



Effect of granite crystal grain size on soil properties and pedogenic processes along a lithosequence



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ABSTRACT

This study generated new insight into the effect of bedrock grain sizes on pedogenesis under identical topographic and climatic environment. The physico-chemical and mineralogical properties of two adjacent Typic Dystrichrepts (USDA, 1999) respectively developed from fine and coarse textured granites were compared. This research study was performed in the Morvan Mountains (France). Analysis of the two underlying bedrocks revealed similar chemical and mineralogical properties, with the crystal grain size being the only parameter which differed. In these soils, bedrock played the key role in the particle size fraction distribution, the main factor controlling water retention in the soils. Weathering reactions of clay minerals were more marked in the fine textured granite soil. In this soil, both clay mineral swelling and mica transformation into expansible phyllosilicates were greater compared to the coarse textured granite soil. In the clay fraction of the fine textured granite soil, there were smaller amounts of low crystallised Fe and Al minerals, with higher carbon content in the topsoil, as compared to the coarse granite soil. The exchangeable cation analysis of the fine textured granite soil revealed a higher proportion of base saturation and a smaller proportion of Al_{tit} than in coarse textured granite soil which could be explained by preferential leaching of Al cations. The decrease in exchangeable Al, the higher swelling of the smectitic layer and the smaller proportion of Fe and Al-oxy-hydroxides could be explained by the complexing acid conditions, which increased mineral weathering and Al leaching. The higher water retention increased the time of contact between minerals and the soil solution, and the higher carbon content in the topsoil could have enhanced the complexing acid conditions.

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1. Introduction

The main factors controlling soil formation were the climate, parent material, organisms, topography and time (Jenny, 1941). In particular, the nature of the parent rock plays a major role in soil forming processes under temperate climates. The mineralogical, chemical and physical nature of the bedrock influences many chemical, physical, mineralogical and morphological properties of the overlying soil and consequently impacts the rooting medium and plant available water and nutrients. Granitic bedrock is an important soil parent material because of its widespread occurrence throughout of the world (Gerrard, 1994; Scarciglia et al., 2005; Sequeira Braga et al., 2002). The role of weathered granitic bedrock in soil genesis, water movement and natural ecosystems has been extensively studied (Evans and Bothner, 1993; Graham et al., 1997; Johnson-Maynard et al., 1994; Megahan and Clayton, 1986). Many field and microscopy studies have focused on the weathering of granitic rocks and soil genesis in broad range of

environmental conditions, but there is still a lack of knowledge concerning the specific effects of bedrock crystal grain size on the soil properties. We investigated this parameter by comparing two adjacent Typic Dystrichrepts (USDA, 1999) formed from granite with different crystal grain sizes. This research was carried out in the Breuil forest located in Morvan mountain region (France). As described by Dejou (1966) and Lameyre and Roques (1964), this area features a main batholith of coarse granite enclosed by fine granite (Fig. 1), and the Breuil forest experimental site straddles these two granite facies.

The aims of the present study were thus to assess the impact of granite texture on soils by comparing their chemical and physicochemical properties and thereby assessing the underlying pedogenetic processes.

2. Material and methods

2.1. Site of study

The Breuil-Chenu forest is located in the Morvan mountains (47°18' N, 4°5' E, France) at 638 m elevation. The mean annual air temperature is 9 °C, with annual precipitation averaging 1280 mm yr⁻¹. The soil is derived from “Pierre qui Vire” granite (Seddoh, 1973), which is

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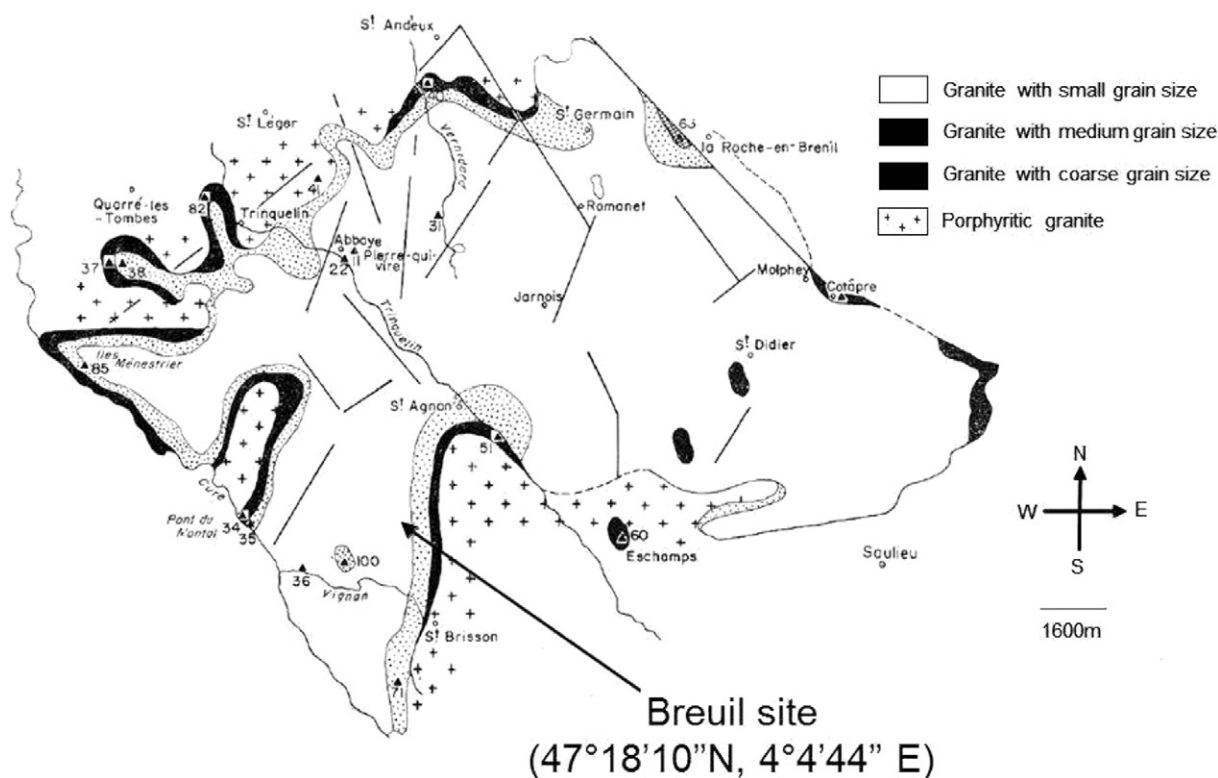


Fig. 1. Localisation of the Breuil site. Modified from the cartography of the granite rock in the Breuil forest area from Dejou (1966).

acidic, well drained and classified as Typic Dystrachrept (USDA, 1999), with a depth ranging from 120 to 140 cm.

The cation exchange capacity (CEC) was low and mainly compensated by Al. The base saturation (BS) was below 10% (Mareschal, 2008). The humus is a moder form (Brêthes et al., 1995). The forest is an old coppice with standards (CwS) stand dominated by beech (*Fagus sylvatica* L.) and oak (*Quercus sessiliflora* Smith).

2.2. Sampling of rock and soil

One 300 m × 200 m flat area was delineated and included two types of bedrock according to geologic maps (Seddoh, 1973; Dejou, 1966). This area was then accurately described in the field using 20 profiles regularly distributed down to the bedrock to ensure that the stones present in the underlying soil were consistent with the parent material. The rock description and analyses were performed from stones sampled in the deepest soil horizons ranging from 120 to 140 cm of depth (lithic contact between soil horizon and the underlying bedrock). The results highlighted a clear limit between the two granite types and allowed us to determine two zones for the soil study. Twenty soil profiles were dug and sampled per soil type.

Systematic volumetric soil sampling was performed at seven depths (0–5, 5–10, 10–15, 15–25, 25–40, 40–55 and 55–70 cm) for all soil profiles. One litre of mineral soil was collected for each soil level. The soil samples were sieved to 2 mm to remove any roots and rocks and then stored before analysis. The following factors were measured: carbon content, nitrogen content, pH, exchangeable acidity (EA), base saturation (BS), cationic exchange capacity (CEC), particle size distribution, selective extraction and mineralogical analysis of the clay fraction.

2.3. Granite analysis

Optical microscopy was used to describe the granite samples and determine their mineralogical and petrographic features. Twenty thin sections were made from the deep rock samples. This microscopy was used

to count points on five sections per granite facies, with 3000 points per section, to assess the proportion of each mineral phase.

Bulk chemical analyses of granite samples were conducted at the Centre de Recherches Pétrographiques et Géochimiques (CNRS-CRPG) in Nancy. The cationic compositions of the rock samples were determined by ICP-OES (Thermo Electron IRIS Advantage). The samples were fused with LiBO₂ and dissolved in 1 N HNO₃. The accuracy of results was assessed according to international geochemical standards. The analysis accuracy was estimated to be less than 1% for Al₂O₃ and SiO₂, 2% for FeO, MgO and K₂O, 10% for TiO₂ and 15% for MnO, depending on the concentrations in the samples.

2.4. Soil analysis

2.4.1. Particle size distribution

The particle size distribution was determined by pipette and wet-sieving methods (Krumbein and Pettijohn, 1938). Thirty grammes of each composite soil sample were first treated to remove organic matter with 5% H₂O₂, followed by deflocculation with NaCl (0.4 N) to avoid aggregate formation. Thereafter, the clay (<2 μm) and fine silt (2–20 μm) fractions of the samples were separated by the pipette method, based on 'Stokes' sedimentation rates. Coarse silt (20–50 μm) and fine sand (50–200 μm) were subsequently isolated by wet sieving.

2.4.2. Physico-chemical analysis

The pH of fine earth samples was measured in water and in a KCl solution (1 N), with a soil to solution gravimetric ratio of 1:5. After 12 h contact, the pH was measured using a Mettler TSDL25 pH metre.

Exchangeable cations in the soil samples were extracted in either 1 N KCl for Mg²⁺, Ca²⁺, Na⁺, Fe³⁺ and Mn²⁺ assays or 1 N NH₄Cl for K⁺ assay according to the method described by Espiau and Peyronel (1976), and determined by ICP-AES (JY180 ULTRACE). The 1 N KCl soil extract was also titrated on an automatic titrimer (Mettler TS2DL25) to assess exchangeable H⁺ and Al_{tit} (Rouiller et al., 1980). The exchangeable acidity (EA) was calculated from the sum of H⁺ and Al_{tit}.

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