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Differential weathering in ultramafic rocks of New Caledonia: The role of infiltration instability

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ABSTRACT

Ultramafic rocks of New Caledonia present extensive pseudokarstic features: undulations of the base of the weathering profile, fractures enlarged by dissolution, dolines. Possible influence of the infiltrative instability on differential weathering of ultramafic rocks in tropical climate is investigated here, starting from the Tiébaghi case for which a groundwater model is available. Infiltration instability is governed by non-dimensional numbers, i.e. the Damköhler and Peclet numbers, and by the permeability contrasts between the bedrock and the different layers of the weathering profile. These numbers are firstly estimated for the Tiébaghi case, and secondly a sensitivity study of the weathering style is achieved through numerical modeling. Computations are firstly carried out without the impervious laterite cover, and then the effect of this cover is considered. The characteristic time constant for weathering of peridotites is directly estimated at around 7 yrs from the thickness of the weathering front and the fluid velocity. The results show that a permeability contrast of at least 100 between the most pervious layer in the weathering front and bedrock and a diffusivity of chemical species lower than 2.5×10^{-8} m^2/s are required to allow instability. The Tiébaghi case lies at the limit of instability and dissolution fingers develop in a time lapse of 1 Ma. However, this requires the infiltration of nearly 800 mm of rainfall yearly, which is not the case presently. The development of dissolution fingers is promoted by any initial pervious zone such as fracture concentration around a faulted zone and the characteristic time for instability development drops to 0.1–0.3 Ma. Extension of these results to other peridotite massifs in the tropical zone submitted to different temperatures and rainfalls is finally discussed.

1. Introduction

The main Island of New Caledonia, Grande Terre (GT), presents an exceptional density of outcrops of ultramafic rocks (Fig. 1) which originate from oceanic crust and mantle obducted onto the Norfolk Ridge during late Eocene (Cluzel et al., 2001). The northern massifs, including the Massif duTiébaghi, are constituted of spinel and plagioclase-rich serpentinized lherzolites (Ulrich et al., 2010). At the outcrop the ultramafic material appears homogeneous and the main heterogeneities originate from stratification within the weathering profile and from fractures. Obduction and further mechanical relaxation (Lagabrielle et al., 2005) resulted in fracturation observed at all scales. At the outcrop several fracturation directions are observed and there are only few examples of a 1x1 m-block devoid of fractures. A regolith cover reaching several tens of meters is generally observed on ultramafic rocks of New Caledonia, except in high slope areas, where mechanical erosion supersedes chemical erosion (Trescases, 1975; Beauvais et al., 2007).

This regolith results from weathering of minerals of ultramafic rocks which are unstable in a tropical climate (Thomas, 1994; Taylor and Eggleton, 2001). The synthetic weathering profile of Fig. 2 was compiled by Maurizot et al. (2016) after original works by Trescases (1975), Pelletier (1983), Latham (1986), Sevin (2014) and Bailly et al. (2014). It includes, from bottom to top: (i) the fractured bedrock, (ii) saprock, which includes unweathered blocks separated by coarse saprolite where initial mineral shapes can still be observed, (iii) fine saprolite, characterized by a high weathering level and the absence of unweathered minerals, (iv) laterites, which are constituted of non-soluble minerals, mainly iron oxides (Sevin, 2014). Coarse saprolite and to a lesser extent fine saprolites and laterites include Ni and Co concentrations which are actively mined. The weathering profile is locally topped by a duricrust a few meters thick resulting from alternating oxidizing and reduc-

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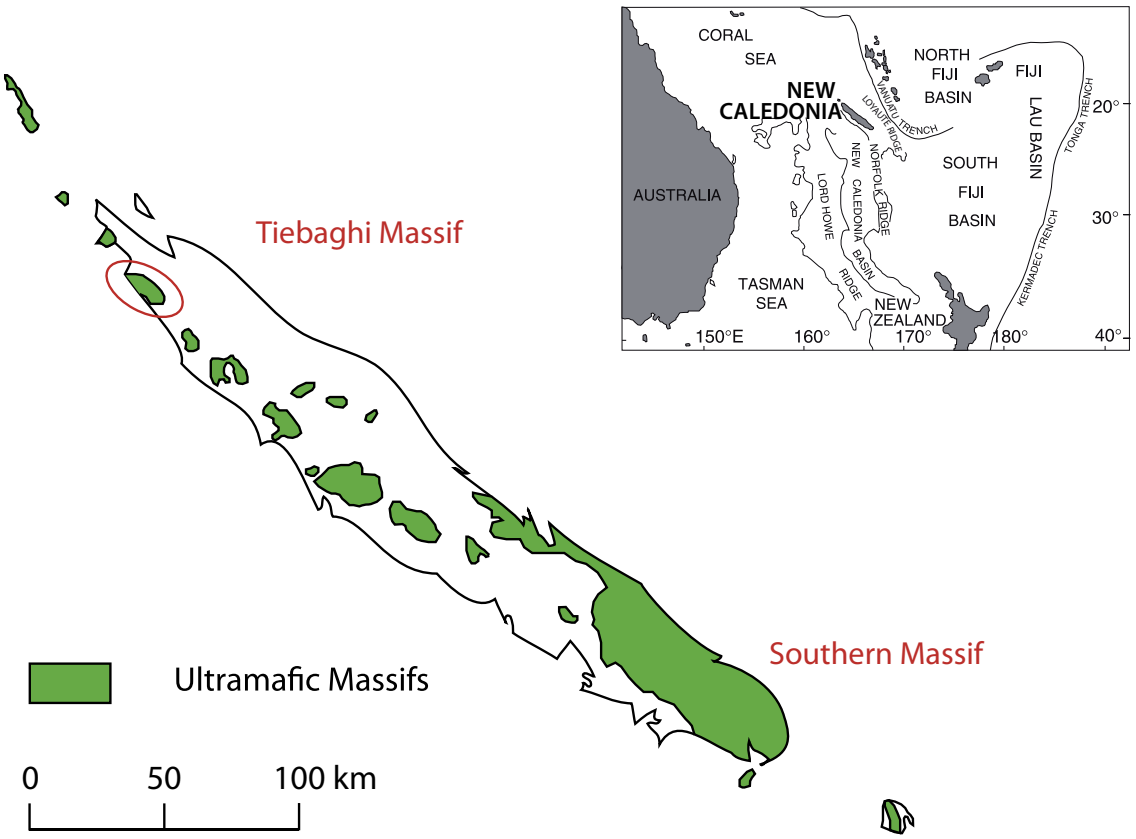

Fig. 1. Location of ultramafic massifs in New Caledonia. The top right inlay indicates the location of New Caledonia in the SW Pacific Region.

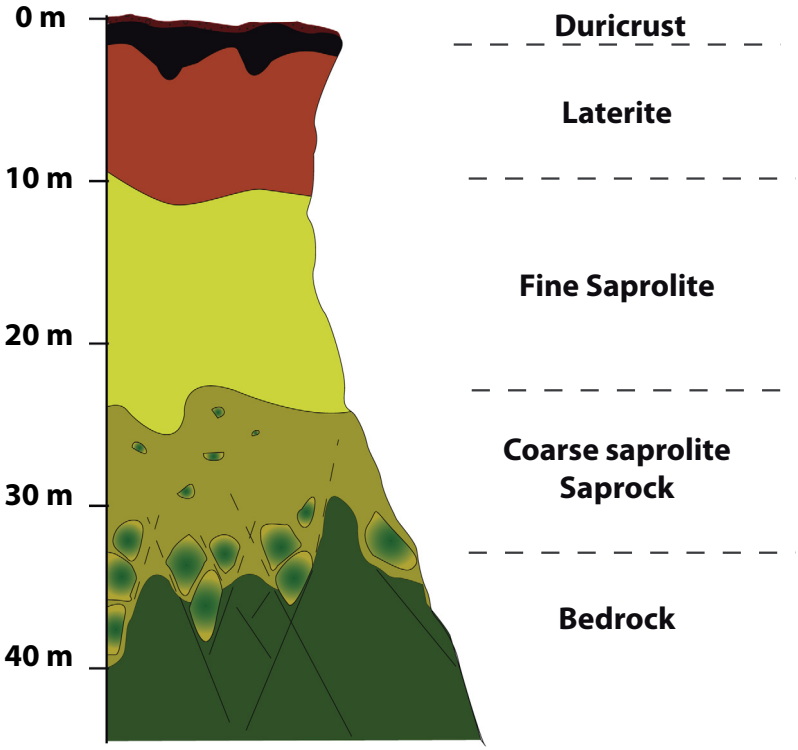

Fig. 2. Weathering profile in the ultramafic rocks of New Caledonia.

tive conditions occurring near the water table (Beauvais and Colin, 1993; Freyssinet et al., 2005). The active weathering front includes the fine saprolite and the saprock layers. Similar weathering profiles are generally observed on basement rocks in tropical climates