The crystal structure of stichtite, re-examination of barbertonite, and the nature of polytypism in MgCr hydrotalcites

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ABSTRACT

Stichtite, ideally Mg₉Cr₃CO₃(OH)₁₂.4H₂O, from Stichtite Hill, Tasmania, Australia, and barbertonite, also ideally Mg₄Cr₅CO₃(OH)₁₂.4H₂O, from the Kaapschoop asbestos mine, South Africa, have been studied by powder X-ray diffraction and their structures have been refined using the Rietveld method. Stichtite from Stichtite Hill crystallizes in the rhombohedral space group R3m, with unit-cell parameters a = 3.09575(3) Å and c = 23.5069(6) Å, V = 195.099(6) Å³, with Z = 3/8. Barbertonite from the Kaapschoop asbestos mine crystallizes in the hexagonal space group P6₃/mmc. The co-type specimens of barbertonite were found to be intergrown mixtures consisting of barbertonite and stichtite. Unit-cell parameters of barbertonite from the co-type specimens were a = 3.09689(6), c = 15.6193(8) Å, and V = 129.731(8) Å³ and a = 3.09646(6), c = 15.627(1) Å, V = 129.76(1) Å³, and Z = ¼. Rietveld refinements of both stichtite and barbertonite show that they are polytypes rather than polymorphs and do not represent distinct mineral species. Several possible nomenclature systems are discussed for the naming of hydrotalcite minerals and groups. Raman band assignments are also presented for stichtite from Stichtite Hill.

Stichtite and hydrotalcite minerals make up a large proportion of the ore at the Mount Keith nickel mine in Western Australia. Bulk powder diffraction shows the ore contains 6.1 wt% stichtite and 5.6 wt% iowaite. Hydrotalcite group minerals provide an important potential reservoir of CO₂. At Mount Keith, the amount of CO₂ mined as stichtite could exceed 45,000 metric tons per year, while exchange of Cl for CO₃ could fix in excess of 40,000 metric tons CO₂ per year if end-member iowaite is reacted to form pyroaurite.

Keywords: Stichtite, barbertonite, polytype, hydrotalcite, carbon sequestration, Stichtite Hill, Kaapschoop asbestos mine, X-ray diffraction

INTRODUCTION

Stichtite, ideally Mg₉Cr₃CO₃(OH)₁₂.4H₂O, is the Cr-analog of hydrotalcite, which occurs in Cr-bearing serpentinites, ophiolites, and greenstone belts in several localities worldwide. Originally identified as “kämmererite” [Cr-rich clinochlore – Nordenskiöld (1840); Lapham (1958)] in 1891, stichtite was recognized as a non-silicate in 1910 (Petterd 1910) and was formally described in 1914 from Stichtite Hill (41°53′9″S, 145°26′16″E), Dundas, Tasmania, Australia (Twelvetrees 1914). It was named stichtite after Robert Sticht, general manager of the Mt. Lyell mines in Tasmania, Australia (Twelvetrees 1914). Stichtite was first identified by X-ray diffraction films which showed a similarity to the diffraction patterns of sjögrenite [Mg₃Fe₃CO₃(OH)₁₂.4H₂O] and manasseite [Mg₆Al₂CO₃(OH)₁₂.4H₂O]. Ashwal and Cairncross (1997) report an unsuccessful attempt to identify and isolate barbertonite from the type material (housed in the collections of the Harvard Mineralogical Museum). The difficulty involved in isolating and identifying this mineral have led several sources to report barbertonite’s status as a mineral to be “questionable” (e.g., Clark 1993). The related mineral, sjögrenite, crystallizes in hexagonal space group P6₃/mmc (No. 194), with a = 3.103 and c = 15.52 Å, which corresponds to the 2H₃ polytype. Members of the sjögrenite group, which include manasseite and barbertonite, previous data on stichtite. Bottrill and Graham (2006) provide further information on the Tasmanian occurrences of this mineral and Mondal and Baidya (1996) provide information on stichtite from the Nuasahi chromite deposits, eastern India.

Barbertonite, also ideally Mg₄Cr₅CO₃(OH)₁₂.4H₂O, was described by Frondel (1941) as the hexagonal polymorph of stichtite from Kaapschoop asbestos mine, Kaapschoop, Barberton district, Mpumalanga, South Africa. Barbertonite was initially identified by X-ray reflection films which showed a similarity to the diffraction patterns of sjögrenite [Mg₃Fe₃CO₃(OH)₁₂.4H₂O] and manasseite [Mg₆Al₂CO₃(OH)₁₂.4H₂O]. Ashwal and Cairncross (1997) report an unsuccessful attempt to identify and isolate barbertonite from the type material (housed in the collections of the Harvard Mineralogical Museum). The difficulty involved in isolating and identifying this mineral have led several sources to report barbertonite’s status as a mineral to be “questionable” (e.g., Clark 1993). The related mineral, sjögrenite, crystallizes in hexagonal space group P6₃/mmc (No. 194), with a = 3.103 and c = 15.52 Å, which corresponds to the 2H₃ polytype. Members of the sjögrenite group, which include manasseite and barbertonite,