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Rockfall frequency in different geomorphological conditions

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The knowledge of the rockfall frequency in a cliff is needed for quantitative rockfall hazard assessment (Hantz et al., 2016). It can be estimated from historical data bases (e.g. Hantz et al., 2003) or from diachronic comparison of digital cliff topographic models (e.g. Dewez et al. 2013, Guerin et al. 2014). An empirical approach is proposed to be used when historical data bases are not significant (not enough events) and diachronic digital models not available.

1 VOLUME-FREQUENCY RELATION AND EROSION RATE

It is well recognised that the frequency of the rockfalls occurring in a rock wall decreases when the volume considered increases. It has appeared that the best law for describing this decrease is a power law, which can be applied either to the temporal frequency or to the spatial-temporal frequency (number of rockfalls per year and per m\textsuperscript{2} of cliff):

\[ F = A V^{-B} \]

(1)

Where \( F \) is the frequency of rockfalls bigger than \( V \), \( A \) is the frequency of rockfalls bigger than 1 m\textsuperscript{3}, and \( B \) is the scaling exponent, whose value is usually between 0.4 and 0.8. Note that the relation holds up to a finite value of \( V \) because there is a maximal rockfall volume (\( V_{\text{max}} \)) which depends on the size of the cliff. This maximal volume is rarely observed because its return period is usually larger than the observation period. Integrating the volume \( V \) from 0 to \( V_{\text{max}} \) (assuming \( B < 1 \)) gives the volumetric retreat rate of the cliff (Hantz et al., 2003):

\[ W = V_{\text{max}}^{(1-B)} A / (1-B) \]

(2)

If the spatio-temporal frequency is used (\( F_s = A_s V^{-B} \)), Equation (2) gives the linear retreat rate (or erosion rate) of the cliff (\( E = V_{\text{max}}^{(1-B)} A_s / (1-B) \)). As this rate includes the biggest possible volumes, it is usually higher than the rate obtained by summing the observed volumes or measuring the retreat of the cliff crest. \( V_{\text{max}} \) is difficult to estimate, but one can note that if its uncertainty is a factor 10, the uncertainty on the erosion rate is lower (factor 10\textsuperscript{1-B}).

The retreat rate given by Equation (2) includes very large rockfalls (flow like movements) as well as smaller rockfalls (with negligible interaction between individual particles). As the methods used to simulate the propagation of these phenomena are different, it is relevant to calculate different volumetric retreat rates using this relation (Hantz et al., 2003):

\[ W = [V_2^{(1-B)} - V_1^{(1-B)}] AB / (1-B) \]

(3)

Where \( W \) is the volumetric retreat rate due to rockfalls whose volume is between \( V_1 \) and \( V_2 \). A method to estimate the frequency of impacts due to small rockfalls is given by Hantz et al. (2016).

2 ESTIMATING THE ROCKFALL FREQUENCY PARAMETERS

Three parameters are necessary to characterize the rockfall activity of a cliff: \( V_{\text{max}}, B \) and \( E \) or \( A_s \). \( V_{\text{max}} \) and \( B \) are geometrical parameters. It is reasonable to assume they depend essentially of the rock mass structure (notably discontinuities extension and spacing). \( A_s \) (or \( E \)) is a temporal parameter (year\textsuperscript{-1}) which reflects the activity of the processes leading to rockfalls. The processes leading to landslides (of all types) have been listed by Popescu (1994). They can be divided in 3 groups: geomorphological processes, physical and chemical processes and human processes. Effendiantz et al. (2004) have listed the processes leading to failure in rock walls. The more relevant ones have to be considered for estimating the erosion rate.

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CONCLUSION

Orders of magnitude have been proposed for the rockfall frequency parameters according to the rock mass properties and geomorphological context.

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