



Paired stable isotopes (O, C) and clumped isotope thermometry of magnesite and silica veins in the New Caledonia Peridotite Nappe

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Abstract

The stable isotope compositions of veins provide information on the conditions of fluid–rock interaction and on the origin of fluids and temperatures. In New Caledonia, magnesite and silica veins occur throughout the Peridotite Nappe. In this work, we present stable isotope and clumped isotope data in order to constrain the conditions of fluid circulation and the relationship between fluid circulation and nickel ore-forming laterization focusing on the Koniambo Massif. For magnesite veins occurring at the base of the nappe, the high $\delta^{18}\text{O}$ values between 27.8‰ and 29.5‰ attest to a low temperature formation. Clumped isotope analyses on magnesite give temperatures between 26 °C and 42 °C that are consistent with amorphous silica–magnesite oxygen isotope equilibrium. The meteoric origin of the fluid is indicated by calculated $\delta^{18}\text{O}_{\text{water}}$ values between –3.4‰ to +1.5‰. Amorphous silica associated with magnesite or occurring in the coarse saprolite level displays a narrow range of $\delta^{18}\text{O}$ values between 29.7‰ and 35.3‰. For quartz veins occurring at the top of the bedrock and at the saprolite level, commonly in association with Ni-talc-like minerals, the $\delta^{18}\text{O}$ values are lower, between 21.8‰ and 29.0‰ and suggest low-temperature hydrothermal conditions (~40–95 °C). Thermal equilibration of the fluid along the geothermic gradient before upward flow through the nappe and/or influence of exothermic reactions of serpentinization could be the source(s) of heat needed to form quartz veins under such conditions.

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1. INTRODUCTION

Carbonate and silica veins occur in various geological contexts, and are the marker of past geological fluid circulation. Understanding the conditions of veins formation is of primary importance to decipher the role of fluids in the transfer of heat and matter, the transport and deposition

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of metals, and the mechanical properties of shear zones and faults. Stable isotopes are one of the historical tools used in the characterization of fluid–rock interactions (Urey, 1947; McCrea, 1950; Epstein et al., 1953; Craig and Boato, 1955; Emiliani, 1966). Theoretically, stable isotopes give access to the fluid stable isotopic composition and the temperature of precipitation of minerals. However, estimates of temperature and fluid composition are interdependent. That is the reason why stable isotopes studies have to be undertaken with a strong knowledge of the local geology and in association with complementary methods of fluid characterization, like fluid inclusions studies or other geothermometers.

The recent development of the carbonate clumped isotope thermometer has rapidly been considered as a very promising tool in Earth Sciences (Eiler, 2007). This method is based on the thermodynamic phenomenon of “clumping” which consists in the preferential bonds formation between the heavy isotopes of carbon and oxygen in carbonate minerals. Unlike conventional carbonate thermometers, the clumped isotope thermometer allows temperatures of formation of carbonate to be estimated independently of the initial fluid isotopic composition. By extension, it can provide an estimate of the $\delta^{18}\text{O}$ value of the parent fluid since the $\delta^{18}\text{O}$ of the carbonate and temperatures are measured independently on the same aliquot of sample.

For the last two decades, the study of carbonate and silica veins developed in ultramafic rocks has attracted a renewed interest given the implications of this process for permanent carbon capture and storage through CO_2 miner-

alization (Kelemen and Matter, 2008; Kelemen et al., 2011; Oelkers et al., 2008; Ulrich et al., 2014), and in the understanding of lateritic nickel ore formation (Butt and Cluzel, 2013 and references herein). The New Caledonia Peridotite Nappe hosts one of the largest lateritic nickel ore deposit representing around 30% of the global reserves in nickel, thus making New Caledonia the 7th nickel producer in the world. In New Caledonia as in many other places worldwide (Caribbean, South America, Balkans, Russia, West Africa, South East Asian, Australia) Ni-laterites result from the intense weathering of ultramafic rocks exposed at the surface under hot and humid climate. Their development requires the dissolution of protolith minerals leading to (i) the export of soluble elements and (ii) the in-situ authigenesis of mineral phases hosting the insoluble elements. In the case of peridotites in New Caledonia, Si and Mg are exported whereas the laterites are enriched in iron oxo-hydroxides. Ni, with an intermediate behavior, is concentrated at the base of the lateritic profile where it reaches economic concentrations as Ni-bearing goethite (Trescases, 1975; Freyssinet et al., 2005). The erratic nickeliferous high-grade ore is located along fractures; it is known as garnierite, a mix of Ni-rich serpentine, Ni talc-like minerals and Ni-sepiolite (e.g. Faust, 1966; Brindley and Hang, 1973; Villanova-de-Benavent et al., 2014; Cathelineau et al., 2015b; Fritsch et al., in press) commonly associated with silica.

In New Caledonia (Fig. 1), numerous magnesite (MgCO_3), quartz and amorphous silica veins occur at

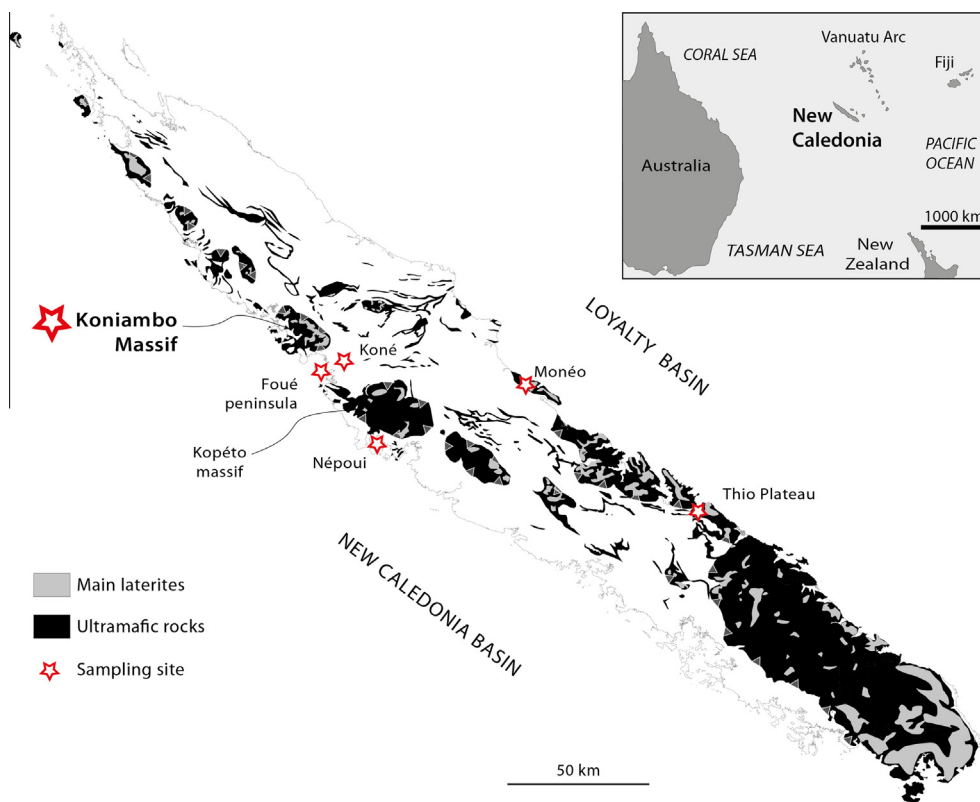


Fig. 1. Simplified geological map of New Caledonia. Ultramafic rocks are from Maurizot and Vendé-Leclerc (2009) and laterites are adapted from Paris (1981).

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