DISCOVERY OF NEW Al-Cu-Fe MINERALS IN THE KHATYRKA CV3 METEORITE.

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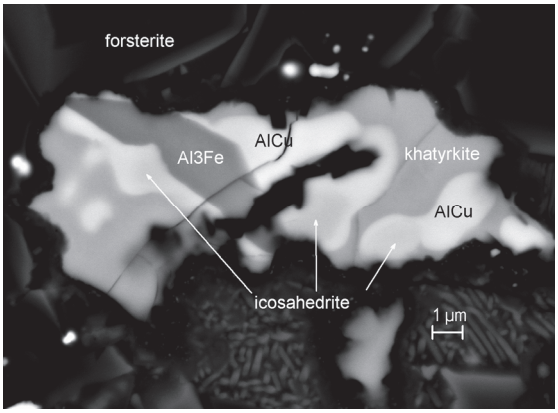
Introduction: During a nanomineralogy investigation of the Khatyrka CV3 carbonaceous chondrite, we have identified two new alloy minerals (AlCu with a *Pm*-3*m* CsCl structure and Al_3Fe with a *C*2/*m* structure) and associated icosahedrite (quasicrystal $Al_{63}Cu_{26}Fe_{11}$ with a five-fold symmetry) at micron scales in section 126A of USNM 7908. The section belongs to the larger Grain 126, which is one of the fragments recovered from an expedition to the Koryak Mountains in far eastern Russia in 2011 [1] as a result of a search for samples that would provide information on the origin of the quasicrystal mineral icosahedrite [2,3,4]. The recovered fragments have meteoritic (CV3-like) oxygen isotopic compositions and are identified collectively as coming from the Khatyrka meteorite [5], which formed 4.5 billion years ago during the earliest stages of the solar system. Khatyrka is unique, so far being the only meteorite to host metallic Al component.

Field-emission scanning electron microscope with energy-dispersive X-ray spectrometer and electron back-scatter diffraction (EBSD), and electron probe microanalyzer (EPMA) were used to characterize chemical compositions and structures of the minerals in section 126A. Synthetic AlCu with a *Pm*-3*m* structure and Al_3Fe with a *C*2/*m* structure are well known as β and λ phase, respectively, in the Al-Fe-Cu system [e.g., 6]. We present here their first natural occurrence as new minerals, and associated icosahedrite in a primitive meteorite.

Results: AlCu occurs within khatyrkite, or along with icosahedrite and/or Al_3Fe and khatyrkite (Fig. 1a), surrounded mainly by forsterite, spinel, and silicate glass. AlCu occurs as small crystals, 0.5 to 3 μm in size, showing an empirical formula (based on 2 atoms *pfu*) of $Al_{1.15}Cu_{0.81}Fe_{0.04}$ by low voltage EPMA. Al_3Fe occurs only as one subhedral single crystal, 2×7 μm in size, having an empirical formula (based on 4 atoms *pfu*) of $Al_{2.89}Fe_{0.77}Cu_{0.32}Si_{0.02}$. EBSD analyses revealed that AlCu has a *Pm*-3*m* CsCl structure with unit cell: $a = 2.9$ Å, $V = 24.4$ Å^3, $Z = 1$ (Fig. 1b). Al_3Fe has a *C*2/*m* structure with unit cell: $a = 15.60$ Å, $b = 7.94$ Å, $c = 12.51$ Å, $\beta = 108.1°$, $V = 1472.9$ Å^3, $Z = 24$. Quasicrystal icosahedrite was found by EBSD, as micro-crystals, 1 to 2 μm in size. It has an empirical formula of $Al_{63.3}Cu_{25.7}Fe_{10.7}Si_{0.4}Ni_{0.1}Cr_{0.1}$, which is similar to the composition of the much-larger type icosahedrite ($Al_{63}Cu_{24}Fe_{13}$) [3]. Associated khatyrkite has an empirical formula of $Al_{2.04}(Cu_{0.89}Fe_{0.06}Si_{0.01})$.

Other minerals identified in the same section are hercynite, chromite, magnetite, corundum, iron, taenite, suessite (Fe_3Si with s.g. *Im*-3*m*), naquite (FeSi with s.g. $P2_13$; empirical formula $Si_{1.05}Fe_{0.86}Al_{0.03}Cu_{0.03}Cr_{0.02}Ni_{0.01}$; its first meteoritic occurrence), xifengite (Fe_5Si_3 with s.g. $P6_3/mcm$), aluminium ($Al_{0.97}Cu_{0.03}$), nickel ($Ni_{0.91}Fe_{0.05}Cu_{0.04}$), copper ($Cu_{0.96}Fe_{0.04}$), and unnamed $Al_{78}Cu_{15}Fe_7$ phase. High-pressure silicate or oxide phases were not observed in this section.

References: [1] Steinhardt P.J. and Bindi L. 2012. *Reports on Progress in Physics* 75:092601–092611. [2] Bindi L. et al. 2009. *Science* 324:1306–1309. [3] Bindi L. et al. 2011. *American Mineralogist* 96:928–931. [4] Bindi L. et al. 2012. *Proceedings of the National Academy of Sciences* 109:1396–1401. [5] MacPherson G.J. et al. 2013. *Meteoritics & Planetary Science* 48:1499–1514. [6] Zhang L. and Lück R. 2003. *Zeitschrift für Metallkunde* 94:91–97.

(a) 

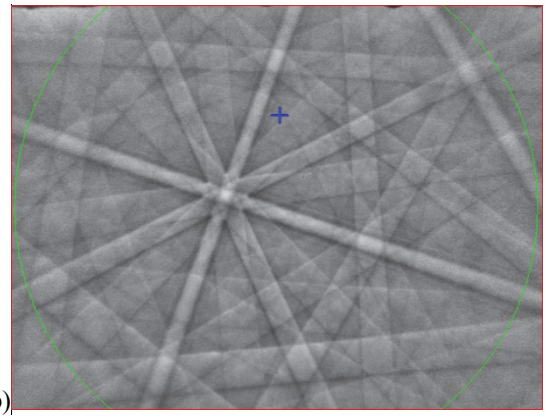
(b) 

Fig. 1. (a) Back-scatter electron image showing new minerals AlCu, Al_3Fe and icosahedrite in section 126A. (b) EBSD pattern of one AlCu crystal revealing a *Pm*-3*m* structure.