SILICA- AND MERRIHUEITE/ROEDDERITE-BEARING CHONDRULES AND CLASTS IN ORDINARY CHONDRITES: NEW OCCURRENCES AND POSSIBLE ORIGIN.

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Merrihueite \((K,Na)_2(Fe,Mg)_5Si_{12}O_{30} (na<0.5, fe>0.5\) is a rare mineral previously described only in several chondrules and irregularly-shaped fragments in the Mezo-Madaras L3 chondrite breccia [1,2]. Roedderite \(((Na,K)_2(Mg,Fe)_5Si_{12}O_{30} (na>0.5, fe<0.5)\) was reported previously only in enstatite chondrites and in silicate inclusions in IAB irons [3-5]. We describe two additional silica- and roedderite-bearing clasts in L3.5 ALHA77011 and LL3.7 ALHA77278 and a silica- and merrihueite-bearing chondrule in L3.5 ALHA77115. We suggest that the silica- and merrihueite/roedderite-bearing clasts and chondrules experienced a complex evolution including: (a) fractional condensation in the solar nebula to produce Si-rich and Al-poor precursors, (b) melting of nebular solids resulting in formation of silica-pyroxene chondrules, (c) fragmentation in the solar nebula or on a parent body, (d) reaction of silica with alkali-rich gas to form merrihueite/roedderite on a parent body, (e) formation of fayalitic olivine and ferrosilite-rich pyroxene due to reaction of silica with oxidized iron on a parent body, and (f) minor thermal metamorphism, possibly generated by impacts.

Merrihueite in Mezo-Madaras chondrules always coexists with ferroan olivine \((Fa_{59,98})\) and magnesian pyroxene \((Fs_{90,10})\). Dodd et al. [6] suggested that the merrihueite-bearing chondrules (MBC) formed by melting K,Na-bearing precursors undersaturated in Al; fayalitic olivine formed by reaction between the silicon-rich MBC and oxidized Fe in the solar nebula. Wood and Holmgberg [2] suggested that the MBC formed in the solar nebula by partial evaporation of solids, recondensation of silica-rich and Al-poor vapors, then melting and reaction with alkali and Fe-rich vapor in an oxidizing environment during chondrule formation. According to this model these events took place during a brief period near the nebular midplane; rapid formation was followed by aggregation into a parent body.

The silica- and merrihueite-bearing chondrule in L3.5 ALHA77115, 700x900 \(\mu\)m in size, has an ellipsoidal shape and porphyritic texture. It consists of subhedral porphyritic low-Ca pyroxene \((Fs_{33.49}Wo_{60.63})\) and silica grains; accessory phases include plagioclase mesostasis, ferroan olivine \((Fa_{75.85.9})\), ferroan pyroxene \((Fs_{4.9}Wo_{2.2})\), merrihueite \((fe = 0.56, na = 0.32)\) and troilite. Merrihueite occurs as thin veins within one of the silica grains that is surrounded by plagioclase mesostasis. Fayalitic olivine and ferrosilite-rich pyroxene are associated with merrihueite and occur as thin veins in silica that transect through the merrihueite veins.

The silica- and roedderite-bearing clast in ALHA77011 is an irregularly-shaped fragment, 1.8x2.5 mm in size, that has a coarse-grained igneous texture. It consists of low-Ca pyroxene \((Fs_{7.7, 42.8}Wo_{0.5,2.1})\), silica, roedderite \((fe = 0.42-0.43, na = 0.52)\) and troilite. Low-Ca pyroxene occurs as anhedral and subhedral grains partially resorbed by the surrounding roedderite. Silica occurs as subhedral inclusions in pyroxene and as anhedral grains within roedderite. The silica grains are corroded by roedderite and contain thin veins of ferrosilite-rich pyroxene \((Fs_{82.7}Wo_{0.1})\) with thin regions of fayalitic olivine. Abundant troilite occurs as veins in pyroxene grains and as thin inclusions in roedderite.

The silica- and roedderite-bearing clast in ALHA77278 is an irregularly-shaped fragment, 1.9x1.9 mm in size, that has a coarse-grained igneous texture. It consists of low-Ca pyroxene \((Fs_{9.8, 22.3}Wo_{0.4,2.4})\), high-Ca pyroxene \((Fs_{9.3-12.4}Wo_{0.23,4.3})\), silica and roedderite \((fe = 0.16, na = 0.50)\). Low-Ca pyroxene occurs as porphyritic grains in silica and in high-Ca pyroxene. Silica forms
compact areas scattered throughout the clast. High-Ca pyroxene fills the interstitial areas between silica and low-Ca pyroxene. Roedderite forms reactional intergrowths with silica. Olivine (Fa\textsubscript{30,2}) occurs in the outer zone of the clast where it substitutes for silica. The clast is enriched in troilite which forms tiny spheroids mainly in high-Ca pyroxene.

Based on the igneous textures of the clasts and chondrules and the normal igneous zoning of low-Ca pyroxene grains and petrographic observations we suggest that the pyroxene and silica in the objects described above crystallized from melts. The ALHA77278 clast contains a significant amount of Ca-rich pyroxene that crystallized after the low-Ca pyroxene and silica. Merrihueite-roedderite is in reactional relationships with silica in all three objects and with low-Ca pyroxene in the ALHA772728 clast, indicating that the merrihueite/roedderite formed after crystallization of silica and low-Ca pyroxene. According to the experimental data for the system K\textsubscript{2}O-MgO-SiO\textsubscript{2} [7], silica and merrihueite should crystallize along the cotectic curve in contradiction to our petrographic observations. The reactional relationships between silica and merrihueite/roedderite possibly indicate that silica and merrihueite crystallized in disequilibrium or, more likely, that merrihueite/roedderite did not crystallize from the melts but it is a secondary phase formed by reaction of silica and alkali-rich fluid. Fayalitic olivine and ferrosilite-rich pyroxene are the late crystallizing phases substituting for silica. These ferroan phases are in disequilibrium with the relatively magnesian pyroxenes of the host objects and are similar in texture and composition to the fayalitic olivines and ferrosilite pyroxenes in silica-fayalite-bearing chondrules in ordinary chondrites [8]. The ferroan olivine and pyroxene in the silica-bearing chondrules as well as in the silica- and merrihueite/roedderite-bearing chondrules and clasts formed by reaction of silica with oxidized iron. The presence of abundant troilite in the ALHA77011 and ALHA77278 clasts indicates that these clasts experienced shock metamorphism after solidification.

We suggest that silica- and merrihueite/roedderite-bearing chondrules and clasts (SMBC) experienced a complex history of formation: (1) In the solar nebula, fractional condensation or partial evaporation and recondensation resulted in the formation of Si-rich and Al-poor precursor. (2) These materials were melted during chondrule formation events, resulting in the formation of silica-pyroxene chondrules. (3) Agglomeration and accretion led to incorporation of the silica-pyroxene chondrules into the parent bodies. (4) Impact heating produced alkali-rich vapors which reacted with SiO\textsubscript{2} to form merrihueite/roedderite. (5) During mild metamorphism, possibly induced by the same impact heating event, reaction of silica with oxidized iron led to the formation of fayalitic olivine and ferrosilite-rich pyroxene. (6) Thermal metamorphism resulted in partial equilibration of the fayalitic olivine with preexisting mafic minerals. (7) Shock metamorphism introduced abundant troilite into some of the silica- and merrihueite/roedderite-bearing chondrules and clasts.