Adrianite, \( \text{Ca}_{12} (\text{Al}_4 \text{Mg}_3 \text{Si}_7) \text{O}_{32} \text{Cl}_6 \), a new Cl-rich silicate mineral from the Allende meteorite: An alteration phase in a Ca-Al-rich inclusion

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**Abstract**

Adrianite (IMA 2014-028), \( \text{Ca}_{12} (\text{Al}_4 \text{Mg}_3 \text{Si}_7) \text{O}_{32} \text{Cl}_6 \), is a new Cl-rich silicate mineral and the Si,Mg analog of wadalite. It occurs with monticellite, grossular, wadalite, and hutcheonite in altered areas along some veins between primary melilite, spinel, and Ti,Al-diopside in a Type B1 FUN (Fractionation and Unidentified Nuclear effects) CAI-Al-rich inclusion (CAI), Egg-3, from the Allende CV3 carbonaceous chondrite. The mean chemical composition of type adrianite by electron probe microanalysis is (wt\%) CaO 41.5, SiO\(_2\) 27.5, Al\(_2\)O\(_3\) 12.4, MgO 7.3, Na\(_2\)O 0.41, C\(_3\)13.0, O=Cl –2.94, total 99.2, giving rise to an empirical formula of \((\text{Ca}_{1.9x} \text{Na}_{a.2}) (\text{Al}_{1.85} \text{Mg}_{1.88} \text{Si}_{1.3}) \text{O}_{32} \text{Cl}_{1.90}\). The end-member formula is \( \text{Ca}_{12} (\text{Mg}, \text{Si}, \text{O})_6 \text{Cl}_6 \). Adrianite has the \( \text{P} \text{3} \text{d} \) wadalite structure with \( a = 11.981 \) Å, \( V = 1719.8 \) Å\(^3\), and \( Z = 2 \), as revealed by electron backscatter diffraction. The calculated density using the measured composition is 3.03 g/cm\(^3\). Adrianite is a new secondary mineral in Allende, apparently formed by alkali-halogen metasomatic alteration of primary CAI minerals such as melilit, anorthite, perovskite, and Ti,Al-diopside on the CV chondrite parent asteroid. Formation of secondary Cl-rich minerals sodalite, adrianite, and wadalite during metasomatic alteration of the Allende CAIs suggests that the metasomatic fluids had Cl-rich compositions. The mineral name is in honor of Adrian J. Brearley, mineralogist at the University of New Mexico, U.S.A., in recognition of his many contributions to the understanding of secondary mineralization in chondritic meteorites.

**Keywords:** Adrianite, \( \text{Ca}_{12} (\text{Al}_4 \text{Mg}_3 \text{Si}_7) \text{O}_{32} \text{Cl}_6 \), new mineral, wadalite group, alteration mineral, Ca-Al-rich inclusion, Allende meteorite, carbonaceous chondrite

**Introduction**

During a nanomineralogy investigation of the Allende meteorite, a new Cl-rich silicate, \( \text{Ca}_{12} (\text{Al}_4 \text{Mg}_3 \text{Si}_7) \text{O}_{32} \text{Cl}_6 \), with the \( \text{P} \text{3} \text{d} \) wadalite structure, named “adrianite,” was identified in Ca-Al-rich inclusion (CAI) Egg-3 (Fig. 1). The Allende meteorite, which fell at Pueblito de Allende, Chihuahua, Mexico, on February 8, 1969, is a CV3 (Vigarano type) carbonaceous chondrite. Much work has been performed on Egg-3 (e.g., Meeker et al. 1983), which is a coarse-grained igneous Type B1 Fractionation and Unidentified Nuclear effects (FUN) CAI from Allende (Wasserburg et al. 2012).

Electron probe microanalysis (EPMA), high-resolution scanning electron microscope (SEM), and electron backscatter diffraction (EBSD) were used to characterize composition and structure of adrianite. Synthetic \( \text{Ca}_{12} (\text{Al}_4 \text{Mg}_3 \text{Si}_7) \text{O}_{32} \text{Cl}_6 \), \( \text{Ca}_{12} (\text{Al}_4 \text{Mg}_3 \text{Si}_7) \text{O}_{32} \text{Cl}_6 \), or \( \text{Ca}_{12} (\text{Mg}_3 \text{Si}_7) \text{O}_{32} \text{Cl}_6 \) has not been reported to date. We describe here the first occurrence of \( \text{Ca}_{12} (\text{Al}_4 \text{Mg}_3 \text{Si}_7) \text{O}_{32} \text{Cl}_6 \) in a meteorite, as a new alteration mineral in a CAI from a carbonaceous chondrite, and discuss its origin and significance for secondary alteration processes that affected CV chondrites (e.g., Brearley and Krot 2012). Preliminary results of this work are given by Ma and Krot (2014b).

**Mineral Name and Type Material**

The new mineral and its name have been approved by the Commission on New Minerals, Nomenclature and Classification of the International Mineralogical Association (IMA 2014-028) (Ma and Krot 2014a). The mineral name is in honor of Adrian J. Brearley (b. 1958), mineralogist and cosmochemist at the University of New Mexico, in recognition of his many contributions to meteorite mineralogy. He is one of the leading authorities on alteration mineralogy studies of chondritic meteorites. The holotype specimen is in section MQM803 in G.J. Wasserburg’s Meteorite Collection of Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, California, U.S.A. This section also hosts holotype hutcheonite (IMA 2013-029; Ma and Krot 2014c).

**Occurrence and Associated Minerals**

Egg-3 is a coarse-grained igneous Type B1 CAI with a core composed of normally zoned melilit (\( \text{Åk}_{46.76} \)) and Ti,Al-diopside (in wt\%: 1.9–11.5 TiO\(_2\), 17.2–21.7 Al\(_2\)O\(_3\)), nearly pure anorthite and MgAl-spinel, and a mantle composed of gehlenitic melilit (\( \text{Åk}_{14.34} \)) poikilitically enclosing rounded inclusions of Ti,Al-diopside (in wt\%: 10.3–16.4 TiO\(_2\), 17.8–20.3 Al\(_2\)O\(_3\)) and spinel (Fig. 1). The coarser spinel grains form a nearly continuous layer in the middle of the melilit mantle. The CAI is surrounded by several rims (from inside outward) (1) a multi-