Rock fall susceptibility assessment using structural geological indicators for detaching processes such as sliding or toppling

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Introduction

A structural geological assessment of cliffs in terms of rockfall susceptibility is expensive and time-consuming particulary in remote areas (exposed cliffs) where it may even be impossible. Hence it is important to develop methods and strategies that can be used to extrapolate the acquired knowledge from representative sub-regions to the whole study area.

As part of a project initiated by the Carinthian Government (Project "Naturgefahren Kärnten II - Methoden für ein effizientes Risikomanagement"), a GIS method was develop which can be used for regional, qualitative determination of the susceptibility of cliffs in carbonatic sedimentary rock, regarding two potential initial detachment processes of rock fall: sliding and/or toppling.

Geology of study area:

* carbonatic sedimentary rocks (bedded limestone and dolomite)
* main dip direction of bedding planes: Southeast-Southwest
* main dip angles of bedding planes: 5 - 60 degrees

Methodology

During the development of the GIS method, it was found that not all of the mapped structural geologic parameters are equally suitable for a comprehensive regionalisation. Subsequently, only those parameters were included in the assessment which experts deemed to be representative in terms of parameter homogeneity/heterogeneity and thus applicable to the entire survey region:

* bedding thickness
* tectonic lineaments
* orientation of discontinuities
* type of rock mass structure

Regions of homogeneity/heterogeneity differ with regard to parameter values, as well as parameter uncertainties and scattering.

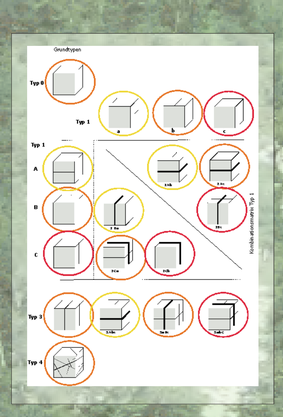
At first the cliffs were categorised in terms of potential form and size of rock blocks by overlaying various parameter maps. In the next step, the relative orientation of the rock mass structure and their variations towards slope aspect and slope inclination were considered within a region of homogeneity. This allowed an accurate estimate of the possible maximum dip angle (or apparent dip angle) of a joint set over a wide area. It also permitted those areas to be pointed out in which process-initialising sliding and/or toppling might be possible along one or several joint sets.

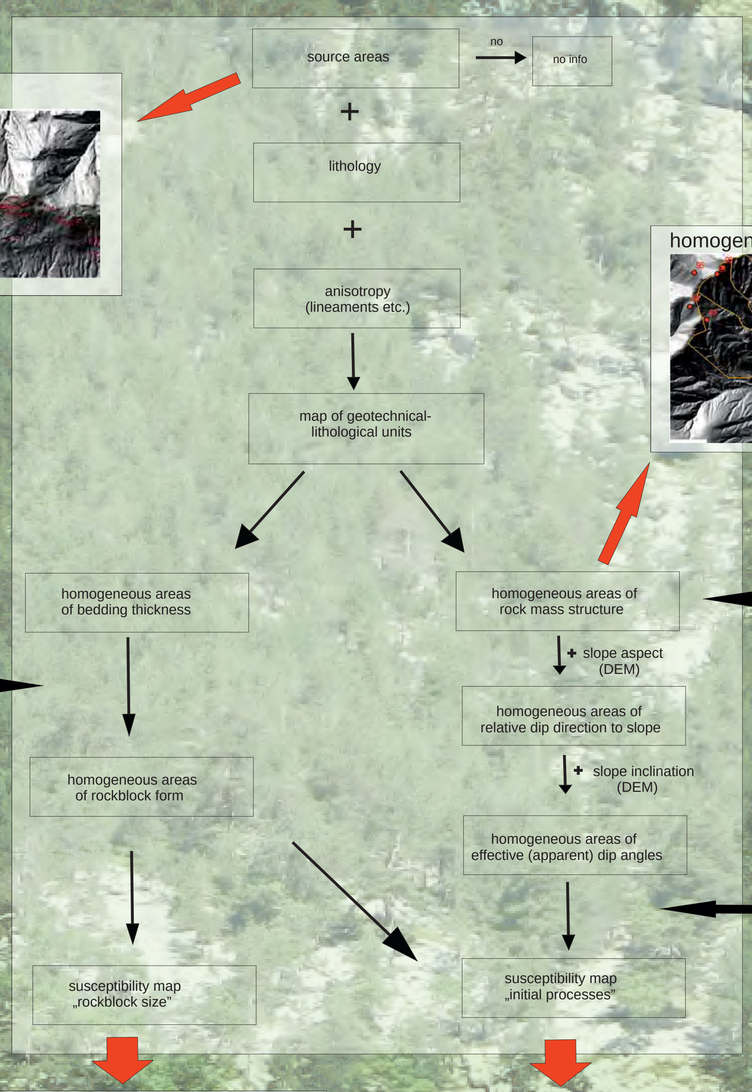
Methods

Processes

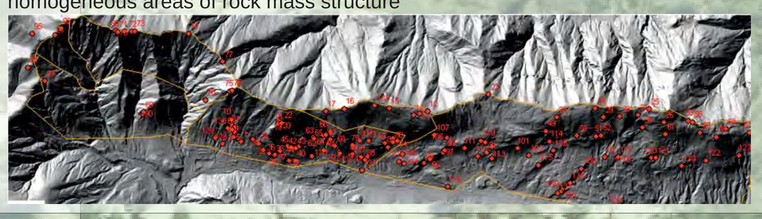
Hazard

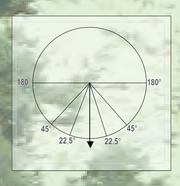
source areas > 45° slope angle





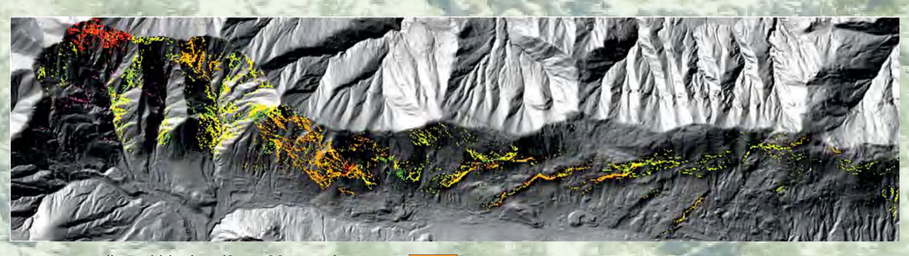
homogeneous areas of rock mass structure



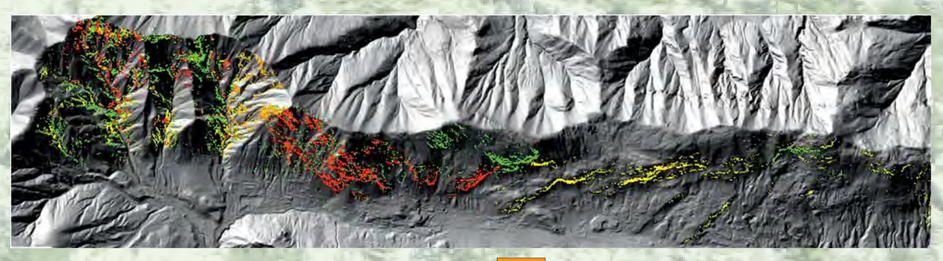


Intervall des effektiven Einfallswinkels	Code Disposition Gleiten
0-30	1
30-35	2
35-45	3
45-90	4

Intervall des effektiven Einfallswinkels	Code Disposition Kippen
-30 (-5)	1
-5-5	2
5-20	3
20-45	4



- small rockblocks (0 - 20 cm in diameter) (EN ISO 14689-1)
- medium rockblocks (20 - 60 cm in diameter) (EN ISO 14689-1)
- large rockblocks (60 - 200 cm in diameter) (EN ISO 14689-1)
- very large rockblocks (> 200 cm in diameter) (EN ISO 14689-1)



- low susceptibility towards both initial processes
- high susceptibility towards „toppling" and low susceptibility towards „sliding"
- high susceptibility towards both initial processes
- high susceptibility towards „sliding" and low susceptibility towards „toppling"

Results

- When applying the developed methodology, the mapping can be reduced to only very few parameters (increased efficiency).
- The step-wise processing in form of a hierarchical procedure guarantees reproducibility and transparency when assessing product quality.
- The resulting susceptibility maps can be used for planning more detailed investigations at slope extent (data validity domain = indication maps).

Plausibility check

high susceptibility towards „sliding", low susceptibility towards „toppling"; tendency to form large to very large rockblocks

high susceptibility towards „toppling", low susceptibility towards „sliding"; tendency to form large rockblocks

Conclusions/Further activities

Comparing the outcomes of this method to the acquired field data has proven the approach to be successful when it comes to assessing the cliffs in carbonate rocks in terms of form and size, but also in terms of varying susceptibilities of rock fall-inducing processes (sliding/toppling), in order to establish a relative rating (e.g. quite likely, quite unlikely). The latter is essential to classify the cliffs according to varying process susceptibilities and thus put special focus on future investigations and/or modelling approaches (e.g. delineation of rock fall runout zones) of particulary susceptible regions. The approach, however, still needs to undergo further testing in terms of usability and efficiency in other carbonatic regions and - if necessary - will be adapted to fit other area settings such as in areas of crystalline rocks.

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