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Letter

Steinhardtite, a new body-centered-cubic allotropic form of aluminum from the Khatyrka CV3 carbonaceous chondrite

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Abstract

Steinhardtite is a new mineral from the Khatyrka meteorite; it is a new allotropic form of aluminum. It occurs as rare crystals up to ~10 μm across in meteoritic fragments that contain evidence of a heterogeneous distribution of pressures and temperatures during impact shock, in which some portions of the meteorite reached at least 5 GPa and 1200 °C. The meteorite fragments contain the high-pressure phases ahrensite, coesite, stishovite, and an unnamed spinelloid with composition $Fe_{3-x}Si_xO_4$ ($x \approx 0.4$). Other minerals include trevorite, Ni-Al-Mg-Fe spinels, magnetite, diopside, forsterite, clinoenstatite, nepheline, pentlandite, Cu-bearing troilite, icosahedrite, khatyrkite, cupalite, taenite, and Al-bearing taenite. Given the exceedingly small grain size of steinhardtite, it was not possible to determine most of the physical properties for the mineral.

A mean of 9 electron microprobe analyses (obtained from two different fragments) gave the formula $Al_{0.38}Ni_{0.32}Fe_{0.30}$, on the basis of 1 atom. A combined TEM and single-crystal X-ray diffraction study revealed steinhardtite to be cubic, space group $Im\overline{3}m$, with $a = 3.0214(8)$ Å, and $V = 27.58(2)$ Å^3, $Z = 2$. In the crystal structure [$R_1 = 0.0254$], the three elements are disordered at the origin of the unit cell in a body-centered-cubic packing (α-Fe structure type). The five strongest powder-diffraction lines [d in Å (I/I_0) (hkl)] are: 2.1355 (100) (110); 1.5100 (15) (200); 1.2329 (25) (211); 0.9550 (10) (310); 0.8071 (30) (321).

The new mineral has been approved by the IMA-NMNC Commission (2014-036) and named in honor of Paul J. Steinhardt, Professor at the Department of Physics of Princeton University, for his extraordinary and enthusiastic dedication to the study of the mineralogy of the Khatyrka meteorite, a unique CV3 carbonaceous chondrite containing the first natural quasicrystalline phase icosahedrite.

The recovery of the polymorph of Al described here that contains essential amounts of Ni and Fe suggests that Al could be a contributing candidate for the anomalously low density of the Earth's presumed Fe-Ni core.

Keywords: Aluminum, chemical composition, TEM, X-ray diffraction, new mineral, steinhardtite.