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Podzolization over ophiolitic materials in the western Alps (Natural Park of Mont Avic, Aosta Valley, Italy)

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ABSTRACT

Soil surveys carried out on ophiolitic rocks and till under subalpine forest in the Natural Park of Mont Avic (Aosta Valley, West Italian Alps) revealed the unexpected occurrence of soils showing a horizon set typical of the podzols. Podzolization is uncommon on mafic and ultramafic substrata: the translocation of organo-metallic compounds in soils developed from such parent materials slows down considerably due to the high Fe and Mg contents, the high base saturation and the close to neutral pH.
In order to determine the real origin and evolution of such soils, 6 pedons, selected among 83 profiles with a similar "podzol" morphology, were sampled and analyzed. Chemical, mineralogical, and petrographic analyses of the sampled soils and parent materials were performed, and correlation analysis of the obtained data was carried out.
Results show that, in favourable environmental conditions (mainly climate and vegetation), even mafic and ultramafic parent materials can undergo different degrees of podzolization. Due to the adopted diagnostic criteria the most common classification systems (particularly the WRB) do not allow satisfactory taxonomic arrangement of such soils.

1. Introduction

Two main processes are currently claimed in order to explain the podzolization: the first one is the formation and illuviation of organic acids complexed with Al and Fe; the second one is the weathering of silicates followed by a downward transport of Al and Si as colloidal inorganic solutions (Lundström et al., 2000). Podzolization is a typical pedogenic process mostly acting on acidic and silicate rocks under subalpine coniferous forests or ericaceous shrubs in cold, humid climates. On the contrary, this process is somewhat inhibited over easily weatherable mafic and ultramafic parent materials (Lundström et al., 2000) due to the high base status, high siderophile content (Souchier, 1984) and neutral pH. In general, these chemical factors slow down podzolization considerably, even when climate and vegetation favour the process.

Few studies have been dedicated to soils developed on ultramafic materials under subalpine vegetation at middle and high latitudes (Sasaki et al., 1968; Sticher et al., 1975; Verger, 1990; Bulmer et al., 1992; Verger et al., 1993; Alexander et al., 1994a,b; Bulmer and Lavkulich, 1994; Gasser et al., 1994; Verger, 1995), whereas many works have focused on "serpentine soils" in tropical areas.

There are only a few reports of podzolic soils developed from serpentinite; moreover, according to the most widespread taxonomic systems, such as the World Reference Base for Soil Resources (IUSS Working Group WRB, 2006) (hereafter WRB) and Soil Taxonomy (Soil Survey Staff, 1999, 2006) (hereafter ST), none of these soils can be classified as Podzols or Spodosols. Alexander et al. (1994a,b) describe soils on ultramafic till in Alaska as having an E horizon but a pH>6 in the Bs horizons, which is inconsistent with that of Spodosols. Bulmer and Lavkulich (1994) report that a soil developed from ultramafic materials in Canada has a spodic Bf horizon (Expert Committee on Soil Science. Agriculture Canada Research Branch, 1987), but lacks the E horizon and has a rather high pH (5.7). A similar soil profile was observed by Ragg and Ball (1964) on the Scottish island of Rhum. Soils with a podzol-like morphology (a bleached E horizon overlying a reddish-brown Bs) described by Gasser et al. (1994) in Switzerland show lithological discontinuity between the wind-driven material from which the E horizon formed and the Bs derived from serpentinite debris. The same profile was previously described by Sticher et al. (1975). The high quartz content (15%) in the eluvial horizon was ascribed to the presence of aeolian material. Sasaki et al. (1968) found a podzol-like soil on serpentinite in Northern Japan: they conclude that podzolization is active, but the pH value (6.5) is higher than the one typical of podzolic soils. Verger (1990, 1995) and Verger et al. (1993) compared soils developed on serpentinite and on mafic and acid rocks in the western Italian Alps. They concluded that podzolization is impossible on ultramafic parent materials, which usually give rise to Eutric or Dystric Cambisols in the most humid sites at the subalpine vegetation stage.

Recent surveys (D'Amico, 2003, 2006) carried out in the ophiolitic area of the Mont Avic Natural Park (Aosta Valley, Italy) on soils,

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Fig. 1. An example of podzol (profile no. 1) developed in mafic and ultramafic parent material.

vegetation and landscapes found soils showing a podzol-like morphology (Fig. 1) at the subalpine altitudinal level, on stable, northward slopes. The aim of the present work is, therefore, to verify the lithological ultramafic composition of the parent material, and to investigate in depth the pedogenic process going on such substrates. 6 pedons, representing the lithological variability and selected among 83 previously studied profiles, were described, analyzed from a chemical and a mineralogical point of view, and classified according to the most used taxonomic systems.

2. Physiographic outlines of the study area

The six selected pedons are located on the north-facing slope of the Chalamy Valley, in the Mont Avic Natural Park (Italian Graian Alps, Aosta Valley) (Fig. 2).

The whole valley is carved in mafic and ultramafic rocks belonging to the "Mont Avic Ophiolitic Complex". The prevailing lithology is serpentinite (mainly composed of antigorite), sometimes associated with chlorite schists, metagabbros, prasinites and amphibolites (Occhipinti, 1997). Until 12,000 years BP the valley was completely covered by local glaciers which deposited a layer of till composed of different proportions of serpentinite and mafic rocks. This till is the parent material of the examined soils.

Active solifluction was observed on the steepest slopes.

The average yearly temperature is around 1–3 °C, and precipitations of 800–1200 mm y^{-1} are mainly distributed in autumn and spring. The snow cover usually lasts from November until late May. Soils normally have water surplus every month (perudic moisture regime) (D'Amico, 2003). The evapotranspiration rate should be low.

The main environmental characteristics of the 6 sites are summarised in Table 1.

The forest is dominated by *Pinus uncinata* and *Larix decidua*, and the understorey vegetation by ericaceous shrubs such as *Rhododendron ferrugineum*, *Vaccinium uliginosum*, *V. myrtillus*, *Loiseleuria procumbens* and *Empetrum nigrum* ssp. *hermaphroditum*. The strictly serpentinicolous sedge *Carex fimbriata* is common on serpentinite and ultramafic till (pedons 3, 4, 5, 6).

Hygrophilous species such as *Trichophorum caespitosum*, *Pinguicola leptoceras* and *Tofieldia calyculata* grow where drainage is poor or somewhat poor (P3, P6).

3. Materials and methods

3.1. Soil description and sampling

Field description of soil profiles was done according to FAO (2006). The suffixes applied to the organic horizons are taken from Référentiel Pédologique (hereon RP) (INRA-AFES, 1995; Baize and Girard, 1998).

Approximately 1 kg of soil material was collected from every mineral horizon in the 6 soil pits; rock fragments were preserved in order to qualitatively and quantitatively determine their lithology. Undisturbed samples are taken from each horizon and later observed with a binocular microscope (40×) in order to verify the existence and the structure of the coatings.

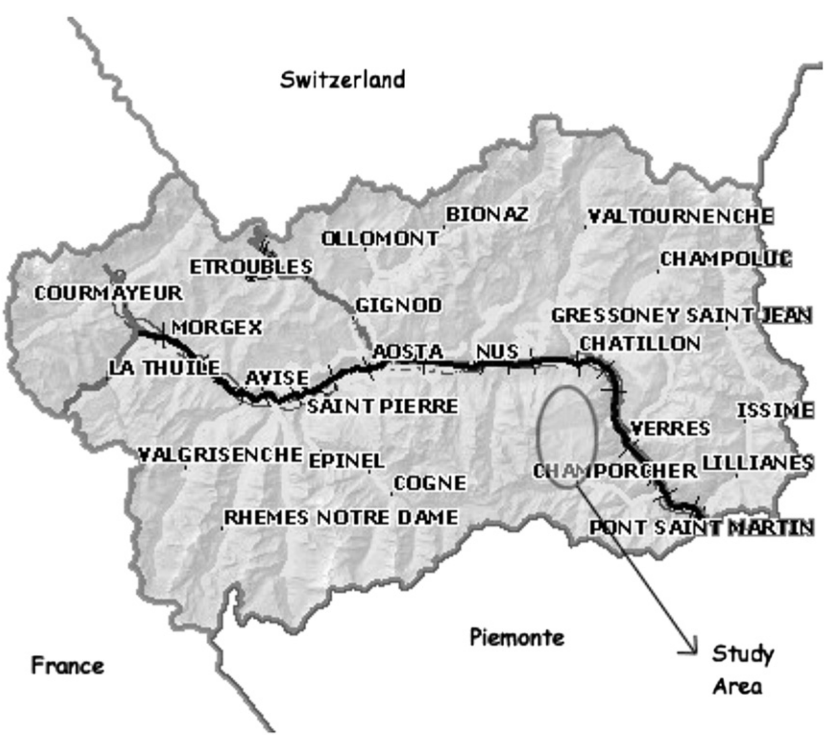

Fig. 2. Location of "Mont Avic Natural Park".