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# Reflections on modern cold-climate landforms and their relation to climate

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The identification of fossil cold-climate landforms is important from a palaeoclimatic point of view. Attempts at reconstructing past cold-climate environments are based mostly on the utilization of certain fossil periglacial and glacial landforms and sedimentary structures, such as ice and sand wedge casts, thermal cracks, fragipan horizons, the systematic occurrence of cryoturbation or solifluction, evidence of strong ice segregation in sediments, fossil rock glaciers, moraines, tills and glacial valleys.
Many attempts of palaeoenvironmental reconstruction are based on biological evidence, which tend to reflect summer conditions, rather than winter conditions. In this respect the use of cold-climate landform in palaeoenvironmental reconstructions is potentially important, as many of such landforms often depend on the presence of ice, which tend to reflect winter conditions rather than summer conditions.
A number of difficulties, however, immediately arise. As an example, climatic changes resulting in the areal disappearance of ice-rich permafrost beyond the margins of Quaternary ice sheets and glaciers tend to blur or confuse the evidence of previously distinct periglacial and glacial features. Traces of their morphology and relict surface and subsurface structures may, however, still be detected in certain regions. Such fossil forms, especially when dated, can then be used as important indicators of a past climate in the region considered.
While geomorphological features such as glacial striae and U-shaped valleys often are good evidence for the former existence of warm-based glaciers, there are few reliable indicators of cold-based glaciers and past frost action in a periglacial environment. For periglacial environments, attention in the past often concentrated upon the identification of relict features of assumed frost-action significance, like asymmetric valleys, ice wedge casts and blockfields. Unfortunately, some of the features assumed to be the result of frost-action also occur under non-periglacial conditions.
In general terms, the rates and processes of many geomorphological processes depend on meteorology, climate, hydrology, geology and topography. Using landforms produced by such processes thus requires knowledge on quantitative relationships between the rate of geomorphological process and these variables.
Recent progress in geomorphological field methodology has now added to the knowledge on timing and environmental conditions at which many periglacial and glacial landforms develop. Laboratory simulations have also provided insight into the mechanisms involved in some key periglacial processes. Such recent advances now enable us to link certain geomorphological process rates with their controlling environmental factors, eventually permitting the construction of a physically based predictive model of landform development as well as improved palaeoenvironmental reconstructions.
There are, however, still a number of important, but unsolved, problems which hinder detailed palaeoenvironmental reconstructions based on cold-climate landforms. Some of these relate to modern meteorological conditions. As an example, many periglacial processes are controlled by ground temperatures and the amount of available moisture. There is, however, no simple relation between air temperature and ground temperature, as the latter is highly influenced by snow cover timing and –thickness. The snow cover development in its turn depends on the amount of solid precipitation, but not exclusively. Redistribution by wind is also of major importance, so

ground temperature conditions are usually the result of complex relations between air temperature, precipitation and wind. In the case of attempts of palaeoenvironmental reconstructions based on the presence of a certain relict cold-climate landform, a number of possible combinations of these variables exist. Another partly unsolved problem relates to the magnitude of past temperature lapse rates. Usually, past temperature conditions are calculated on the basis of modern lapse rates and present snowlines in alpine regions. This sort of analysis tend to masks the considerably variability of modern lapse rates which occur in modern cold-climate mountain regions. Moreover, there is no guarantee that lapse rates were similar during past climatic periods to those observed today. During periods of colder climate, strong temperature inversions were probably more common than they are today, both in high-relief areas and in lowlands.