American Mineralogist, Volume 105, pages 1021–1029, 2020

The Cr-Zr-Ca armalcolite in lunar rocks is loveringite: Constraints from electron backscatter diffraction measurements

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Abstract

"Cr-Zr-Ca armalcolite" is a mineral originally found in Apollo samples five decades ago. However, no structural information has been obtained for this mineral. In this study, we report a new occurrence of "Cr-Zr-Ca armalcolite" and its associated mineral assemblage in an Mg-suite lithic clast (Clast-20) from the brecciated lunar meteorite Northwest Africa 8182. In this lithic clast, plagioclase (An = 88–91), pyroxene (Mg#[Mg/(Mg+Fe)] = 0.87–0.91) and olivine (Mg# = 0.86–0.87) are the major rock-forming minerals. Armalcolite and "Cr-Zr-Ca armalcolite" are observed with other minor phases including ilmenite, chromite, rutile, fluorapatite, merrillite, monazite, FeNi metal, and Fe-sulfide. Based on 38 oxygen atoms, the chemical formula of "Cr-Zr-Ca armalcolite" is $(Ca_{0.99}Na_{0.01})_{\Sigma 1.00}(Ti_{14.22}Fe_{2.06}Cr_{2.01}Mg_{1.20}Zr_{0.54}Al_{0.49}Ca_{0.21}Y_{0.05}Mn_{0.04}Ce_{0.03}Si_{0.03}La_{0.01}Nd_{0.01}Dy_{0.01})_{\Sigma 20.91}O_{38}$. Electron backscatter diffraction (EBSD) results reveal that the "Cr-Zr-Ca armalcolite" has a loveringite $R\bar{3}$ structure, differing from the armalcolite *Bbmm* structure. The estimated hexagonal cell parameters *a* and *c* of "Cr-Zr-Ca armalcolite" are 10.55 and 20.85 Å, respectively. These structural and compositional features indicate that "Cr-Zr-Ca armalcolite" is loveringite, not belonging to the armalcolite family. Comparison with "Cr-Zr-Ca armalcolite" and loveringite of other occurrences implies that loveringite might be an important carrier of rare earth elements in lunar Mg-suite rocks. The compositional features of plagioclase and mafic silicate minerals in Clast-20 differ from those in other Mg-suite lithic clasts from Apollo samples and lunar meteorites, indicating that Clast-20 represents a new example of diverse lunar Mg-suite lithic clasts.

Keywords: Loveringite, armalcolite, Cr-Zr-Ca armalcolite, monazite, Mg-suite lithic clast, NWA 8182, lunar meteorite, EBSD