

## Numanoite, $\text{Ca}_4\text{CuB}_4\text{O}_6(\text{OH})_6(\text{CO}_3)_2$ , a new mineral, the Cu-analogue of borcarite from the Fuka mine, Okayama Prefecture, Japan

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Numanoite, the Cu-analogue of borcarite, is found in an irregular patch in the crystalline limestone near gehlenite-spurrite skarns at the Fuka mine, Okayama Prefecture, Japan. Numanoite (up to 1 mm long) is observed in a core of borcarite crystals (up to 5 mm long). The mineral is also found as a veinlet (up to 0.4 mm wide) in aggregates of borcarite crystals. The associated minerals are nifontovite, bultfonteinite, calcite and an unidentified magnesium silicate. In hand specimen, numanoite is blue-green to colorless with vitreous luster. The mineral has {100} and {110} perfect cleavages. Numanoite is monoclinic with space group  $C2/m$ ,  $a = 17.794$  (2),  $b = 8.381$  (1),  $c = 4.4494$  (7) Å,  $\beta = 102.42$  (2) °,  $V = 648.0$  (2) Å<sup>3</sup> and  $Z = 2$ . The strongest lines in the powder XRD pattern [ $d$  Å (I) ( $hkl$ )] are 7.57 (100) (110), 2.671 (84) (-421), 2.727 (68) (221), 1.887 (52) (041, 440), 2.272 (48) (-331), 2.899 (44) (600), 1.698 (34) (640). EPMA (WDS mode) and TGA gave B<sub>2</sub>O<sub>3</sub> 24.09, CaO 38.11, CuO 10.32, MgO 1.02, ZnO 0.51, CO<sub>2</sub> 15.80, H<sub>2</sub>O 9.75 and total 99.60 wt.%. The empirical formula calculated on the basis of O = 18 is  $\text{Ca}_{3.898}(\text{Cu}_{0.744}\text{Mg}_{0.145}\text{Zn}_{0.036})_{\Sigma 0.925}\text{B}_{3.969}\text{O}_{5.615}(\text{OH})_{6.208}(\text{CO}_3)_{2.059}$ , which gave the ideal formula  $\text{Ca}_4\text{CuB}_4\text{O}_6(\text{OH})_6(\text{CO}_3)_2$ . The Cu/(Cu+Mg) value shows the variation range from 0.721 to 0.956. The variation of Cu vs Mg (pfu) shows a strong negative correlation, and suggests the substitution of Mg with Cu. The IR spectrum shows absorption bands at 3540 and 3260 cm<sup>-1</sup> for O-H stretching vibrations, 1410, 870 and 290 cm<sup>-1</sup> for carbonate group, and 1410, 870 and 290 cm<sup>-1</sup> for borate group. The DTA curve shows two endothermic peaks at 489 and 692°C. Optically, numanoite is biaxial negative with refractive indices  $\alpha = 1.618$  (2),  $\beta = 1.658$  (2),  $\gamma = 1.672$  (2), and calculated  $2V = 60$  °. The density is 2.96 (2) g cm<sup>-3</sup> (maes.) and 2.96 g cm<sup>-3</sup> (calc.). The Vickers microhardness is 376 (290-464) kg mm<sup>-2</sup> (25 g load), and the Mohs' hardness is 4.5. The properties of numanoite are closely related to that of borcarite with similar type of XRD data, IR spectrum and thermal behavior. It is likely that numanoite from the Fuka mine formed as a primary mineral from Cu- and Mg-bearing late-hydrothermal solutions activity on crystalline limestone. Numanoite was named after the late Dr. Tadayuki Numano (1931-2001), Emeritus Professor of Okayama University.