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Georgeite, a new amorphous copper carbonate from the Carr Boyd Mine, Western Australia

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SUMMARY. Georgeite, an amorphous copper carbonate-hydrate, has been found in the oxidation zone of the Carr Boyd nickel deposit, Western Australia. It forms thin coatings mostly associated with malachite and chalconatronite on partly weathered tremolite rock containing disseminated copper and iron sulphides.

Physical properties: Colour light blue, streak pale blue, lustre vitreous to earthy, fracture conchoidal, soft, sp. gr. 2.55; transparent to sub-opaque (aggregates), $n(\mathrm{Na_D}) = 1.593$, isotropic. Amorphous to X-rays and electron beam.

Chemical microanalysis gave (wt %) CuO 54.9, ZnO 0.4, Na_2O 2.7, CO_2 20.8, H_2O 21.7, sum 100.5. After deduction of all Na_2O and corresponding amounts of CuO, CO_2, and H_2O as chalconatronite (12.35 wt %) the atomic ratios correspond to an empirical formula $(\mathrm{Cu_{5.0}, Zn_{0.05}})(\mathrm{CO_3})_3(\mathrm{OH})_{4.12}.6.3\mathrm{H_2O}$, the ideal formula being $\mathrm{Cu_5(CO_3)_3(OH)_4.6H_2O}$.

THE new mineral was found in 1975 by the senior author at the dump from the 'glory hole' of the Carr Boyd Nickel Mine (30° 04′ S, 121° 37′ E) 80 km NNE of Kalgoorlie, Western Australia. It was named georgeite in honour of George Herbert Payne, past Chief of the Mineral Division, WA Government Chemical Laboratories. Both the mineral and the name have been approved by the Commission on New Minerals and Mineral Names, IMA. Type specimens are preserved in the collections of the WA Government Chemical Laboratories as MDC 5775. Additional specimens have been placed in the US National Museum and the Natural Science Museum, Tokyo, Japan.

Occurrence. The nickel-copper mineralization at the Carr Boyd deposit occurs in an Archaean greenstone belt of the Kalgoorlie subprovince of the Yilgarn Block of the Western Australian Shield (Williams, 1974). The geology of the mine area has been described in detail by Purvis *et al.* (1972).

The dumps have been a prolific source of interesting minerals. Secondary minerals so far recorded from the deposit are: azurite, carrboydite (Nickel and Clark, 1977), chalconatronite (Embrey and Bridge, *in prep.*), epsomite, gaspéite, glaukosphaerite (Pryce and Just, 1974), gypsum, magnesite, malachite, morenosite, natrojarosite, nickelblödite (Nickel and Bridge, 1977), nickelian magnesite, paratacamite, takovite (Nickel *et al.*, 1977), thenardite, and trona.

The georgeite-containing material was found in a single large boulder of weathered tremolite rock containing disseminated chalcopyrite, pyrite, marcasite, covelline, and digenite and trace amounts of mackinawite, bornite, and blaubleibender covelline. Fracture surfaces in the rock were coated with nickelian magnesite, gypsum, malachite, chalconatronite, and georgeite. Many specimens show only the latter two or three minerals. Georgeite and chalconatronite appear to be formed by a reaction between malachite and meteoric solutions rich in Na^+ and CO_3^{2-} possibly, according to the equation.

$$\underset{\text{(malachite)}}{3\mathrm{Cu_2CO_3(OH)_2}} + 2\mathrm{Na^+} + 2\mathrm{HCO_3^-} + 7\mathrm{H_2O} \rightleftarrows \underset{\text{(georgeite)}}{\mathrm{Cu_5(CO_3)_3(OH)_4.6H_2O}} + \mathrm{Na_2Cu(CO_3)_2.3H_2O}$$

Georgeite could have been formed also by decomposition of chalconatronite.

$$\underset{\text{(chalconatronite)}}{5\mathrm{Na_2Cu(CO_3)_2.3H_2O}} \rightleftarrows \underset{\text{(georgeite)}}{\mathrm{Cu_5(CO_3)_3(OH)_4.6H_2O}} + 10\mathrm{Na^+} + 4\mathrm{HCO_3^-} + 3\mathrm{CO_3^{2-}} + 5\mathrm{H_2O}$$

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The occurrence of trona, $Na_3(CO_3)(HCO_3).2H_2O$, indicates presence of both CO_3^{2-} and HCO_3^- ions in ground waters in the oxidation zone.

Physical properties. The georgeite coatings are pulverulent or have an appearance of a desiccated gel; thicker coatings appear quite coarsely crystalline but are also amorphous. The colour of the mineral is Ridgway Light Cerulean Blue 45-BG-Bb, Pale Cerulean Blue 45-BG-Bd to Calamine Blue 45-G-Bd, streak is very pale blue, lustre vitreous to earthy. The mineral is very soft and brittle and has sub-conchoidal fracture; no cleavage was observed. Sp. gr. determined by the sink-float method, is 2.55 (10). Georgeite is sub-opaque in pulverulent aggregates but transparent in dense layers: in transmitted light it is pale blue, isotropic, and has $n(Na_D) = 1.593(2)$.

Thorough examination using both X-ray (Debye–Scherrer and Gandolfi methods) and electron-diffraction techniques proved georgeite to be totally amorphous.

Chemical composition. The chemical analysis gave (wt %) CuO 54.9, ZnO 0.4, Na_2O 2.7, CO_2 20.8, H_2O 21.7, sum 100.5. It was carried out by M. H. H. by microanalytical methods on a very small sample contaminated with chalconatronite, the presence of which was established by X-ray diffraction and qualitative examination of a portion of the analytical sample with EPMA. After deduction of 12.35 wt % of chalconatronite and normalization we obtain CuO 58.3, ZnO 0.6, CO_2 19.3, H_2O 22.0, corresponding to an empirical formula $(Cu_{5.01}Zn_{0.05})_{\Sigma 5.06}(CO_3)_3(OH)_{4.12}\cdot 6.3H_2O$, calculated on the basis of three carbon atoms. Ideal formula $Cu_5(CO_3)_3(OH)_4\cdot 6H_2O$ requires CuO 59.2, CO_2 19.59, H_2O 21.39.

The mineral is insoluble in water but soluble in dilute acids with effervescence.

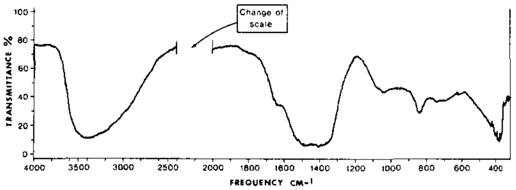

FIG. 1. Infra-red spectrum of georgeite.

Infra-red spectrum of georgeite is distinctly different from that of any other copper carbonate and shows the presence of both H_2O and OH^- in the mineral. The spectrum was obtained on a Perkins-Elmer instrument Model 521 using KBr pellet technique.

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