**UNUSUAL SIDERITE–BEARING DENDRITES IN MELT POCKETS OF THE ELGA IIE IRON.** S. N. Teplyakova[1], V. V. Artemov[2], A. L. Vasiliev[2,3] ,[1]Vernadsky Institute of RAS, Kosygina st., 19, 119991, Moscow, Russia, (elga.meteorite@gmail.com), [2]Shubnikov Institute of Crystallography RAS, Leninskij pr., 59, 11933, Mocow, Russia, [3]Russian Research Center "Kurchatov Institute", Kurchatov Sq., 1, 123098, Moscow, Russia.

**Introduction:** Partially melted areas which are known as melt pockets often occur in chondrites [1] and iron meteorites. In iron meteorites, the melt pockets of different Fe-Ni-P-S compositions are observed along the boundaries of phosphides or Fe-sulfides with a host Fe,Ni-metal phase [2]. Melt pockets have dendritic texture and are surrounded by microcrystalline Fe,Ni-metal described as martensite [4, 5]. The Fe,Ni-metal dendrites consist of primary trunks with secondary branches (or arms) and the spacing between these secondary branches is inversely proportional to the cooling rate [1, 2]. The dendritic texture resulted from rapid crystallization of melt during moderate to severe shock events [1, 2].

The IIE iron meteorites differ from other iron meteorites in the higher abundance of the silicate inclusions [6] and melt pockets [3-6]. The Fe-Ni-P and Fe-Ni-P-S melt pockets inside Fe,Ni-metal hosts of Elga [6], Verkhne Dnieprovsk [4] and Watson [5] meteorites are similar in shape and mineralogy.

The Elga IIE iron meteorite is a finest octahedrite containing the silicate inclusions [7]. The Elga iron meteorite, unlike other iron meteorites, contains melt pockets not only inside Fe,Ni-metal but also inside silicate inclusions. The mineragraphy of these melt pockets was well-described [6], but small sizes of dendritic crystals (0.5-2 μm) made difficult to investigate the composition of each phase of the dendritic assemblage by routine electron probe microanalysis. We reported results on focused ion beam (FIB) method, transmission electron microscopy (TEM) together with scanning electron microscopy (SEM), electron probe microanalysis (EPMA), EELS mapping and Raman spectroscopy to investigate detail microstructural and chemical compositions of melt pockets inside the silicate inclusions of the Elga iron.

**Results:** Only 3 of 25 silicate inclusions, found in section of the total area of 12.37 $cm^2$, contain the melt pockets with dendritic texture. The melt pockets, 0.05 - 1 mm in size, consist of dendritic Siderite-Schreibersite Assemblage (SSA) and silicate glass with schreibersite globules. The dendritic melt pocket SSA #3.3A, 0.5x0.5 mm in size, has irregular shape. One part of this melt pocket occurs along a contact of silicate inclusion with Fe,Ni-metal but other part locates in a center of the silicate inclusion. The melt pocket consists of dendritic SSA and silicate glass with schreibersite microglobules (Fig. 1.) This glass optically and chemically differs from the glass of the silicate inclusion. Therefore, we have distinguished two types of glass: glass of silicate inclusions (type I) and glass of melt pocket (type II).

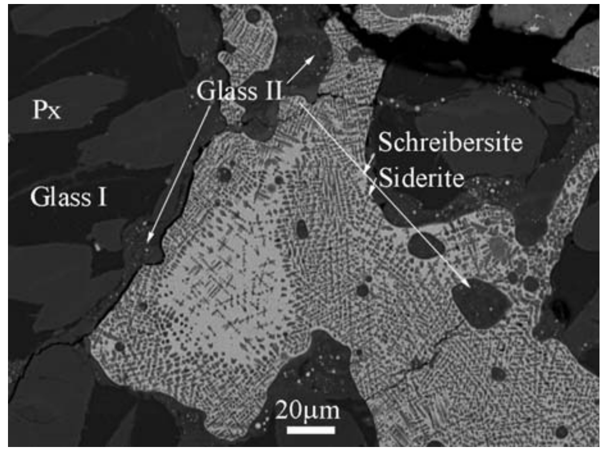


**Fig. 1**. BSE image of the melt pocket in silicate inclusion of Elga.

BSE image (Fig. 1) of the dendritic melt pocket demonstrates the presence of two phases – bright and dark. Bright phase also forms an “island” among SSA. The chemical composition of the bright phase corresponds to schreibersite (wt. %: Fe - 68.9, Ni - 13.5, P – 16.5). The grain size of dark phase was not enough for quantative analysis of composition by EMPA. The crystal structure of the dark phases was investigated by electron diffraction (ED) technique. The selected area diffraction patterns indicate that bright phase is tetragonal $(Fe,Ni)_3P$ - schreibersite ($I\bar{4}$, a = 0.9013 nm, c = 0.4424nm) observed in [111] and [210] zone axis. The chemical composition of the schreibersite defined by EDXS is consistent with that determined by EPMA. The EDXS spectra obtained of the dark dendrite crystals showed peaks of Fe, O and C and analysis demonstrated the composition of siderite, $FeCO_3$. The ED study of the dark phase pointed to trigonal ($R\bar{3}c$ , a=0.472 nm, c = 1.546 nm) $FeCO_3$ - siderite. To prove the presence of carbon in the sample, which could appear as a result of contamination during sample preparation or sample examination in the TEM, an EELS study in combination with ED was performed. The results of the EELS mapping (Fig. 2), unambiguously confirmed the presence of C and O in dendritic crystals. The 1085 $cm^{-1}$ intense band in Raman spectra also confirms the presence of carbonate in the SSA.

**Discussion:** The SSA #3.3A is unusual and has never been previously observed in any types of meteorites. The textural relationship between the siderite dendrites and schreibersite indicates their crystallization from a melt. Unfortunately, the Fe-Ni-P-C-O phase diagram under different P-T conditions is unknown. Since the presence $CO_2$ is unusual in iron meteorite, we should discuss the possible sources of $CO_2$. $CO_2$ could originate either from an external (during processes on the surface of the body) or internal source (as a result of decomposition of silicate inclusions).

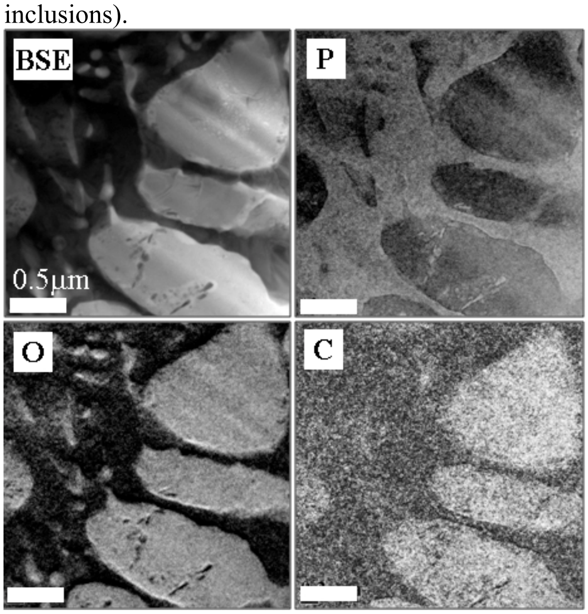


**Fig. 2.** The bright field image and EELS maps of the dendritic melt pocket.

Rare finds of siderite were discovered in various types of meteorites: lunar [8], martian [9] and CR1 chondrite [10]. It was assumed [11], that the carbonate and possibly the goethite formed on the Moon from a fluid derived from the vaporization of a volatile-rich impactor during impact processes. It has been proposed several mechanisms of formation of siderite in the martian ALH84001 meteorite - by biogenic process [9], alternatively the carbonate may be formed by secondary process implying that $CO_2$-rich fluids infiltrated the rock while on Mars [12]. In CR chondrites siderite indicates aqueous activity on the CR parent body [10] as it was shown for GRO 95577 (CR1).

If siderite in the Elga iron was formed during impact process with a $CO_2$ - fluid derived from impactor we would expect siderite in the whole meteorite. Instead, siderite occurs only in melt pockets related with silicate inclusions. If siderite in Elga iron was formed due to reaction of metal with $CO_2$-rich aqueous fluid we would expect to observe oxidized iron (e.g. hematite, goethite) like in lunar, martian meteorites and Earth weathering product, or phillosilicate and tochilinite like in CR chondrites. These minerals were not found in the silicate inclusion of Elga. It seems unlikely, that siderite was formed during terrestrial or extraterrestrial weathering and the mechanism of siderite formation in Elga should be different from that proposed for the martian and lunar meteorites. Thus, we concluded that $CO_2$ should be related with the silicate inclusions, and $CO_2$ might be released from silicate material during the shock event which leads to the formation of melt pockets. The presence of $CO_2$ could be the result of carbon oxidation (graphite, carbide or dissolved carbon) during melting of silicate inclusions with Fe,Ni-metal. We did not observe any traces of $CO_3^{-2}$, graphite and carbide in the silicate inclusion and Fe,Ni-metal of Elga.

It is not clear how dissolved $CO_2$ was incorporated into the melt pocket during its formation but obviously the SSA texture resembles texture crystallization from the melt. We may propose that after dendrite growth subsequent cooling of the melt pocket may lead to formation of SSA as a eutectic assemblage of residual liquid between dendrites. However, the presence of a siderite – schreibersite eutectic is unlikely or may exist in exotic P-T conditions. The alternative explanation of formation of SSA is that the Fe,Ni-dendrites (taenite or kamacite) crystallized from a Fe-Ni-P that had been saturated by $CO_2$ during rapid cooling. The mechanism for formation of dendritic taenite – schreibersite melt pockets from Fe-Ni-P melt has been described [2] and confirmed by the Fe-Ni-P phase diagram [13]. The cooling of the system resulted to release of $CO_2$ which was accumulated in the interstitial area between the dendrites of taenite or kamacite. In this case siderite could be formed as a result of the $CO_2$ - kamacite reaction and Fe and Ni ion exchanges between dendrites and Fe-Ni-P melt below $600^0$C [13]. The siderite dendrite in SSA #3.3A represents an aggregate of nanocrystalline grains, up to 100 nm in size, and is not a single crystal. This could be an additional evidence that the siderite was formed during subsolidus reaction of taenite or kamacite with $CO_2$.

**References:** [1] Scott E. R. D. et al. (1982) *GCA 46*, 813-823. [2] Buchwald V. F. et al. (1966) *Acta Polytech. Scandinavica, 51*, 1-45. [3] Bevan A. W. R. et al. (1979) *Mineralogical magazine 43*, 149-54. [4] Buchwald V. F. and Clarke Jr. (1987) *Meteoritics 22*, 121-135. [5] Olsen E. et al. (1994) *Meteoritics 29*, 200-213. [6] Osadchii E. G. et al. (1981). *Lunar Planet Science, 12th*, 1049-1068. [7] Wasson J. T. (1970) *GCA, 34*, 957-964. [8] Korotev R. L. (1994) *GCA, 58*, 3931-3969. [9] McKay D. S. et al. (1996) *Science, 273*, 924-930.[10] Weisberg M. K. et al. (1993). *GCA, 57*, 1567-1586. [11] Zeigler R. A. et al. (2001). *LPS XXXII*, Abstract #1243. [12] Gleason J. D. et al. (1997) *GCA, 61*, 3503-3512. [13] Raghavan V. (1988) *Indian Inst. Met.* 121-137.