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# Solifluction activity in the present periglacial belt of Sierra Nevada during the last 8 ky BP

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Solifluction records in Sierra Nevada (Andalusia, Spain) reveal a succession of environmental changes during the last millennia in this massif mostly related to Holocene climate dynamics. Geomorphological processes in Sierra Nevada react sensitively to small changes in temperature or moisture regimes, showing the proximity of these processes to their climate boundaries and the small climate range necessary to carry environmental changes in the summits of this massif.

Solifluction dynamics in Sierra Nevada is influenced by a complex interaction between environmental factors (slope, vegetation cover, texture) and climate parameters (ground thermal regime, length and thickness of the snow cover, water supply). Interdependant feed-back mechanisms among all these variables make difficult to understand the key factors involved in present and past solifluction processes, although monitoring control performed on lobes with different emplacements suggest today's favourable environmental conditions for solifluction displacements. Water availability controls both vegetation cover and slope processes. In fact, currently water supply determines the grass cover in gentle valley floors, but it is also decisive to provide water for the small solifluction displacements detected during the monitored period. Thermal conditions also play a decisive role to activate solifluction or soil formation with similar moisture regimes.

The very weak activity pattern of hundreds of solifluction lobes suggests that they must have developed in other more favourable climate conditions. We studied more than 30 sedimentological profiles from solifluction lobes in San Juan and Rio Seco valleys, which reveal an alternation of solifluction/edaphic cycles during the Holocene, with nine different geomorphic phases in the highest western cirques of Sierra Nevada. In San Juan valley, north exposed, there are several generations of solifluction lobes covering the last 8-9 ky BP, while in the southern Rio Seco cirque lobes developed more recently, during the last 2 ky BP.
The most intense solifluction periods in Sierra Nevada are similar to those reported in mid and high latitudes by Veit (1988) and Repelewska-Pekalowa & Pekala (1993) with active phases during the event 8.2 (S9: ?-8 ky BP), the Neoglacial period (S6: 3.6-3.4 ky BP) and the LIA (S2 and S1: 850-700 and 400-150 years BP). Other relative solifluction advances with minor slope activity occurred between 7.6-7 (S8), 5-4 (S7), 3-2.8 (S5), 2.5-2.3 (S4), 1.8-1.6 ky BP (S3). Edaphic processes evolve preferably during warm periods; according to water availability in the ground, soils are more or less developed: dry periods mostly favour regosol formation whereas wet phases promote well structured histosols. Regosols only developed between 3.4-3.2 ky BP (E6) and 700-400 years BP (E2). By contrast, several periods during the Holocene were suitable for histosols formation: 8-7.6 (E9), 7-5 (E8), 4-3.6 (E7), 2.8-2.5 (E5), 2.3-1.8 ky BP (E4), 1600-850 (E2) and 150 years BP onwards (E1).

In relation to climate variability, we deduce that colder and/or wetter periods are favourable for solifluction movements, whereas warm phases induce extension of grass cover and soil formation in valley floors above 2500 m in Sierra Nevada. Cold and/or wet periods postpone snow melting, prolong the existence of the seasonal frost layer for several weeks, increase late-lying snow patches and lengthen the water runoff period. These conditions also shorten the vegetation growing period, implying slopes with scarcer vegetation cover and enhanced geomorphic processes. The combination of larger water supply with a frozen layer underneath would be favourable in late spring and early summer to trigger active solifluction processes in this massif. On the other hand, warmer periods with similar moisture conditions would induce soil formation.

The seasonality of the climate variability is certainly decisive to understand the geomorphological processes dominating in the summits of Sierra Nevada. Solifluction is enhanced during periods with increased precipitation in winter and early spring that imply more snow and a longer water runoff in late spring and early summer. Otherwise, edaphic processes are more effective when significant precipitations (either in winter or summer) are combined with warm temperatures in late spring and summer. Higher temperatures than present do not seem to promote solifluction unless being accompanied by very increased precipitations in winter and early spring.