

## **Intermediate members of the lime-monteponite solid solutions (Ca<sub>1-x</sub>Cd<sub>x</sub>O, x = 0.36–0.55): Discovery in natural occurrence**

**HANI N. KHOURY<sup>1</sup>, ELLA V. SOKOL<sup>2,\*</sup>, SVETLANA N. KOKH<sup>2</sup>, YURII V. SERYOTKIN<sup>2,3</sup>,  
OLGA A. KOZMENKO<sup>2</sup>, SERGEY V. GORYAINOV<sup>2</sup>, AND IAN D. CLARK<sup>4</sup>**

<sup>1</sup>Department of Geology, The University of Jordan, Amman 11942, Jordan

<sup>2</sup>V.S. Sobolev Institute of Geology and Mineralogy, Siberian Branch of the Russian Academy of Sciences, 3 Koptuyg Avenue, Novosibirsk, 630090 Russia

<sup>3</sup>Novosibirsk State University, Novosibirsk, 2 Pirogov Street, Novosibirsk, 630090 Russia

<sup>4</sup>Ottawa-Carleton Geoscience Centre, Department of Earth Sciences, University of Ottawa, 140 Louis Pasteur Street, Ottawa, Ontario K1N 6N5, Canada

### **ABSTRACT**

Lime-monteponite solid solutions [(Ca,Cd)O ss] with 58.5–73.3 wt% CdO were discovered as an accessory phase in medium-temperature combustion metamorphic (CM) spurrite-fluorellestadite/fluorapatite marbles from central Jordan. The type locality is situated in the northern part of the Siwaqa complex (Tulul Al Hammam area), the largest area of the “Mottled Zone” Formation in the Dead Sea region. The marbles were derived from bitumen-rich calcareous marine sediments of the Muwaqqar Chalk Marl Formation, which have high Cd, Zn, U, and Ni enrichments and contain Cd-rich wurtzite and sphalerite. Oxidative sintering of these sediments at 800–850 °C gave rise to unusual oxide accessories: lime-monteponite solid solutions, Cd-bearing Ca and Zn aluminate—tululite, zincite, and Zn-, Ni-, and Cu-rich periclase. Cadmium incorporation into different oxides was controlled by steric factors, while Cd<sup>[6]</sup> → Ca<sup>[6]</sup> was the principal isomorphous substitution. The intermediate members (Ca<sub>0.645</sub>Cd<sub>0.355</sub>)O–(Ca<sub>0.453</sub>Cd<sub>0.547</sub>)O with a halite-type structure have a cadmium incorporation ratio ( $K_{Cd} = Cd_{\text{mineral}}/Cd_{\text{rock}}$ ) of about 843 and are the main sites for cadmium in CM marbles. In supergene environments, at low water/rock ratios, (Ca<sub>1-x</sub>Cd<sub>x</sub>)(OH)<sub>2</sub> ss ( $x \leq 0.5$ ) constitute the main secondary phase after (Ca,Cd)O ss. At higher water/rock ratios and in the presence of Cl<sup>-</sup> and F<sup>-</sup> in the solutions, calcium, and cadmium precipitated as separate phases {fluorite (CaF<sub>2</sub>) and basic cadmium chloride [Cd(OH)<sub>2-x</sub>Cl<sub>x</sub>]}. A part of cadmium becomes retained in calcium silicate hydrates. The common occurrence of anhydrous (Ca,Cd)O grains in natural rocks, only partly altered to (Ca,Cd)-hydroxide after at least 100 ka exposure to weather and climate, proves that both phases are effective long-term Cd immobilizers.

**Keywords:** Lime-monteponite CaO-CdO solid solution, cadmium enrichment, hydrous alteration, combustion metamorphism, central Jordan