SILICA-BEARING OBJECTS IN THE CH CHONDRITE NWA 470: EVIDENCE FOR THEIR FORMATION IN FRACTIONATED NEBULAR SYSTEMS. Michail I.Petaev[1], Marina A.Ivanova[2], Michail A.Nazarov[2], and John A.Wood[1], [1]Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA; [2]Vernadsky Institute of the Russian Academy of Sciences, 19 Kosygin St., Moscow 117795, Russia.

Introduction. Silica is a rare, but ubiquitous component of many unequilibrated chondrites which experienced little or no secondary alteration on their parent bodies. It might have formed by fractional crystallization of En-normative (Mg/Si≈1) chondrule melts (*e.g.*, in enstatite [1] or carbonaceous chondrites [2,3]), by oxidation of Si initially dissolved in Fe,Ni metal (in enstatite [1] or ordinary [*e.g.*,4] chondrites), or by disequilibrium nebular condensation [5] (*e.g.*, in ordinary [6] and carbonaceous chondrites [3,7,8]). Here we report on various occurrences of SiO_2-bearing objects in the CH chondrite NWA 470.

Sample and Analytical Techniques. The NWA 470 meteorite was found in Morocco and recently classified as a new CH chondrite [9]. A polished thin section of the meteorite made at the Vernadsky Institute was studied by JEOL SuperProbe 733 at the Harvard-Smithsonian. Chemical analyses were performed at 15 KeV accelerating voltage, 20 nA beam current, and 40 sec counting time. The standards and correction procedures were the same as described in [10,11].

Results. Most Si-rich objects identified in SiKα X-ray maps are silica phases with > 96 wt.% SiO_2 (Fig.1 B-J). A few analyses of Si-rich objects have SiO_2 contents <90 wt.% with complementary increases in Al_2O_3, CaO, and MgO probably due to contamination of the silica analyses with tiny crystallites of plagioclase and Ca-rich pyroxene.

Table 1. Chemical composition of unknown phase (wt.%).

Pt#	94	95	96	97
SiO_2	68.73	69.56	70.35	69.49
Al_2O_3	12.99	13	13.04	13.23
FeO	0.27	0.30	0.39	0.26
MgO	9.66	9.88	9.78	10.14
CaO	4.43	4.12	4.30	4.17
Na_2O	1.27	1.42	1.51	1.57
K_2O	0.60	0.58	0.66	0.54
Total	98.04	98.91	100.13	99.48
Cations Formula Based on 24 Oxygen Atoms				
Si	9.088	9.107	9.113	9.058
Al	2.025	2.007	1.991	2.032
Fe	0.030	0.033	0.042	0.028
Mg	1.904	1.928	1.889	1.969
Ca	0.628	0.578	0.596	0.583
Na	0.325	0.362	0.380	0.397
K	0.101	0.097	0.110	0.090
Total	14.110	14.116	14.132	14.166

The only exception is a relatively large angular grain (Fig. 1A) which contains substantial amounts of Al_2O_3, MgO, CaO, Na_2O, and K_2O in addition to ~70 wt.% SiO_2 (Table 1). In transmitted light this grain has high relief and appears to be a single isotropic phase. Although the grain has sharp boundaries with the surrounding materials and gives a 'pressed-in' impression in both BSE images and transmitted light, the presence of secondary alteration products in its cracks suggests that the grain is indigenous, not a laboratory contamination. Four microprobe analyses of the grain yield remarkably similar chemical compositions throughout the grain, implying that it may be a crystalline phase with the general formula $(K,Na,Ca)Mg_2Al_2Si_9O_{24}$. This formula doesn't match that of any known mineral, but it is somewhat similar to the minerals of the millarite – osumilite series. The substantial concentrations of volatile Na and K along with the lack of more refractory Ti, Cr, and Mn imply that the grain formed in a volatility-fractionated system.

The silica-bearing objects (Fig. 1B-J) can be divided into two groups based on the SiO_2 abundance. The objects with low abundances of silica are mainly chondrule fragments (Fig. 1C-E,I). The silica phases typically form fine-grained intergrowths with low- and high-Ca pyroxenes (±plagioclase) in them texturally similar to the mesostases of the anorthite-rich chondrules [2,3]. In some instances the silica phase forms arc-shaped masses at the chondrule periphery (*e.g.*, Fig. 1D). These masses look like discontinuous rims, but they are texturally different from the silica-bearing chondrule rims of the CR chondrites [8]. One object (Fig. 1I) contains pockets of a silica phase at the periphery of a large grain of forsterite separated by a continuous layer of enstatite. The silica phase always contains substantial amounts of Al_2O_3 (up to ~3 wt.%) in addition to FeO (0.7 – 2.2 %), CaO, and MgO. The fine-grained pyroxenes typically have MnO/FeO > 1, whereas a large grain of low-Ca pyroxene (Fig. 1D) has MnO/FeO ≈ 0.1.

Although there is unequivocal textural evidence for the igneous origin of these silica-bearing objects, the depletion of the objects in Mg along with substantial enrichment in Mn require formation of their precursors in fractionated nebular systems depleted in olivine. CWPI-type condensation calculations [12,13] suggest that isolation of high-temperature olivine at a rate of ~1 rel.% per degree K (due to early chondrule formation) may result in the appearance of silica and MnO-rich orthopyroxene among nebular condensates at medium temperatures. Mixing of these condensates with a Ca,Al,Ti-rich component followed by remelting in a chondrule-forming event could account for the chemistry and mineralogy of these silica-bearing chondrules.

The objects (Fig. 1F-H) with high silica abandances contain a MnO-rich orthopyroxene in addition to an Al_2O_3-free silica phase (1 – 3 % FeO). These seem to be primary or remelted nebular condensates devoid of both olivine and Ca,Al,Ti-rich component.

Object E1-314 (Fig. 1J) consists of a large grain of bronzite (13.20 – 14.12 % FeO, 0.18 – 0.20 % MnO) partially replaced by hypersthene (29.98 % FeO, 0.44 % MnO). An arc-shaped, Al_2O_3-bearing silica mass separates the bronzite grain from a polycrystalline rim of ferrohypersthene (33.56 % FeO, 0.54 % MnO). The rim contains a euhedral grain of Ni-bearing troilite (2.98 wt.% Ni). The

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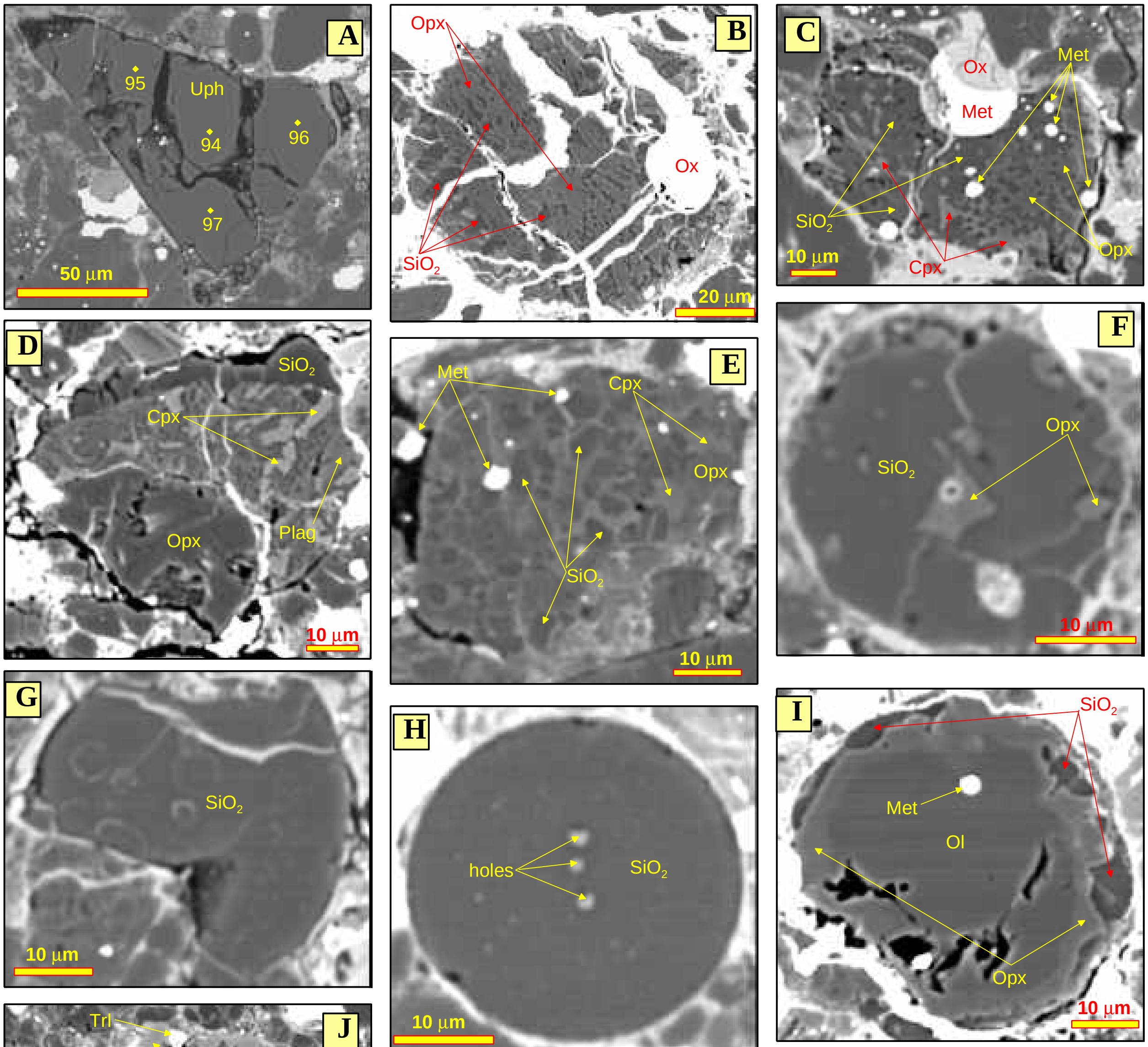
texture of the object suggests secondary origin of the hypersthene, ferrohypersthene, and troilite at relatively low temperatures in a highly oxidizing environment.



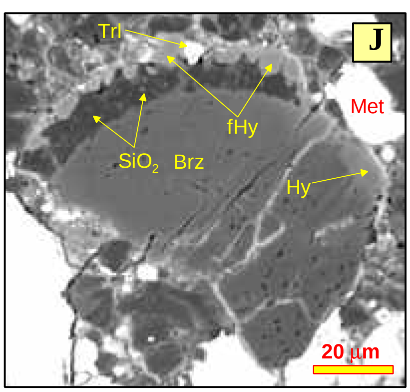


Fig. 1. BSE images of SiO2-rich objects in the CH chondrite NWA 470. Uph – unknown Si,Na-rich phase; Opx – Mg-rich orthopyroxene; Ox – terrestrial weathering products; SiO2 – a silica phase; Met – Fe,Ni metal; Cpx – Ca-rich clinopyroxene; Plag – plagioclase; Ol – olivine; Trl – troilite; Bzn – bronzite (Fs10-30); Hy – hypersthene (Fs30-50); fHy – ferrohypersthene (Fs50-70). Numbered yellow diamonds in panel A show analytical points listed in Table 1.

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