Interpretation of the infrared spectra of the lizardite-nepouite series in the near- and mid-infrared range

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ABSTRACT

A series of 1:1 silicate clays of the lizardite-nepouite series [Si2Mg3–xNixO7(OH4)] with x = 0, 0.5, 1, 1.5, 2, 2.5, and 3] was synthesized at 220 °C during 7 days from coprecipitated gels in hydrothermal conditions. A clear relationship was evidenced between the d(06–33) and the Ni/Mg ratio of the synthesized samples following a Vegard’s law and suggested a random distribution of octahedral cations. For the first time, infrared spectra of this series were given in both near and mid-infrared spectral regions (250–7500 cm⁻¹). Notably, the bands due to the OH stretching vibrations and those of their first overtones in the lizardite-nepouite series were attributed. The combination bands observed in the near infrared region for both end-members could be attributed thanks to combinations of two or three middle-infrared features. Some of the observed combination bands are clearly linked to combination of different vibrational groups.

Infrared spectroscopy is simple to use and is a powerful tool to study the crystal chemistry of garnierites. More broadly, the improvement of band attributions especially in near infrared contributes to develop the infrared analyses in field geology and remote sensing.

Keywords: Lizardite, nepouite, infrared spectroscopy, near infrared, mid-infrared, synthesis, nickel, clay minerals, serpentine, phyllosilicates, garnierite

INTRODUCTION

Nickel ore deposits are found in lateritic or sulfide forms. The major part of produced Ni comes from sulfide deposits (60%), but Ni-laterite ores make up 10 to 70% of the world’s Ni resources (Butt and Cluzel 2013). Ni concentration in laterites results from an intensive weathering of ultramafic rocks or their serpentinized equivalents under tropical or rainforest conditions like in New Caledonia (Wells et al. 2009) or Brazil (Mano et al. 2014). These deposits are divided in two ore types, an oxidized one and a hydrous silicate type currently named “garnierite” (Faust 1966; Trescases 1975, 1979). The garnierite group is a general name for an intimate mixture of hydrous Ni-Mg silicates that commonly includes two or more of the following minerals: serpentine, talc, smectite, and chlorite (Faust 1966; Brindley and Hang 1973; Springer 1974; Brindley et al. 1979; Gleeson et al. 2004). Ni-bearing minerals in the serpentine group are mainly lizardides and chrysotiles, whose Ni-analogs are nepouite and pecoraite. Nepouite was first described by Glassere (1907) as the Ni-lizardite analog, and Maksinovich (1973) showed the occurrence of the lizardite-nepouite series. The phyllosilicates belonging to the lizardite-nepouite series are generally mixed with other minerals in garnierite. The study of the crystal chemistry of these natural phyllosilicates is then uneasy. Moreover, as far as the authors are aware, spectral data concerning this series are not available in literature, notably in the near infrared (NIR) range (4000–7000 cm⁻¹), although NIR field spectrometers could be used widely by Ni-mining companies for exploration. Field spectrometers are commonly used to distinguish mineral compositional variations, which may vary with the composition of altering fluids, temperature, and composition of host rocks in an alteration system. Mapping the mineralogical variations at both geological scale with field/airborne/spaceborn infrared spectrometer (Bowen et al. 2007; Di Tommaso and Rubinstein 2007; Chen et al. 2007; Brandmeier et al. 2013) using NIR data and at the microscopic scale with infrared microspectroscopy (IRM) (Robin et al. 2013) using mid-infrared (MIR) data, contributes to improve the understanding of the functioning of an alteration system and to determine the mineralization/alteration relationships. To map mineralogical variations in lateritic Ni ore deposit, spectral data in NIR range on the nepouite-lizardite series must be known. And generally, even if spectral data exist for clay minerals, any band interpretations in NIR range are available.

Therefore samples from the lizardite-nepouite series were synthesized to obtain pure reference samples for a Fourier transform infrared (FTIR) study, in both NIR and MIR regions and band attributions were made.

EXPERIMENTAL METHODS

Clay synthesis

Samples of the lizardite-nepouite series were synthesized using a coprecipitated gel as starting material as in Baron et al. (2016). Coprecipitated gels of Si3Mg1.5Ni0.5O7 theoretical composition with x = 0, 0.5, 1, 1.5, 2, 2.5, and 3 were obtained by mixing solutions of sodium silicate, Mg and/or Ni chloride, and sodium hydroxide (reaction 1).

\[ 2SiO_2Na_2O + (3 – x)MgCl_2 + xNiCl_2 + 2NaOH \rightarrow Si_3Mg_{3–x}Ni_xO_7 + 6NaCl + H_2O \] (1)

After precipitation, the gel was collected by filtration and gently washed with deionized water to remove sodium chloride and then dried at 60 °C for 48 h before...