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Self-similar distribution of the cumulative number of potential landslides volumes

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Any mass located above sea level, or above a given base level, can be considered erodible, but it can take several 100 M years to reach a flat topography (peneplanation). Gravitational processes such as landslides produce part of the short term erosive budget from large scale to small scale. Based on that principle, a sliding surface can be considered as a local base level, a Sloping Local Base Level (SLBL). A SLBL can be defined using invariant points such as rivers incising the bedrock. This limiting surface can be assumed as a potential basal sliding surface above which rocks are considered erodible within a short period of time (say 10,000 years). The erodible volume varies with the stream order chosen to define the SLBL. At the valley scale, the SLBL defines deep-seated landslides affecting steep and deep valleys. At the scale of a slope, several orders of SLBL can be found, ranging from the entire slope to small spurs. The study of gneissic slopes in the Mattertal valley (Switzerland) shows that the cumulative number of potential unstable volumes (V) that exists in the slope (N(V)), defined by the SLBL using different stream orders, follows a fractal distribution ($N(V) \sim V^{-b}$) with an exponent (b) of –0.67. This result is close to the exponent values obtained for released landslides ranging from -0.19 to –0.72 with an average of -0.49.

The ratio of the volume of two recent rockfalls (Randa 30 M m^3 in 1991 and Meidji $\sim$70'000 m^3 in 2001) is about 430, but the ratio of their frequencies deduced from the power law is equal to approximately 60. The power law indicates that the erosion budget is strongly controlled by large rockfalls like Randa. Only a part of the unstable volumes defined by the SLBL is released by landsliding, because only this part is subject to high enough shear stress. For the Randa rockfall, the SLBL results are in agreement with published finite element simulations of the failure mechanism. The above results indicate that the volume distribution of released landsides and relief characteristics are linked through a power law of potential available erodible volume. Such a result may be useful for hazard assessment, sediment budget calculations, and the understanding of the evolution of mountain landscapes.