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Pleistocene permafrost features in soils in the South-western Italian Alps

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Because of extensive Pleistocenic glaciations which erased most of the previously existing soils, slope steepness and climatic conditions favoring soil erosion, most soils observed on the Alps (and in other mid-latitude mountain ranges) developed only during the Holocene. However, in few sites, particularly in the outermost sections of the Alpine range, Pleistocene glaciers covered only small and scattered surfaces because of the low altitude reached in the basins, and ancient soils could be preserved for long periods of time on particularly stable surfaces. In some cases, these soils retain good memories of past periglacial activity.
We described and sampled soils on stable surfaces in the Upper Tanaro valley, Ligurian Alps (Southwestern Piemonte, Italy). The sampling sites were between 600 to 1600 m of altitude, under present day lower montane Castanea sativa/Ostrya carpinifolia forests, montane Fagus sylvatica and Pinus uncinata forests or montane heath/grazed grassland, on different quartzitic substrata.
The surface morphology often showed strongly developed, fossil periglacial patterned ground forms, such as coarse stone circles on flat surfaces, or stone stripes on steeper slopes. The stone circles could be up to 5 m wide, while the sorted stripes could be as wide as 12-15 m.
A strong lateral cryogenic textural sorting characterized the fine fraction too, with sand dominating close to the stone rims of the patterned ground features and silt and clay the central parts.
The surface 60-120 cm of the soils were podzolized during the Holocene; as a result of the textural lateral sorting, the thickness of the podzolic E and Bs horizons varied widely across the patterns. The lower boundary of the Holocene Podzols was abrupt, and corresponded with dense layers with thick coarse laminar structure and illuvial silt accumulation (Cjj horizons). Dense Cjj diapiric inclusions were sometimes preserved in the central parts of the patterns. Where cover beds were developed, more superimposed podzol cycles were observed: the deeper podzols, included in the dense layer, were strongly cryoturbated and showed convoluted horizons and buried organic horizons.
The presence of the dense Cjj horizons also influenced surface soil hydrology, which in turn influenced the expression of E and Bs horizons, in addition to textural lateral variability.
In conclusion, surface morphology and soil properties evidence the presence of permafrost during cold Pleistocene phases, with an active layer 60-120 cm thick, associated with a particularly strong cryoturbation. However, all the permafrost features were not necessarily formed during the same periods, and dating of different materials would be necessary in order to obtain precise paleoenvironmental reconstructions of cold Quaternary phases in the Alps.