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SOIL MINERALOGY IN A RECENTLY EXPOSED HIGH ALPINE CHRONOSEQUENCE: INVESTIGATION WITH CATHODOLUMINESCENCE (CL) AND NOMARSKI DIC MICROSCOPY

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CLIMATE CHANGE AND LANDSCAPE ADAPTATION

Global warming and climate change are widely accepted as the main responsible of the melting of ice caps. With the glacial retreat, fresh sediments are exposed to open-air, and start weathering. This process triggers the transformation, through weathering and elemental loss, of sediments into soils (*i.e.*, Mavris *et al.*, 2010).

It is commonly considered that low temperatures, typical of cold regions, inhibit weathering mechanisms. Newly exposed sediments, derived from subglacial environment, are geochemically quite reactive and responsive. In this frame, the high availability of water has a double role. The high weathering rates observed in those settings are linked to proton activity typical for subglacial waters and to the leaching activity of large cations from the sediment minerals. There is no agreement concerning the weathering speed of the proglacial sediments. Anderson *et al.* (2000) stated that silicate weathering is not enhanced in proglacial areas, unless vegetation cover is established first. This implies the involvement of organic acids as strong proton source. Contrasting data have been provided by other authors, such as Hosein *et al.* (2004), Egli *et al.* (2003), and Wadham *et al.*, (2001), that suggested an intense chemical weathering as soon as the sediment is transferred from the subglacial (semi-closed system) to the proglacial (open system) environment.

Information about the weathering rates of primary minerals in early exposed sediments in cold environment are therefore lacking or very little and, thus, the datasets are rather poor.

The project "Initial stages of soil and clay mineral formation - Case study: Morteratsch proglacial area" aims to understand what is the weathering pattern of a granitoid morain when exposed to high Alpine climatic conditions, within a time span of 0-150 years. Ranging from pedological to geochemical approaches - but keeping mineralogy as key decoder - this project has achieved remarkable results in the field of soil formation as a proxy for climate change and its implications.

In general, the combined use of different analytical techniques can provide significant insights in the weathering of minerals. The combination of transmitted-light cathodoluminescence (CL) and Nomarski DIC microscopy is an example of this approach. In fact, it may provide significant insights on the chemistry and lattice structure of mineral phases (*i.e.* point defects, cationic changes, bonds, etc.).

Despite the fairly simple preparation of the samples - carbon coated thin sections - and the high amount of information obtainable by the combination of both techniques, their application is rarely documented (Götze & Siedel, 2004, 2007).

Luminescence is a common phenomenon in inorganic and organic compounds, resulting from an emission transition of anions, molecules, or a crystal from an excited electronic state to a ground or other state with lesser energy (Götze, 2009). CL is a transmitting microscopy luminescence technique that allows the collection of spectra, and it is, therefore, effective on transparent phases. CL has been applied in several fields (*e.g.*, Götze *et al.*, 2000; Lapuente *et al.*, 2000; Michalski *et al.*, 2002; Richter *et al.*, 2003; Götze & Siedel, 2004, 2007; Götze, 2009).

Nomarski DIC (DIC = differential interference contrast) microscopy is a modern technique applied to material science to visualise different phases and/or to image the surface relief of samples (see Note). It allows the observation of micromorphological features in natural materials, but it is widely used on metal alloys, as well. Its applications are mostly in the fields of metallurgy and petrography (*e.g.*: Pearce *et al.*, 1987; Pearce & Kolisnik, 1990; Keevil & Walker, 1992).

The aim of the investigation with CL and Nomarski DIC microscopy is to provide a comprehensive documentation of the soil mineralogy evolving across a recently exposed granitic till (time span 0-150 years). Structural arrangements and transformations were investigated to detect changes within the 150 yr old proglacial chronosequence.

As feasible case study, the Morteratsch proglacial area was selected (Fig. 1). The Morteratsch glacier is located in SE Switzerland and it is extending from the Bernina group in the N-S direction. Due to the absence of abrupt altitude stacks and the availability of a detailed isochrones map (Burga, 1999), the area feature ideal settings for environmental studies.

For the first time, samples from high Alpine soils were investigated with CL and Nomarski DIC microscopy. The same samples were later on investigated with SEM-EDX for elemental loss and eventual dissolution structures and patterns (ClayLab, ETH Zurich). This part, however, will not be discussed in this summary.

The results of this investigation were included in a peer-reviewed manuscript (see Note) that has been recently submitted.

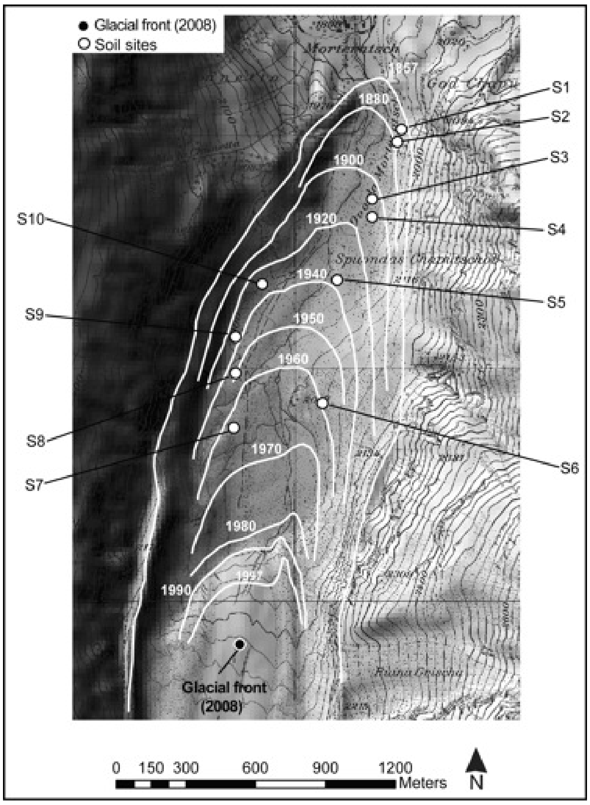

Fig. 1. Overview of the proglacial area, with the soil sampling sites and glacial isochrones. Modified after Mavris *et al.* (2010).

SUMMARY OF DISCUSSION AND CONCLUSIONS

Considering chemico-physical properties of mineral phases, the larger the cation, the weaker the bond to the crystal lattice (*i.e.* Ca-rich members). Freeze-thawing cycles represent a valid example of physical weathering agents, and their activity results in the weakening of crystal structures and elemental bonds. Due to the large cation-bond in their crystal lattices, tectosilicates are among the first phases undergoing elemental leaching (see Note).

CL and Nomarski DIC proved a diffused, incipient weakening along preferential surfaces. The investigated silicate-structured phases (*i.e.*, K-feldspar, plagioclase, epidote, quartz) showed a weakening in their lattice structures already after 140 yr. Also biotite weathers very quickly within the considered time span. In apatite it was possible to detect dramatic changes in the crystal chemistry. CL spectroscopy was a helpful tool to detect such nano-scale features (see Note).

RESEARCH PERSPECTIVES

The combined use of optical and spectroscopic analyses proved to be a useful approach in deciphering precise weathering patterns even at the atomic bond scale (crystal structures). CL and Nomarski DIC have a great potential in detecting and analyzing chemical, physical and mineral structural changes due to weathering also in soils.

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NOTE

Some of the carried out investigations and related results are discussed in "Weathering and mineralogical evolution in a high Alpine soil chronosequence: a combined approach using SEM-EDX, cathodoluminescence (CL) and Nomarski DIC microscopy" (C. Mavris, J. Götze, M. Plötze, W. Haeberli & M. Egli), recently submitted to *Sedimentary Geology*.

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