ni_{0.23})_3P$ adjacent to the silicate inclusion and the Fe,Ni-oxides adjacent to the FeNi metal host; a thin sublayer of SiO_2 occurs within Fe,Ni-oxide(s) layer. Hematite and Ni-magnetite were identified with EMPA and Raman spectroscopy in oxide layer of the rim. Rounded aggregates of fine-grained FeS troilite and blebs of $Fe_{0.97}Ni_{0.03}CO_3$ siderite are embedded into Fe,Ni-oxide(s) layer of the rim. The data evidence that both silicate and FeNi melts contributed into the Sch-Ox reaction rim formation. Schreibersite layer has a lot of transversal cracks of ≈ 3 μm thick connecting the silicate inclusion and the oxide layer of the stratified rim. X-ray elemental maps show that the cracks are filled by SiO_2-FeO* glass with FeO* enriched the middle parts of cracks and SiO_2 concentrated nearby the walls of cracks. The data show that SiO_2-FeO* partial melt has been extruded from the silicate inclusion and then involved in oxide layer formation. Iron oxide(s) in the oxide layer contain up to several at. % Ni thus indicating a contribution from the FeNi metal too.

The melt pockets inside the silicate inclusion and the brecciated zone are composed by shock-melted fragments of the stratified Sch-Ox rim transferred by a *later* shock wave from the silicate-metal boundary. Thus melt pockets and breccias resulted from a late shock transformation of already formed Sch-Ox rim. The melt pocket demonstrates rounded siderite precipitates of 1 – 2 μm in sizes which are isolated from each other and uniformly distributed in the Sch matrix of the melt pocket; such a pattern is consistent with a liquid immiscibility in phosphide-carbonate melt. Siderite in the melt pocket was identified with Raman spectroscopy, SAED, EDS/TEM analyses and X-ray elemental maps.

Discussion: Newly formed phases in shock-induced zones are schreibersite $(Fe,Ni)_3P$, Ni-phosphide, troilite FeS, millerite NiS, sarcopside $Fe_3(PO_4)_2$, siderite $Fe_{0.97}Ni_{0.03}CO_3$, Fe,Ni-oxides (hematite Fe_2O_3 and Ni-magnetite), and disordered sp^2 carbon. Fe, Ni, P, S, C and O_2 have been involved in shock transformation process, wherein each of these elements occurs in different valence states due to inhomogeneous distribution of redox potential during shock wave propagation.

We suggest the following contributions from the FeNi metal and silicate into the siderite-bearing Sch-Ox rim formation: (i) *Shock-induced zonal melting and purification* of P-, C-, and S-bearing FeNi metal to form schreibersite, troilite, millerite and CO_2 in the reaction rim; (ii) *liberation of P_2O_5* due to decomposition of Ca-phosphate in silicate inclusion followed by reaction of P_2O_5 with FeNi metal and C to form the schreibersite, Fe,Ni-oxide layers and CO_2 gas; (iii) injection of *FeO, SiO_2-bearing jet flows* from the silicate material into lateral residual space between schreibersite layer and FeNi matrix with subsequent siderite segregation.

Extraterrestrial shock-induced origin of siderite is proved by (i) siderite occurrence both in early and late generated shocked areas; (ii) siderite-phosphide liquid-liquid phase separation in the melt pocket.

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