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Hidden paleosols under periglacial landforms at high elevation in the Alps (Stolenberg Plateau - NW Italy)

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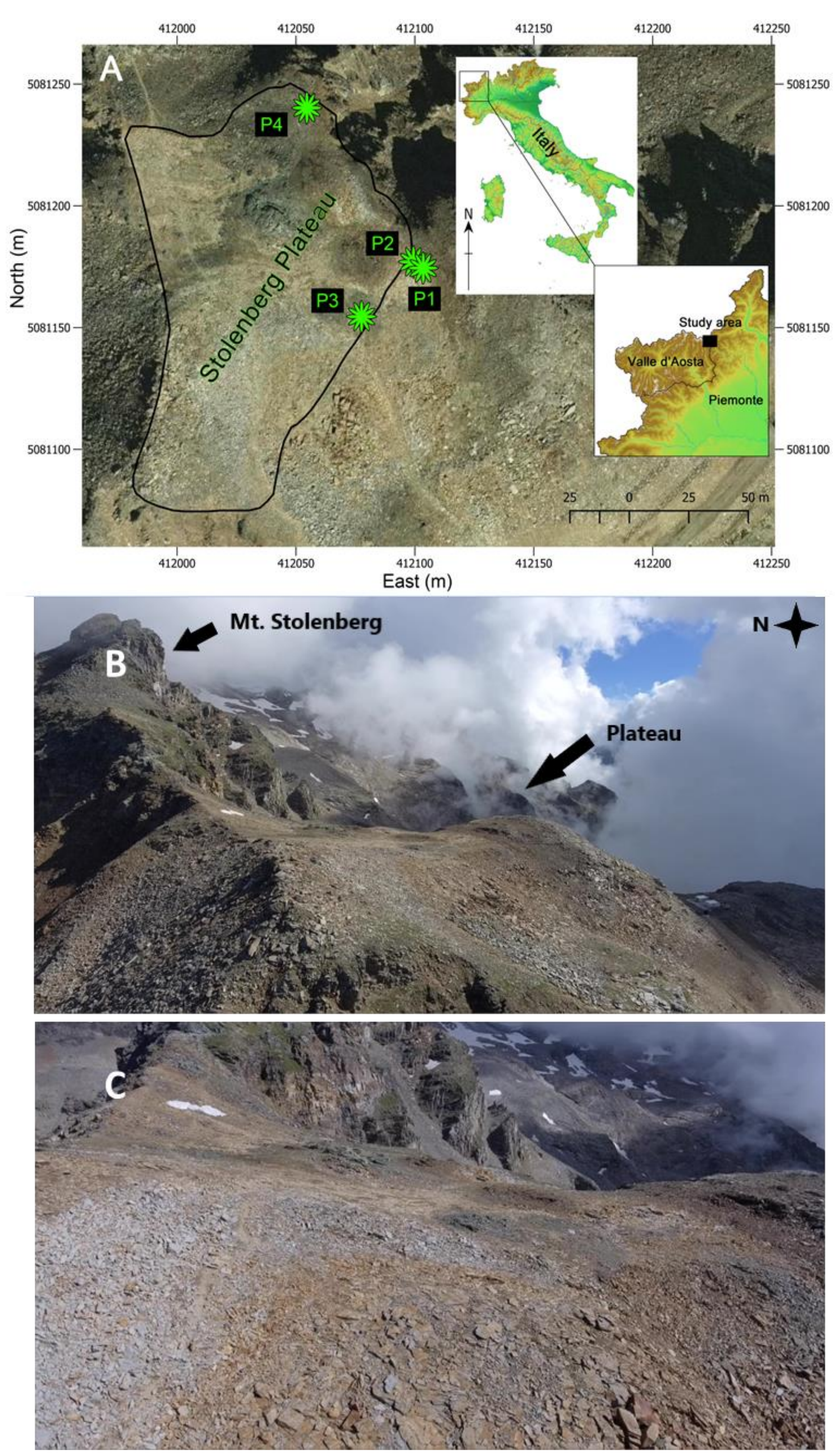
Introduction

In the framework of climate change research, mountain soils provide valuable paleo-environmental information, representing a powerful tool for paleoclimate reconstruction. However, reconstructing soil and landscape evolution in high mountain areas can be a difficult task because Pleistocene glaciations and erosion-related processes erased most of the pre-existing landforms and soils, leading to the formation of a complex mosaic of Quaternary sediments and soils of different ages.

The object of this study is the periglacial environment of the Stolenberg Plateau (LTER site Istituto Mosso), located along the border between Valsesia and Lys Valley, at the foot of the southern slope of the Monte Rosa Massif (Western Italian Alps) at an elevation around 3030 m a.s.l.. The plateau is entirely covered by a thick stone layer, organized in different periglacial features (e.g. blockfields, blockstreams, etc.), with or without patterned ground reorganization, while the plant cover reaches no more than 3-5% of the surface.



Coordinates	45°52'42.85"N - 7°51'59.55"E
Elevation	3030 m a.s.l.
Aspect	S-E
Climate	MAAT -2.4° C, mean annual snowfall ~ 800 cm, rain ~ 360 mm
Geology	Gneiss and mica-schists (Monte Rosa nappe, pennidic basement), metabasites (Zermatt-Saas ophiolitic unit)
Vegetation	Cover 3-5%: *Silene exscapa, Carex curvula, Salix herbacea, Festuca halleri, Poa alpina, Ranunculus glacialis, Leucanhtemopsis alpina, Cerastium uniflorum,*, etc.)
Landforms	Frost shattered rocks, blockfield, blockstream

Fig. 1. Location of the study area in the NW Italian Alps and overview of the study area: green forms indicate the location of the three soil profiles (P1, P2, P3) and the vegetated patch (P4); (B, C) views of the Plateau.

Despite the strong geomorphic activity characterizing this area, extremely well developed soils were observed under the periglacial landforms. In particular, below a surface reworked stone layer, thick (between 30 and 65 cm) and dark organic C-rich horizons were observed, with the presence of several cryoturbation features, such as inclusions of different materials and convolutions along the profile. Below these umbric horizons, cambic Bw ones were often developed but discontinuous. Soils were classified as Skeletic Umbrisol (Arenic, Turbic), according to IUSS Working Group WRB (2015). In contrast, below more stable surfaces covered by alpine grassland (Caricetum curvulae), the soils were Cambisols with a thin (10-15 cm deep) A horizon and a moderately developed Bw, showing weak signs of cryoturbation. Despite the lack of vegetation cover, below periglacial surface stone layers, the organic C stocks were surprisingly high (over 5 kg*m^{-2}), comparable to vegetated or even forest soils at lower elevation.

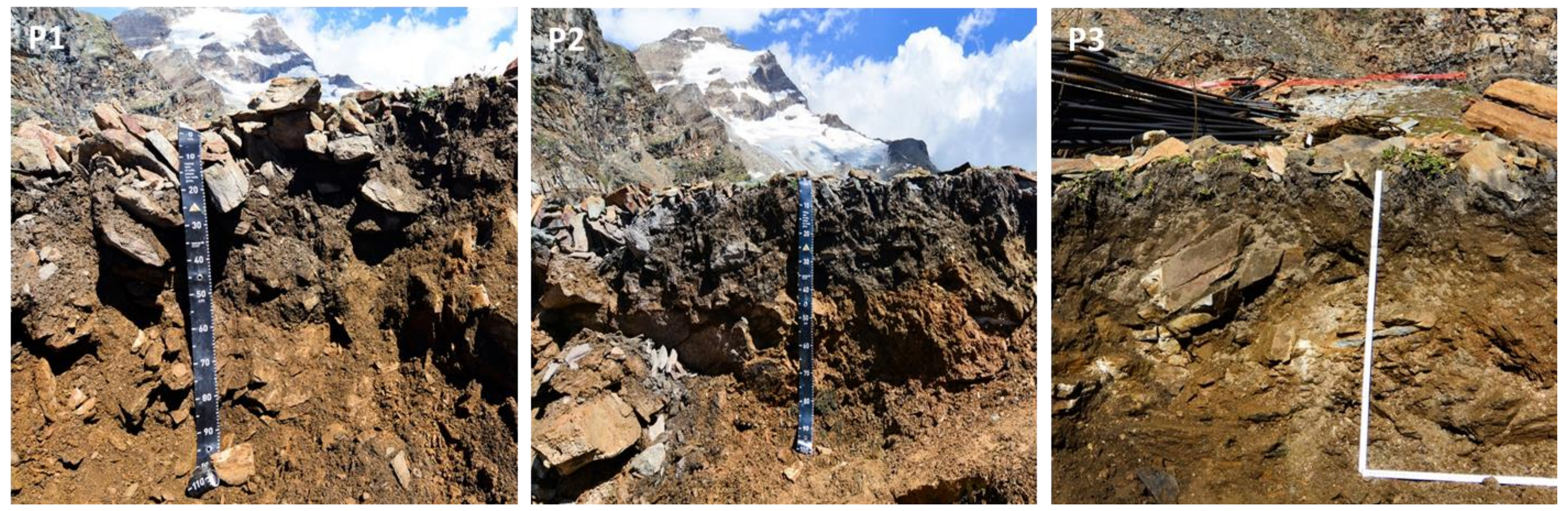


Fig. 2. Profiles P1, P2, P3

Methods

- Geophysical investigation: Electrical resistivity Tomography (ERT)
- Soil ^{14}C datings (AMS)
- Soil $\delta^{13}C$ (IRMS)

Results

Geophysical investigations (e.g. Electrical Resistivity Tomography, etc.) revealed that these soils ranged between ca. 30 and 90 cm in thickness (mean ~ 50 cm) and were widespread under the stony cover, involving a large part of the plateau surface. Greater depth were found under periglacial landforms, whereas less depth were found close to the rocky outcrops.

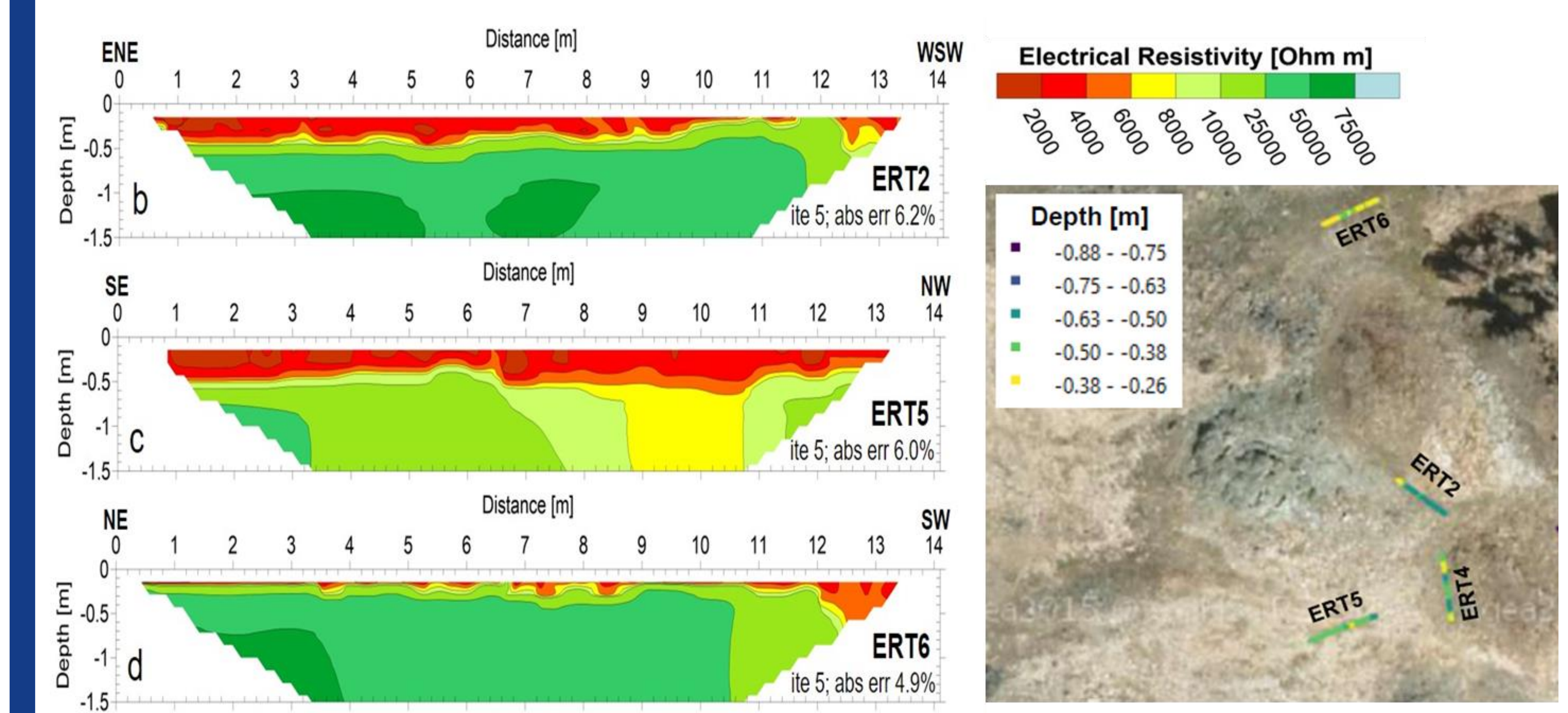


Fig. 2. Example of ERT section s: (b) ERT2; (c) ERT5; (d) ERT6 and their location on the Plateau.

Radiocarbon dating and soil $\delta^{13}C$ signatures indicated that these hidden soils were paleosols that recorded exclusively the main warming phases occurring since the end of LGM (~21 ka BP) until the beginning of Neoglacial (~5-4 ka BP). This finding suggests that the environmental conditions on the Plateau could have been suitable for alpine plant life and pedogenesis, already since the end of LGM.

Sample	Cal. Radiocarbon Age (yrs cal. BP)	$\delta^{13}C$ (‰)	Phase
P1-1	8782 – 8412 (92.1%)	-24.7	Holocene Climatic Optimum
P1-2	5735 – 5589 (95.4%)	-23.9	Holocene Climatic Optimum
P2-7	6506 – 6306 (95.4%)	-24.2	Holocene Climatic Optimum
P2-8	8561-8300 (92.1%)	-23.9	Holocene Climatic Optimum
P2-9	17866 – 17352 (95.4%)	-24.5	Early Lateglacial Ice Decay
P3-2	20533 – 19973 (95.4%)	-23.8	Early Lateglacial Ice Decay
P3-5	13306 – 13076 (95.4%)	-23.6	Bølling-Allerød
P4	4360 – 4090 (88.5%)	-22.7	Neoglacial

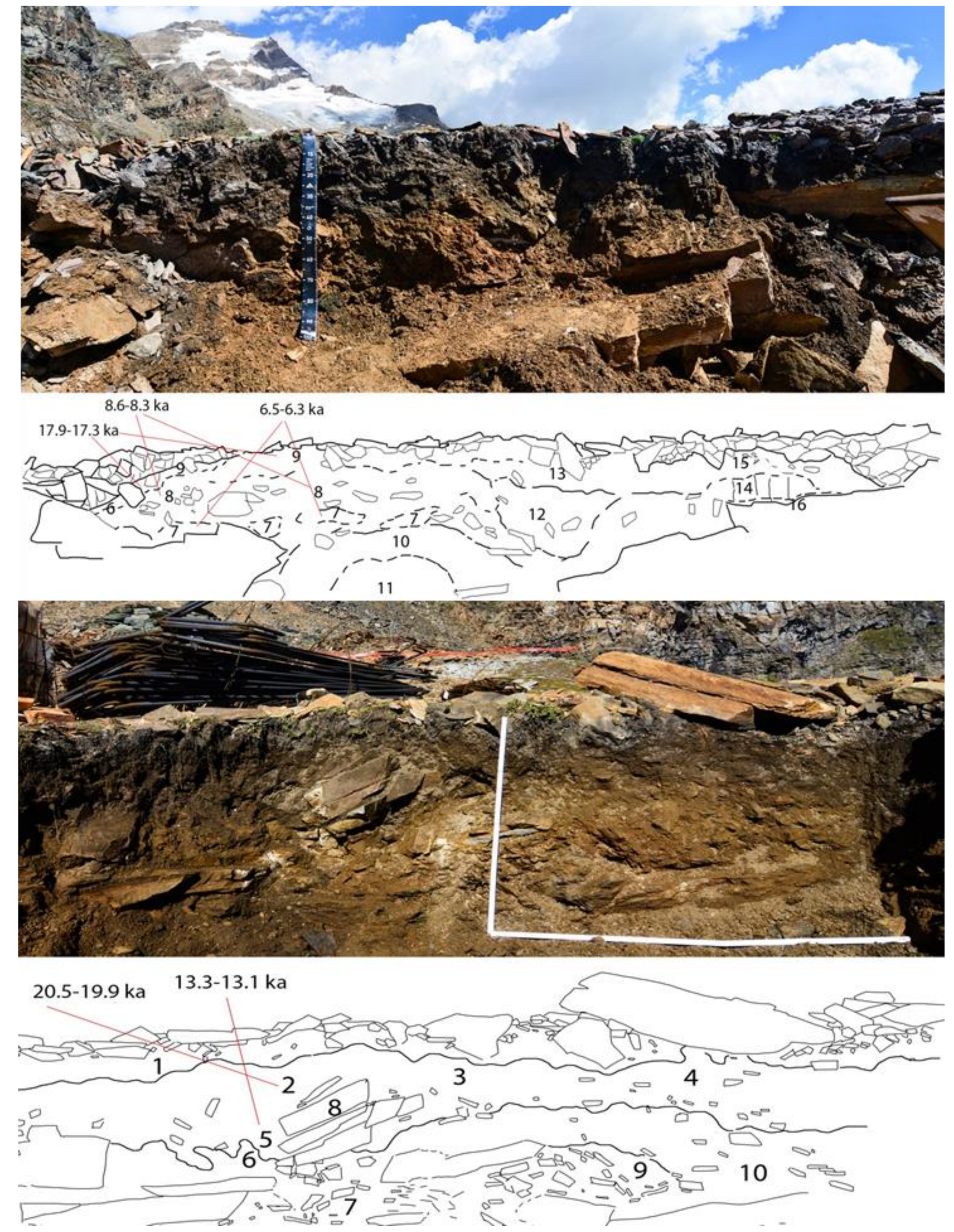


Fig. 4. Soil profile P2 and P3, with the corresponding scheme (below) reporting sampling points (number), the horizon limits (lines therein) and the age of soil samples (cal. ka BP).

Conclusion

Our results, together with the high carbon stocks of these paleosols, the presence of strong geomorphological evidences (i.e., periglacial features such as blockstreams/blockfields), as well as the overall specific morphology, aspect and position, indicate that these hidden soils can be considered a direct evidence of a Lateglacial Alpine Nunatak. Thus, the Stolenberg Plateau recorded the transition between Pleistocene and Holocene, representing therefore a unique natural and historical archive for unravelling the post-LGM history of the high-elevation landscape of the European Alps.

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