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The active control of bedrock geology on landslide development in Storfjorden area (Norway)

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The western coast of Norway is particularly vulnerable to active rockslide development due to the recent post-glacial uplift and the deep incision of the fjords created by glacial activity, leading to extremely steep fjord sides. The purpose of this work was to determine the likelihood of landslide activity in the Storfjorden area. This is an area particularly historically vulnerable to landslide development and also an area which is relatively highly populated relative to the potential landslide development. This area is 360 km2 and comprises Sunnylyvsfjorden, Geirangerfjorden, Norddalsfjorden, Tafjorden and the southern part of Storfjorden. We have examined over 40 potential landslide sites within this area. The objective with this study was to determine if a series of particular geological factors were important for landslide development in order to construct a predictive geometrical model for the development of landslides within the area. Regional foliation mapping has shown a series of complex recumbent isoclinal folds in the host granodioritic to dioritic gneisses, where the dip of the foliation is between 20-40˚. The fjord system in Storfjorden consists of several east-west and several north-south trending fjords. Therefore, the orientation of the foliation with respect to the fjord can result in geometrically different types of landslide geometry and hazard. The potentially active areas can be divided into two geometrical groups. These are i) toppling and ii) sliding. Detailed structural fieldwork has demonstrated that the toppling geometry make up the smallest volumes of potential landslides and in specific areas: where the foliation dips in the opposite direction to the fjord. Rockslides display the largest potential landslide volumes and occur specifically where the pre-existing structural geometries are favourable. i.e. rock slides occur where the foliation dips between 20-35˚ *towards the fjord*. This allows for the construction of a predictive spatial-geometrical model for the development of large rockslides in the

Storfjorden area. Several critical factors must be present for the development of large potential rockslides: 1) the orientation of the foliation with respect to the fjord is just one of these. 2) A Basal Shear Plane (BSP) at the base of the potentially moving block is critical. This can be a relatively planar structure but more often displays a complex step geometry due to the complexity of the fjord-dipping foliation. 3) The presence of a fault breccia on the BSP is also critical. These non-cohesive fault rocks demonstrate that the detached block is actually moving and at the same time provides a lubricating base for the block movement. 4) The presence of exfoliation, due to the depressurisation due to the removal of ice is an important factor in weakening the BSP. 5) A steep extensional fracture at the back of the moving block – a 'back crack'- is necessary to detach the block. Where these factors are not presence, there is generally no evidence for activity in the hangingwall block (hangingwall disintegration by fracturing, kinematic evidence, breccia development). 6) The presence of a transfer fault with a strike parallel to the movement direction of the block is important in order to detach the block from the mountainside. We find that many back cracks are localised on and reactivate many pre-existing geological lineaments. Small fold development within the foliation also appears to have a large affect on the development and movement rockslides. We present a geometrical model for the development and predicted location of the largest potential rockslides in the Storfjorden area.