Ni-phyllosilicates (garnierites) from the Falcondo Ni-laterite deposit (Dominican Republic): Mineralogy, nanotextures, and formation mechanisms by HRTEM and AEM

Cristina Villanova-de-Benavent1,*, Fernando Nieto2, Cecilia Viti3, Joaquín A. Proenza1, Salvador Galí1, and Josep Roqué-Rosell4

1Departament de Cristal·lografia, Mineralogia i Dipòsits Minerals, Facultat de Geologia, Universitat de Barcelona (UB), Martí i Franqués s/n, 08028 Barcelona, Spain
2Departamento de Mineralogía y Petrología and IACT, Universidad de Granada, CSIC, Av. Fuentenueva, 18071 Granada, Spain
3Dipartimento di Scienze Fisiche, della Terra e dell’Ambiente, Università degli Studi di Siena, Via Laterina 8, 53100 Siena, Italy
4Advanced Light Source, Lawrence Berkeley National Laboratory, One Cyclotron Road, MS 15R0317, Berkeley, California 94720, U.S.A.

ABSTRACT

Ni-bearing magnesium phyllosilicates (garnierites) are significant Ni ores in Ni-laterites worldwide. The present paper reports a detailed TEM investigation of garnierites from the Falcondo Ni-laterite deposit (Dominican Republic). Different types of garnierites have been recognized, usually consisting of mixtures between serpentine and talc-like phases that display a wide range of textures at the nanometer scale. In particular, chrysotile tubes, polygonal serpentine, and lizardite lamellae are intergrown with less crystalline, talc-like lamellae. Samples consisting uniquely of talc-like and of sepiolite-falcondoite were also observed, occurring as distinctive thin lamellae and long ribbon-shaped fibers, respectively. HRTEM imaging indicates that serpentine is replaced by the talc-like phase, whereas TEM-AEM data show preferential concentration of Ni in the talc-like phase. We suggest, therefore, that the crystallization of Ni-bearing phyllosilicates is associated with an increase in the silica activity of the system, promoting the replacement of the Ni-poor serpentine by the Ni-enriched talc-like phase. These results have interesting implications in material science, as garnierites are natural analogs of Ni-bearing phyllosilicate-supported synthetic catalysts. Finally, SAED and HRTEM suggest that the Ni-bearing talc-like phase corresponds to a variety of talc with extra water, showing larger d001 than talc (i.e., 9.2–9.7 Å), described as “kerolite”-“pimelite” in clay mineral literature.

Keywords: Ni-laterites, garnierites, chrysotile, polygonal serpentine, lizardite, “kerolite”-“pimelite”, sepiolite-falcondoite, HRTEM

INTRODUCTION

Garnierite was originally the name of a mineral species discovered in 1863 in New Caledonia (Garnier 1867), although it was later proved to be a mixture of different Ni-hydrous silicates (e.g., Pecora et al. 1949; Faust 1966). Since then, the term garnierite has been widely used in the literature to refer to the group of green, fine-grained, poorly crystallized, Ni-bearing magnesium phyllosilicates, including serpentine, talc, sepiolite, smectite, and chlorite, often occurring as mixtures (e.g., Faust 1966; Brindley and Hang 1973; Springer 1974; Brindley 1978; Wells et al. 2009; Villanova-de-Benavent et al. 2014a). Therefore, despite not being a valid mineral name, garnierite became a convenient field term used by mine geologists to designate all green Ni-phyllosilicates when a more specific characterization was not possible (Brindley 1978), and many authors have used this term with this general meaning (e.g., Moraes 1935; Pecora and Hobbs 1942; Pecora et al. 1949; Varela 1984; Gleeson et al. 2003, 2004; Freyssinet et al. 2005; Wells et al. 2009).

In addition, the classification and naming of the garnierite minerals represents a complex, long-lasting controversy because of their fine-grained nature, poor crystallinity, and frequent occurrence as intimate mixtures of different mineral species (Brindley and Hang 1973). Brindley and co-authors, after various studies, distinguished the following Mg-Ni series: the serpentine group minerals (1) lizardite-népouite and (2) chrysotile-pecoraite; (3) berthierine-brindleyite; the talc-like structures (4) talc-willemseite and (5) “kerolite”-“pimelite”; (6) the chlorite series clinohlore-nimite; and finally (7) sepiolite-falcondoite (Brindley and Hang 1973; Brindley and Maksimović 1974; Brindley 1978, 1980). The most common garnierites found in nature are formed by lizardite-népouite and “kerolite”-“pimelite” (Brindley 1978), and many authors have been referred to them as “serpentine-like” (or “7 Å-type”) and “talc-like” (or “10 Å-type”) garnierites, respectively (e.g., Brindley and Hang 1973; Brindley and Maksimović 1974; Wells et al. 2009; Gali et al. 2012). “Kerolite” and “pimelite” can be described as phases with t alc affinity and extra water in their structure, within the ideal structural formula (Mg, Ni)Si₃O₁₀(OH)₂·n(H₂O). Faust (1966) classified “pimelite” into the smectite group, although other authors proved that neither “kerolite” nor “pimelite” exhibit intracrystalline swelling (e.g., Kato 1961; Brindley and Hang 1973; Brindley 1978). Regardless of both discredited species by the Commission on New Minerals, Nomenclature and Classification of the International Mineralogical Association (CNMNC-IMA), these names have been used during the following decades (e.g.,