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What if the power-law model did not apply for the prediction of very large rockfall events?

J. Rohmer and T. Dewez
BRGM, Natural Risks Division, Orléans, FRANCE (j.rohmer@brgm.fr)

Extreme events are of primary importance for risk management in a variety of natural phenomena, and more particularly for landslides and rockfalls, because they might be associated with huge losses. Numerous research works have addressed this problem based on the same paradigm: if events exhibit the same statistical properties across a broad range of sizes, the probability of extreme events can be evaluated by extrapolating the frequency-size distribution. Considering landslides' areas or rockfalls' volumes, the frequency distribution has been found to be heavy-tailed and the well-known power law distribution has been proposed to model it. Yet, the vision of very large extreme event (catastrophic) frequency being an extrapolation of the power laws fitted on small and intermediate events has been challenged in various contexts, in particular by Sornette and co-authors, who proposed viewing such catastrophic events as "outliers" from the power-law model, i.e. they deviate by an abnormal large distance from the extrapolated prediction.

In this study, we address such an issue considering a rockfall inventory, containing >8500 events spanning 8 orders of magnitudes of volume and collated from 2.5 years of high-accuracy repeated terrestrial laser scanning (TLS) surveys on a coastal chalk cliff in Normandy (France). This inventory contains a particularly large event of 70,949 m3 which occurred some time between February 1 and 7 April 2008. It is the second largest cliff failure reported in Normandy, and is larger than those collated in historical cliff failure inventories across various geological and geomorphological coastal settings. Is this event an outlier of the power-law volume-frequency distribution ? And if so, why?

This largest event recorded appears to stand out of the rest of the sample. We use it to revisit the techniques to fit power-law distribution with robust techniques (robust weighted maximum likelihood estimator), rarely used in rockfall studies, and presenting the appealing feature to be less sensitive to the presence of outliers by assigning a weight within [0 ; 1] to each observation according to its representativeness. Through a bootstrap-based technique, we demonstrate the statistical significance (with p-value <1 %, i.e. not arising by chance) of the low weight assigned to the largest rockfall event i.e. of the deviation from the fractal set of the smaller events.

Excluding gross volumetric error on our observation since we used a high-accuracy TLS, we discuss possible mechanisms and their implications for prediction, focusing on two main issues:
1. normal faults bounding the largest rockfall and along which the rupture occurred, which may suggest the hypothesis of a "characteristic" rockfall, i.e. presenting a characteristic scale of the same order of the fault length, as suggested for earthquakes;
2. possible log-periodic signature that decorates the pure power law and linked with the concept of Discrete Scale Invariance. This concept means that scale invariance is kept, but only for specific scales organized in a discrete hierarchy and with some fixed preferred scaling ratio. Such scaling ratio may itself be linked to pre-existing fracture networks.