INITIAL STAGES OF SOIL AND CLAY MINERAL FORMATION

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INTRODUCTION

Weathering of rocks is fundamental for pedogenesis and landscape evolution. It represents the main source of inorganic nutrients for plant growth, and therefore the basis for life. A major interest in chemical alteration and physical denudation of rocks is also due to their potential to affect the local up to global cycle of elements.

Alpine and cryic environment show a high sensitivity to climate changes. Previous investigations in Alpine areas indicated that weathering, as well as and mineral formation and transformation processes, should theoretically be very fast at the beginning of soil formation. Understanding the processes on a small scale is of major importance. The answers to these queries can be then extended, as a basis for numerical modelling, to other proglacial areas dominated by acidic moraines.

The study of soil chronosequences is an important tool to derive weathering rates and the consequent formation or transformation of soil minerals. Weathering rates of young soils (age < 1.000 years) seem to be two to three orders of magnitude higher than in ‘old’ soils (approximately 10.000 years). However, very little is known on the speed of such processes.

CASE STUDY AND AIMS

The present PhD project investigated soils developing in a proglacial area within a 0-150 years time span. Selected case study is the Morteratsch proglacial forefield (Upper Engadine, Switzerland). Since the end of 1850s the Morteratsch glacier, like all Alpine glaciers, continuously retreated leaving fresh sediments to weathering (Mavris *et al*., 2010). Compared to other glaciers, however, its retreat was constant and not interrupted by readvancements (*i.e*., Damma glacier; Bernasconi *et al*., 2011).

The aim of this study is to understand soil formation processes involved in the first 150 yr of sediment exposure. The combination of pedology, (soil) mineralogy and water chemistry was the innovative, multidisciplinary approach proved to be successful in answering our research question.

RESULTS AND DISCUSSION

The morainic sediments derive from the abrasive action of the glacier on the granitoid bedrock (Lower Austroalpine Bernina Nappe). A progressively decrease in *p*H and grain size were measured with the increasing age of moraine exposure. As a consequence of exposure, pedogenesis was observed as continuously occurring (Fig. 1). Its development was more advanced on north-facing sites (Egli *et al.*, 2011).

The occurrence of biotite and epidote significantly decreased with time. Calcite, occasionally observed as disseminated veinlets in local rocks, was confirmed by mineralogical and water chemistry investigations, and it was quickly leached as a function of soil formation (Mavris *et al*., 2010).

The mineralogical study of the clay fraction (< 2 μm) gave important insights about chemical and structural transformations (Fig. 2; Mavris *et al*., 2011). Special emphasis was hereby given to the weathering of micas (biotite and muscovite). These phases were progressively (and quickly) transformed into hydroxy-interlayer vermiculite (HIV), vermiculite and smectite-like phases. The presence of the latter, widely accepted in literature as a proxy for soil formation, was confirmed to be time-dependent in Morteratsch.

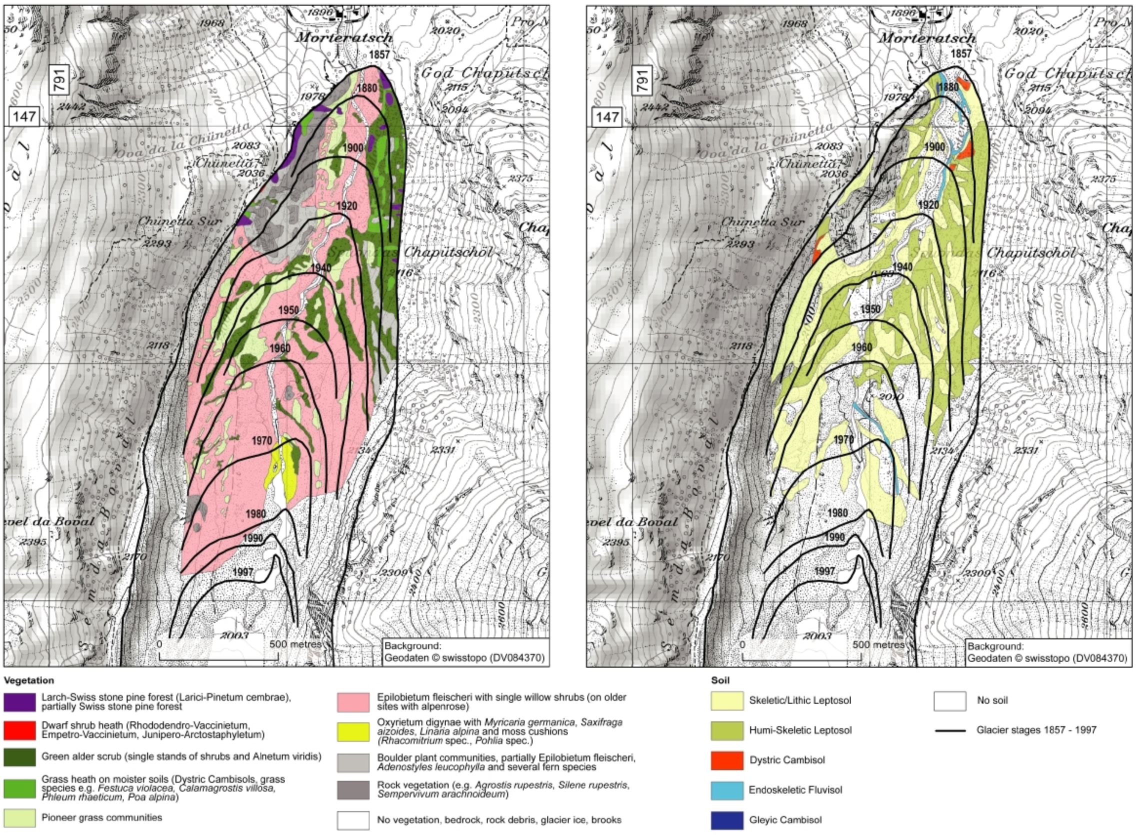

Fig. 1 - Digital maps of vegetation (left) and soil (right) of the proglacial area (Egli *et al*., 2011).

When specific phases did not show a remarkable weathering trend, the combined application of cathodoluminescence, Nomarski DIC microscopy and scanning electron microscope (SEM) was proved to be a helpful tool (Fig. 3). This is the first time that such a combined technique was applied to soil science and mineral weathering (Mavris *et al.* 2012).

Even notoriously resistant minerals (*i.e.*, quartz) underwent weathering steps at the bond scale, much before chemical leaching was involved. The same was observed for plagioclase, alkali feldspar and apatite, whose alteration patterns could be observed and described. Element mass balances of soil fine earth fraction (< 2 mm) showed no significant trend, confirming that mineral dissolution is at the very early stages (Mavris *et al*., 2012).

PERSPECTIVES

The study of mineral weathering processes in high Alpine areas is a complex subject due to the broad amount of variables involved in an open system, such as the soil. However, the combination of several techniques was proved to be a successful approach in decoding these processes, allowing to answer to the research question from different points of view. This multiple approach, quite innovative in the field of pedogenesis, opens new pathways for the study of several proglacial areas with granitoid bedrock and similar climatic settings.

With a broader statistical study, a more precise quantitative evaluation can be performed, from single mineral weathering to clay mineral formation, to elemental loss and finally to their bioavailability.

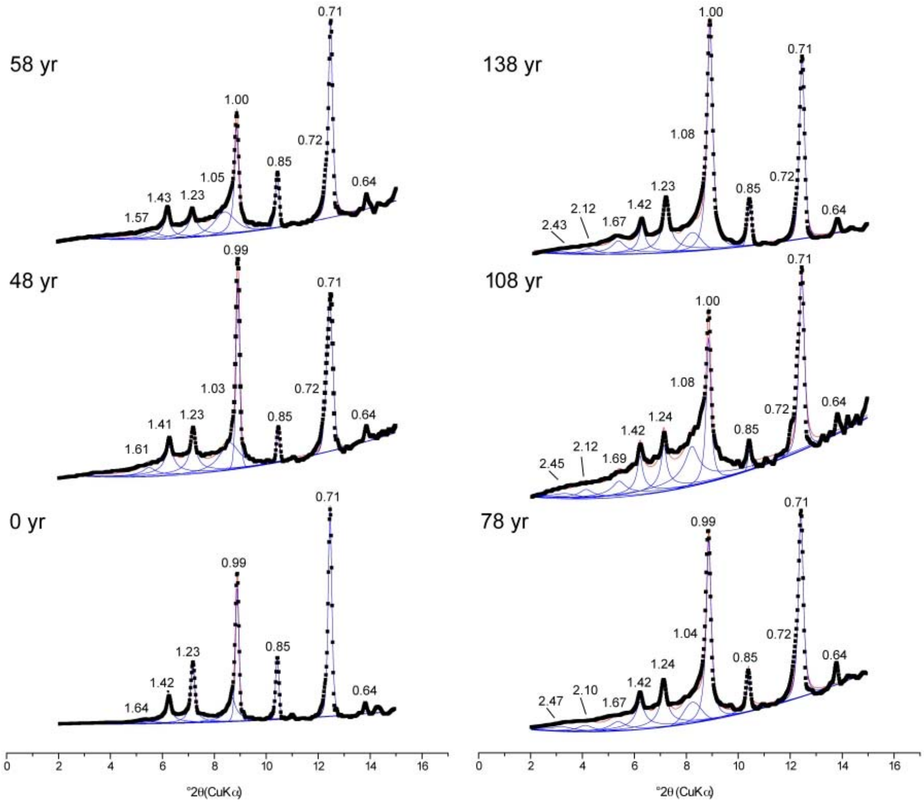

Fig. 2 - XRD patterns of the EG-solvated clay fraction from the selected topsoils along the chronosequence. Given are the measured values (squares), modelled elementary curves, and the modelled overall curve. Noteworthy, the increase of smectite (approx. 1.6 nm), vermiculite (approx. 1.4 nm), and hydrobiotite (approx. 2.4 and 1.2 nm) with increasing age. Biotite (approx. 1.0 nm) weathers as a function of time, as shown by the peak broadening (up to 1.08 nm) and the appearance of another basal reflection (approx. 2.1 nm). Actinolite-group member (0.85 nm) and plagioclase (0.64 nm) were also detected (Mavris *et al*., 2011).

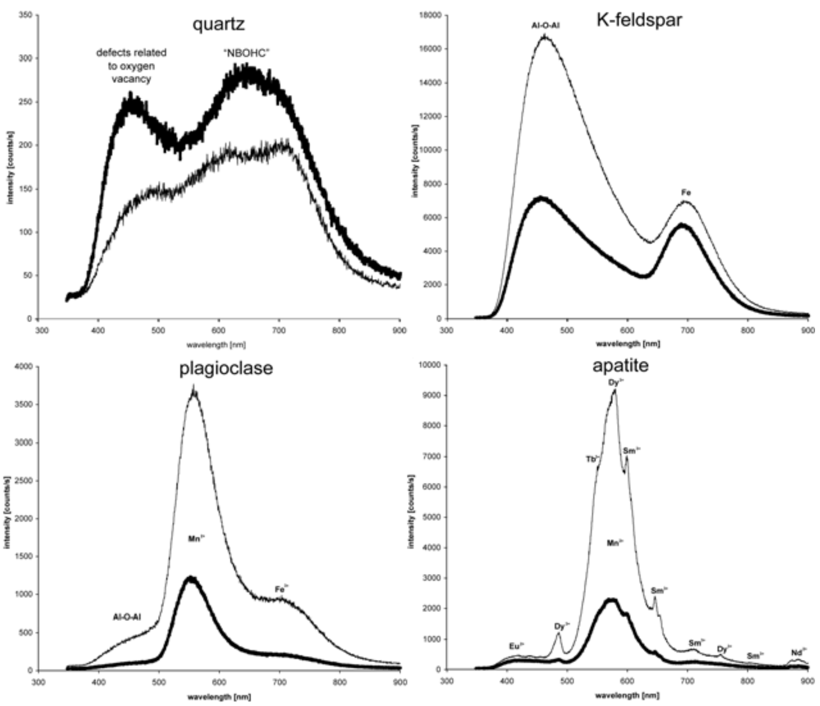

Fig. 3 - Cathodoluminescence emission spectra of apatite, alkali feldspar, plagioclase, and quartz. The bold line denotes the 140 yr topsoil and the thin line the parent material (Mavris *et al*., 2012).

ACKNOWLEDGEMENTS

The project was supported by the Swiss National Fundation for Science (SNFS) via the research grant n. 200021-117568. The research performed at the TU Bergakademie Freiberg (Germany) was funded by the SIMP fellowship 2009, awarded to the author during the SIMP General Meeting (Geoitalia 2009, Rimini, September 2009).

The author would like to thank all the scientific contributors, namely: Prof. Markus Egli and Prof. Wilfried Haeberli (Department of Geography, University of Zurich, Switzerland), Dr. Michael Plötze (ClayLab, ETH Zurich, Switzerland), Prof. Jens Götze (TU Bergakademie Freiberg, Germany), Prof. Joel D. Blum (Department of Geosciences, University of Michigan, Ann Arbor, USA), Prof. Aldo Mirabella and Daniele Giaccai (ISSDS, Florence, Italy), and Dr. Filippo Favilli (EURAC, Bolzano, Italy).

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