Geophysical Research Abstracts
Vol. 20, EGU2018-17998, 2018
EGU General Assembly 2018

36Cl exposure dating of moraines and rock glaciers in the Northern Alps - implications for Younger Dryas equilibrium line altitudes and European precipitation patterns.

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Although glaciers are among the most valuable paleoclimatic information sources, until recently the stratigraphic position of old moraines in the Northern Alps of Austria remained enigmatic. As a consequence we decided to try dating some moraines and rock glaciers in strategic positions to get a first impression of the stabilization age of these landforms. We moved to the Northern Alps of Tyrol between the Lech valley to the West and the Kaisergebirge in the East. Various limestones and dolostones form the most widespread bedrock. Lateglacial moraines and relict rock glaciers at differing altitudes are abundant and have been mapped in detail during the past few years.

Surface exposure dating with 36Cl showed that rock glaciers and moraines with post-depositional rock glacier overprint started their activity during the late Younger Dryas and remained active until the early Holocene [1]. Moraines clearly beyond the Little Ice Age glacier extent indicate glacier activity until the early Holocene [2]. This implies that a well developed and almost omnipresent set of moraines further down at the upper end of most valleys and in front of the cirques may represent the Younger Dryas Egesen Stadial. More recent surface exposure dating (36Cl) of such a set of moraines confirms this assumption.

As a consequence, equilibrium line altitudes (ELA) of the Egesen maximum advance were at altitudes between 1900 m in more sheltered areas and around 1700 m or even lower in those areas which are most exposed to the North and Northwest. ELA lowering was in the range of at least 400 m against the Little Ice Age and 500 m or more relative to average 20th century conditions.

This implies that at least during the earlier phase of the Younger Dryas annual precipitation sums along the Northern fringe of the Alps were similar to modern amounts or likely even higher. The precipitation gradient from the Northern Alps to the dry interior valleys was more pronounced than today and also more pronounced than previously assumed [3]. This points to a Younger Dryas circulation pattern dominated by meridional airflow and an increased importance of northwesterly circulation types for precipitation in the Northern Alps.

[1] Moran, A. P.; Ivy-Ochs, S.; Vockenhuber, Ch.; Kerschner, H. (2016): Rock glacier development in the Northern Calcareous Alps at the Pleistocene-Holocene Boundary. Geomorphology 273, 178-188; http://dx.doi.org/10.1016/j.geomorph.2016.08.017

[2] Moran, A. P.; Ivy-Ochs, S.; Vockenhuber, Ch.; Kerschner, H. (2016): First 36Cl exposure ages from a moraine in the Northern Calcareous Alps. Eiszeitalter & Gegenwart / Quaternary Science Journal 65(2), 145-155; DOI 10.3285/eg.65.2.03; http://quaternary-science.publiss.net/issues/79/articles/921

[3] Kerschner, H. and S. Ivy-Ochs (2007):Palaeoclimate from glaciers: Examples from the Eastern Alps during the Alpine Lateglacial and early Holocene. Global and Planetary Change 60(1-2), 58-71, doi: 10.1016/j.gloplacha.2006.07.034.