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Evolution of supraglacial brittle and ductile structures and drainage systems at a partly debris-covered alpine valley glacier during a 15 yr period

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Based on five glacier stages (1998, 2003, 2006, 2009 and 2012) covering a period of 15 years, supraglacial crevasses and other structures as well as the drainage system at the tongue of Pasterze Glacier were mapped and interpreted. Pasterze Glacier is the largest glacier (c.16.5 km2) of the entire Eastern European Alps located in the Hohe Tauern Range, Central Austria at 47°05'N and 12°43'E. The glacier is in a stage of rapid recession and downwasting. The tongue is connected with the firn area by a mighty ice fall. 75% of the c.4.5 km long glacier tongue is covered by a supraglacial debris cover affecting glacier surface morphology related to differential ablation influencing the glacier's stress and strain field. High resolution orthoimagery and digital elevation models/DEM (both data sets with 20-50 cm grid resolution) were analysed. A structure glaciological mapping key was applied to discern relevant brittle (normal faults, thrust faults, strike-slip faults commonly associated with and en èchelon structures, and ice disintegration expressed as normal faults) and ductile structures (band ogives). Additionally, a geometric mapping key was used differentiating between chevron, splaying, transverse, and longitudinal crevasses as well as complex crevasse fields related to ice disintegration (commonly circular and semi-circular collapse features). The drainage system was mapped differentiating between supraglacial channels and moulins. Observations made during annual glacier measurement campaigns were additionally considered. Results indicate that the lower half of the glacier tongue was characterised during the observation period by ice disintegration (with semi-circular collapse features since 2003 near the glacier terminus and since 2009 in the central part) and thrust faults with downslope convexity (steady upslope migration of first occurrence during the observation period). In general, the crevasse density increased towards the left (NE), less debris covered margin. Since 2009 the number of crevasses (particularly normal faults) increased at the continuously debris-covered part of the tongue related to differential ablation. In contrast, a reduction of en èchelon structures since 2006 was observed related to decreasing glacier movement rates. The total length of mapped brittle structures increased by trend with 38.3 km in 1998, 49.4 km in 2003, 53.3 km in 2006, 64.2 km in 2009, and 56.9 km in 2012. The length of mapped supraglacial channels was 6.2 km in 1998, 11.7 km in 2003, 10.9 km in 2006, 18.1 km in 2009, and 12.1 km in 2012. Based on the mapped band ogives (in some years mappable >3km below the ice fall) three different flow units were detected related to different source areas of the glacier. However, an increase in the spatial extent of the supraglacial debris cover hampered ogive mapping for the more recent stages. DEM differencing revealed a strong correlation between high surface differences and spatial distribution of brittle structures. A large number of brittle structures can therefore be described as being increasingly independent from glacier motion. These structures can be rather seen as adjustment to high relief. Therefore, we can conclude that the tongue of Pasterze Glacier is currently slowly turning into a large dead ice body characterized by movement cessation and ice disintegration and related normal fractures.