



NEW PERSPECTIVES ON PARTIALLY CRYSTALLINE MATERIALS IN GEMMOLOGY: AN INTEGRATED APPROACH TO THE CHARACTERISATION OF CHRYSOCOLLA

S. Monico¹, N. Marinoni¹, G.D. Gatta¹, I. Adamo², L. Prosperi², R. Conconi^{3,4},
G. Capitani³, A. Bernasconi⁵

¹Department of Earth Sciences “Ardito Desio”, University of Milan, Via Botticelli 23, 20133 Milan, Italy

²Istituto Gemmologico Italiano (IGI), Piazza San Sepolcro 1, 20123 Milan, Italy

³Department of Earth and Environmental Sciences, University of Milano-Bicocca, Piazza della Scienza 4, 20126 Milan, Italy

⁴Université de Lille, CNRS, INRAE, Centrale Lille, UMR 8207-UMET-Unité Matériaux et Transformations, Lille, France

⁵Department of Earth Sciences, University of Turin, Via Valperga Caluso 35, 10125 Turin, Italy

email of the presenting author: sara.monico1@unimi.it

Partially crystalline materials used in gemmology include a wide variety of mineral species with distinctive compositional and structural properties, which influence their appearance, durability, and aesthetic value. A notable example is chrysocolla, classified as a hydrated copper silicate ($\text{Cu}_{2-x}\text{Al}_x(\text{H}_{2-x}\text{Si}_2\text{O}_5)(\text{OH})_4 \cdot n\text{H}_2\text{O}$; $x < 1$) [1], and compositionally described as a colloidal system of hydrated silica and copper oxides. The term *chrysocolla* has ancient origins (Theophrastus, 315 BC) and derives from the Greek words *chrysos* (gold) and *kolla* (glue), referring to the material historically used for gold soldering [2]. Chrysocolla appears in a range of colours, influenced by compositional impurities. In its characteristic green-blue hues, it has been valued since antiquity as a pigment, but more notably as a gem material for amulets, ornaments, and jewellery. Thanks to its vivid colouring and unique aesthetic qualities, chrysocolla continues to be widely used in gemmology today.

Chrysocolla was officially recognised as a mineral species by the International Mineralogical Association (IMA) in 1969 [3]. However, its nature remains debated, as it is still unclear whether it represents a distinct mineral phase, an aggregate of multiple phases, or a colloidal gel. Research has often led to conflicting results, due to the inherent complexity of the material and its pseudo-amorphous character, which make it analytically challenging [4,5] and unstable under certain analytical conditions [1]. These critical aspects complicate the identification and classification of chrysocolla in mineralogical and gemmological fields.

The present study aimed to characterise chrysocolla from compositional, mineralogical, and microstructural perspectives, employing a multi-methodological approach. To this end, an *ad hoc*

analytical protocol was developed, designed to highlight the peculiarities of the material without compromising its stability. Both conventional and high-resolution techniques were employed to reveal distinctive features of chrysocolla not previously observed. The research involved the analysis of various samples sourced from two internationally recognised mining localities (Capo Calamita, Capoliveri (LI), Italy, and Cornwall (Lebanon County), Pennsylvania, USA). Particular attention was given to determining chemical composition through point and spatial surveys using electron microprobe analysis with wavelength-dispersive spectroscopy (EMPA-WDS). Multivariate analysis of the data allowed for identification of correlations between compositional variations and the specific formation conditions. The Pair Distribution Function (PDF) technique using synchrotron radiation was employed to investigate atomic organisation at the local scale, revealing previously unknown features concerning bond distances and structural coherence that conventional diffraction techniques cannot access. Finally, given the partially crystalline nature of the material—where distinctive properties are expressed at the level of local domains—the investigation was extended to the nanometric scale using transmission electron microscopy (TEM), in order to deepen textural and chemical characterisation.

The results provided new insights into the compositional, microstructural, and textural properties of chrysocolla, helping to define its specific features. Furthermore, the study introduced new methodological approaches for the recognition and classification of this material, with significant implications in both mineralogical and gemmological fields.

Keywords: chrysocolla; partially crystalline materials; nanoscale characterisation; short-range order; synchrotron radiation.

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