Permafrost-glacier relationships in an unstable sediment complex (Tsarmine, Arolla Valley, Western Swiss Alps)

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In Switzerland, numerous small lateral glaciers have deposited large amounts of loose sediments on steep slopes where torrents and debris flows are very common. These sediment complexes are often located in permafrost areas where debris flow hazards may grow in case of permafrost degradation. The lateral glacial cirque of Tsarmine located in the right side of the Arolla Valley (Western Swiss Alps) was investigated. Altitudes range from 2400 to 3000 m a.s.l. Geomorphology is dominated by a debris covered glacier and its morainic complex. The glacier variations have built a huge morainic bastion that dominates the bottom valley situated 1000 metres below. In the northern part of the glacier forefield, several push moraines located upstream a debris rock glacier show geometric modifications of frozen sediments due to Little Ice Age (LIA) glacier advance. In the southern part of the margin, a small proglacial lake is present above the frontal moraine dam. By using geoelectrical soundings and mapping, ground surface thermal measurements and geomorphological mapping, the study aimed to map and characterize the ice and permafrost distribution in the area and to evidence the relationships between the debris covered glacier, the debris rock glacier and the push-moraines in the glacier forefield. The possible presence of ice within the morainic bastion below the lake was particularly investigated. 6 DC resistivity soundings and 5 DC resistivity mapping lines were carried out in summer 2003. Ten mini data-loggers measured the ground surface temperature every two hours from September 2003 to September 2004. DC resistivity prospecting revealed that a large part of the glacier forefield contains ground ice. Two different types of terrains can be distinguished. On the upper part, resistivities ranging from 400 to 700 kΩm, outcrops of ice and other geomorphological evidences attest the presence of the buried Tsarmine glacier on a wide area covered with debris. Downstream, resistivities lower than 400 kΩm point to the existence of massive ice that could either be dead ice from Tsarmine glacier LIA position or older frozen sediments recovered by the Tsarmine glacier during the LIA. The area of the lake, and especially the frontal moraine dam that limits it, is free of ice (specific resistivities <7 kΩm). On the rock glacier, resistivities range from 10 to 100 kΩm, what is typical of permafrost bodies. Geomorphological evidences (steep front, absence of vegetation, numerous ridges and furrows) indicate that the rock glacier is probably still active. The presence of numerous push-moraines with resistivities higher than in the rock glacier shows that the rock glacier was disturbed and geometrically modified by the LIA advance of the Tsarmine glacier and that glacier ice was probably incorporated in the frozen sediments. In conclusion, large amounts of sediments are still frozen, but the area occupied by the lake is free of ice. This could have implication in terms of potential geomorphological hazards. The presence of the lake in the unfrozen morainic bastion may be a factor of debris flows triggering. Geophysical investigations combining seismic and geoelectricity are necessary in order to determine the structure and stability of the moraine dam.

Rock glacier “speed-up” throughout European Alps - a climatic signal?

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key words: rock glacier, speed-up, Alps, climate change, dynamics

At the PACE21 meeting in Longyearbyen, Svalbard in September 2004 an intense discussion on spatio-temporal variations in rock glacier movement and corresponding reasons began. Thus, an initiative started compiling an inventory of rock glaciers which show increased surface velocities from all over the European Alps in order to compare their characteristics and detail probable controls. Acceleration of rock glacier movement was observed in all parts of the entire Alpine arc from the Hautes Alpes, France, via Valais and Grisons in Switzerland, to the Austrian provinces

of Carinthia and Tyrol. For the quantification of kinematics and its variations, different methods (terrestrial geodetic survey, GPS and digital photogrammetry) were applied covering mostly periods between 1975 and 2004. The monitored horizontal surface velocities depicted accelerations of different magnitudes (5 to 350%), mostly starting in the 1990s. Additionally, distinct vertical changes were observed in some areas. Main objectives of the cooperation are first of all the differentiation of topographic (e.g., slope) versus climatic controls and thus the separation of local versus regional influences on rock glacier dynamics. Then, focus is given on the investigation of both regional and temporal differences in the amount of acceleration in order to define controlling parameters. Since variations in rock glacier movement are mostly discussed in the context of temperature fluctuations, horizontal and vertical velocities are correlated with Bottom Temperature of the winter Snow cover (BTS), Mean Annual Air Temperature (MAAT), etc. Finally, a uniform monitoring design for rock glaciers is demanded in order to set up an alpine rock glacier monitoring system and use these sensitive landforms as valuable environmental indicators.

Rock glacier acceleration in the Turtmann valley (Swiss Alps) - A discussion on probable controls

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Temporal variations in mountain permafrost creep are analysed within a regional study on rock glacier kinematics. On all 16 active rock glaciers on the east side of the Turtmann valley an acceleration of horizontal velocities is ascertained, partially accompanied by distinct vertical changes. This signal of rock glacier speed-up was measured by digital photogrammetry for the period 1993 to 2001 and was confirmed by terrestrial geodetic survey in the years 2001 to 2004. Different topographic parameters (altitude, aspect, length of the rock glaciers) as well as climatic parameters (Mean Annual Air Temperature (MAAT), Bottom temperature of the winter snow cover (BTS), etc.) are correlated with the surface velocities, in order to separate local and regional controls. Since temperature is discussed to be the major parameter influencing rock glacier creep, the link between surface velocities and temperature developments is focused and is investigated on two different scales. The general increase in temperature in the Alps within the last century and especially since the 1990s fits well with the observed rock glacier acceleration. A different signal is revealed on the local scale, where BTS-values of the years 2001 to 2004 are correlated with horizontal surface velocities and depict a good coincidence. In areas with high velocities the BTS-values are clearly below -3°C and inactive parts show temperatures close to 0°C. Thus, the link of 'warming' and consequently accelerating rock glaciers, like it is shown in other studies, is not confirmed by our data. In general, the results do not deny the assumption that permafrost creep variations are correlated with climatic fluctuations. But, the relation between temperature and rock glacier dynamics seems to be much more complex and can not easily be described in simple correlations.

Thermal and physico-chemical characteristics of springs issuing from rock glaciers in the Ortles-Cevedale Region (Italian Alps)

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The south and eastern sectors of the Ortles-Cevedale Massif (Peio, Rabbi and Ultimo valley, Italian Alps) are characterized by widespread and spectacular periglacial and permafrost-related landforms, like pattern grounds, ploughing boulders, solifluction lobes and block streams. Rock glaciers are very well developed, with lobate and tongue-shape landforms in some cases more than 1.5 km in length. The lower limit of active/inactive rock glaciers ranges between 2400 and 2900 m a.s.l. Thermal and physico-chemical characteristics of springs issuing at the base of the frontal slope of some rock glaciers have been examined. Temperatures and electrical conductivities of 16 rock glacier-related springs have been checked several times during field work in the Summer 2004 using an hand-held conductivity-meter.