Nakhlite Caleta el Cobre 022: Initial Description and Comparison with other Nakhlites

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Introduction: Nakhlites are olivine clinopyroxenite meteorites sampling hypovolcanic rock from the Martian subsurface [1]. There are currently nine known unpaired nakhlites, including the only fall, Nakhla. We present here the initial description and the first results obtained on a recently discovered tenth nakhlite: Caleta el Cobre 022.

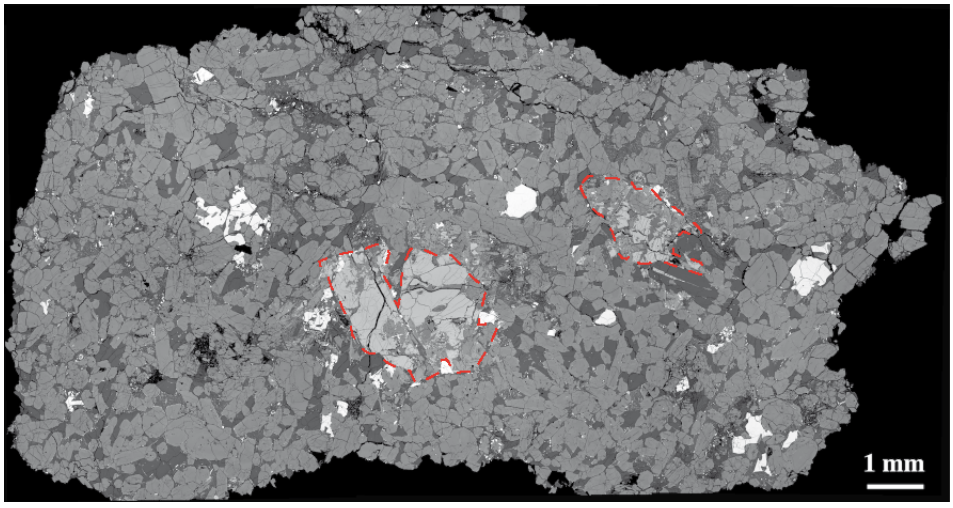
Petrography: The meteorite is a cumulate with euhedral elongated augite crystals (~70 vol%, typical size 1 mm by 300 µm). Intercumulus phases are interstitial plagioclase (typical size 250 µm, birefringent, ~17 vol%) and fine-grained mesostasis (~8 vol%) containing skeletal magnetite and small sulfide grains. Olivine crystals (~2 vol%, up to 2.5 mm) are crosscut and surrounded by aqueous alteration products (the so-called iddingsite) and contain melt inclusions (up to 100 µm in size). Fe-Ti oxides up to 1 mm in size display fine-scale exsolutions. Sulfides (pyrrhotite>>pentlandite-chalcopyrite, often surrounded by magnetite, some with weak terrestrial alteration) are unusually abundant as large-sized intercumulus grains (up to 200 µm in size) around olivine. They were remobilized as stringers and locally altered in FeOOH phases where olivine was replaced by hydrated phases. Overall terrestrial weathering is minimal.

Geochemistry: Augite composition is $Fs_{28.4\pm2.9}Wo_{40.0\pm0.6}$ (N=20), with Fe-rich ~10 µm thick rims (cores down to $Fs_{24.5}$, rims up to $Fs_{33.3}$). Plagioclase composition is $An_{30.4\pm1.0}Ab_{66.9\pm0.8}Or_{2.8\pm0.4}$ (N=7). Olivine composition is $Fa_{70.2\pm3.4}$ (range $Fa_{67.2\text{-}76.4}$). Major element composition is typical of nakhlites, and trace element compositions are nearly identical to NWA 817 [2] except a clear positive anomaly in Ce likely related to terrestrial alteration.

Discussion: Although this nakhlite shares some petrographic characteristics with NWA 10153 [2] and paired stones, it shows significant differences to other nakhlites, including high abundances of plagioclase (~17 vol%), iron-titanium oxides (~2 vol%), and sulfides (0.15±0.05 vol%). The coexistence of crystalline plagioclase and mesostasis as intercumulus phases is unusual. Olivine shows pervasive alteration. Reflectance spectra measured in an olivine alteration area reveal the presence of aqueous alteration phases, with diagnostic features at 1.9 µm (H_2O) and 2.3 µm (-OH). Raman spectra obtained on individual alteration phase throughout the section also systematically exhibit the OH-stretching band at ~3560 cm^{-1} related to molecular water and hydroxyl groups (several wt%), consistent with IR results. The Raman spectra of this hydrated mineral phase also exhibit broad bands (~ 565, 665, 977, 1130 cm^{-1}), characteristics of a poorly crystalline material.

Ongoing analyses include radiometric age (Sm-Nd, U,Th-He, K-Ar), cosmic ray exposure age and trapped gases (He, Ne, Ar, Kr, Xe), Nd isotopes, and D/H of olivine weathering products. With this data in hand, we will discuss the relation of this meteorite to other nakhlites, and its insertion in the nakhlite pile. Some attention will be dedicated to the study of secondary phases.

References: [1] Treiman A. (2005) *Chemie Erde* 65:203-270. [2] Sautter V. et al. (2002) *EPSL* 195:223-238. [3] Irving A. J. et al. (2015) *Meteoritics & Planetary Science* 50:5251.



BSE image of Caleta el Cobre 022. Notable features include the abundance of intercumulus plagioclase (dark grey), aqueous alteration of olivine (contoured in red) and abundance and size of iron oxides (bright crystals).