Permafrost conditions in the Mediterranean region since the Last Glaciation

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Cold-climate geomorphological processes today in the Mediterranean region are only distributed in the highest mountain environments. However, climate conditions prevailing during the Late Pleistocene and Holocene have conditioned significant spatio-temporal variations of the glacial and periglacial domain in these mountains, including permafrost. In this communication we examine permafrost conditions in the Mediterranean region taking into account five periods: Last Glaciation, deglaciation, Holocene, Little Ice Age (LIA) and present-day. The distribution of currently inactive permafrost-derived landforms and sedimentary records indicates that the permafrost elevation during the Last Glaciation was ca. 1000 m lower than present. Permafrost was also widespread in non-glaciated slopes above the snowline forming rock glaciers and block streams, as well as in relatively flat summit areas where meter-sized stone circles developed. As in most areas of the Northern Hemisphere, the deglaciation in the Mediterranean region started ca. 19-20 ka. The exposed terrain by retreating glaciers was affected by paraglacial dynamics and intense periglacial processes, mostly associated with permafrost conditions. Many rock glaciers, protalus lobes and block streams formed in these recently deglaciated environments, becoming gradually inactive as temperatures rose during the Bølling-Allerød. Following the Younger Dryas glacial advance, the last massive deglaciation in Mediterranean mountains took place during the Early Holocene together with a progressive shift of the periglacial belt to higher elevations. It is unlikely that widespread permafrost have existed in Mediterranean mountains during the Holocene, except in the highest massifs exceeding 2500-3000 m. The colder climate prevailing during the LIA favoured a minor glacial advance and the spatial expansion of permafrost, with the development of new protalus lobes and rock glaciers in the highest massifs. Finally, the warming started during the second half of the 19th century has led to glacial retreat and/or complete metlingmelting, increased paraglacial activity, migration of periglacial processes to the highest lands and degradation of alpine permafrost along with geoecological changes.