Icosahedrite, ideally $\text{Al}_{63}\text{Cu}_{24}\text{Fe}_{13}$, is a new mineral from the Khatyrka River, southeastern Chukhotka, Russia. It occurs as dark gray-black anhedral to subhedral grains up to 100 $\mu$m across, closely associated with spinel, diopside, forsterite, nepheline, sodalite, corundum, stishovite, khatyrkite, cupalite, and an unnamed phase of composition $\text{AlCuFe}$. Icosahedrite is opaque with a metallic luster, possesses a gray streak, and is brittle with an uneven fracture. The density could not be determined. For quasicrystals, by definition, the structure is not reducible to a single three-dimensional unit cell, so neither cell parameters nor $Z$ can be given. In plane-polarized incident light, icosahedrite exhibits neither bireflectance nor pleochroism. Between crossed polars, it is isotropic. Reflectance percentages ($R_{\text{min}} = R_{\text{max}}$) for the four standard COM wavelengths are 62.3 (471.1 nm), 60.6 (548.3 nm), 58.1 (586.6 nm), and 56.0 (652.3 nm), respectively.

The X-ray powder pattern was indexed on the basis of six integer indices, as conventionally used with quasicrystals, where the lattice parameter (in six-dimensional notation) is measured to be $d_{6D} = 12.64$ $\AA$, with probable space group $Fm\overline{3}5$. The four strongest X-ray powder-diffraction lines $[d$ in $\AA$ $(h_1h_2h_3n_1n_2n_3)]$ are: 2.006 (100) (420 042), 2.108 (90) (422 222), 1.238 (30) (604 064), and 3.41 (25) (31T 111). Average results of 34 electron-microprobe analyses gave, on the basis of total $\text{Al}_{43.02}$, $\text{Cu}_{38.60}$, $\text{Fe}_{18.38}$, total 100.00 wt%. The new mineral is named for the icosahedral symmetry of its internal atomic structure, as observed in its diffraction pattern. Both the new mineral and mineral name have been approved by the Commission on New Minerals, Nomenclature and Classification, IMA (2010-042).

**Keywords:** Icosahedrite, new mineral, natural quasicrystal, electron-microprobe data, reflectance data, X-ray diffraction data, Khatyrka, Kamchatka, Russia

**ABSTRACT**

Icosahedrite, ideally $\text{Al}_{63}\text{Cu}_{24}\text{Fe}_{13}$, is a new mineral from the Khatyrka River, southeastern Chukhotka, Russia. It occurs as dark gray-black anhedral to subhedral grains up to 100 $\mu$m across, closely associated with spinel, diopside, forsterite, nepheline, sodalite, corundum, stishovite, khatyrkite, cupalite, and an unnamed phase of composition $\text{AlCuFe}$. Icosahedrite is opaque with a metallic luster, possesses a gray streak, and is brittle with an uneven fracture. The density could not be determined. For quasicrystals, by definition, the structure is not reducible to a single three-dimensional unit cell, so neither cell parameters nor $Z$ can be given. In plane-polarized incident light, icosahedrite exhibits neither bireflectance nor pleochroism. Between crossed polars, it is isotropic. Reflectance percentages ($R_{\text{min}} = R_{\text{max}}$) for the four standard COM wavelengths are 62.3 (471.1 nm), 60.6 (548.3 nm), 58.1 (586.6 nm), and 56.0 (652.3 nm), respectively.

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**INTRODUCTION**

Historically, all known natural minerals with translational order have been crystals or incommensurate crystals with rotational symmetries restricted to the finite set of crystallographic possibilities established mathematically in the 19th century. In this paper, we present the first exception: a natural quasicrystal, icosahedrite (ideally $\text{Al}_{63}\text{Cu}_{24}\text{Fe}_{13}$), with a three-dimensional icosahedral symmetry that is strictly forbidden for crystals. Quasicrystals can violate the conventional rules of crystallography because their structure is “quasiperiodic” rather than periodic (Levine and Steinhardt 1984); that is, their atomic density can be described by a finite sum of periodic functions with periods whose ratio is irrational. Their diffraction pattern consists of true Bragg peaks whose positions can be expressed as integer linear combinations of wavevectors whose magnitudes have irrational ratios. The first synthetic examples were found in the laboratory 25 years ago (Shechtman et al. 1984) and, today, well over 100 quasicrystalline materials have been synthesized, typically by mixing precise ratios of selected elemental components in the liquid and quenching under controlled conditions ranging from rapid to moderately slow (Janot 1994). Many have icosahedral symmetry, which includes 6 fivefold symmetry axes, 10 threefold axes, and 15 twofold symmetry axes, although quasicrystals with other crystallographically forbidden symmetry have also been synthesized (e.g., see Steurer 2004).

The new mineral reported here is the result of a decade-long systematic search for a natural quasicrystal described in Lu et al. (2001). There are numerous motivations for mounting a search. The discovery of natural quasicrystals would fundamentally alter the conventional classification of mineral forms. In condensed matter physics, the fragility and stability of quasicrystals has been a subject of considerable debate; a discovery could push back