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Rockfall frequency and influence of meteorological factors on a limestone cliff of the urban area of Grenoble.

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The spatial temporal frequency of rockfall events helps to quantify diffuse rockfall hazard. The influence of meteorological factors can also be studied in order to better know the failure triggering factors, and to predict dangerous periods of the year. Detection and dating of some hundreds of rockfalls has been carried out for the Saint Eynard cliff, which towers above a residential area of the town of Grenoble (French Alps), and which consists of a thinly bedded limestone cliff. The rockfalls have been detected by a diachronic comparison of digital models of the cliff, obtained from annual terrestrial laser scanning. They have been dated by means of a continuous photographic and seismic survey of the cliff. Meteorological data are given by local temperature and rain stations. These data allowed to study the influence of meteorological factors in the failure process.

Six hundreds rockfalls (volume 0.005m3 to 1500m3) have been dated by periods of 2 to 11 weeks. The average frequency of the detected rockfalls for the 18 months of survey is 1.0 rockfall per day. The winter periods (with freeze-thaw cycles) clearly show a higher rockfall frequency, up to 1.9 rockfall per day for the most active winter periods. Summer periods show a lower rockfall frequency, between 0.1 and 0.5 rockfall per day. The frequency is close to 0.5 for periods with more rainfall.

126 rockfalls were dated with a precision of 10 min to several hours. For these rockfalls, the average frequency is 0.010 rockfall/h. The frequency is 0.015 rockfall/h for the freezing days (days with negative minimal temperature), 0.029 rockfall/h for the days without freeze but following a freezing day, 0.011 rockfall/h for the days with a rainfall and 0.002 rockfall/h for the other days.

Rainfall and freeze-thaw events have also been determined hourly. A rainfall event begins with the beginning of a rainfall, and ends at the beginning of the next 24 hours period without rain. The 24h period has been chosen considering the water transit in the forested ledge upon the cliff. A freeze-thaw event is defined from the air temperature at the average altitude of the cliff (900 m), which permits to calculate the freezing potential (FP): The FP at the time t is the sum of the difference between freezing point of water (0°C) and the air temperature for a time interval beginning when the temperature becomes negative and ending at the time t. Negative temperatures give rise to positive FP, and positive temperatures decrease the FP. A freeze thaw event ends when FP=0. The rockfall frequency is 0.022 rockfall/h during rain events, and 0.019 rockfall/h during freeze-thaw events.

These results show that both freeze-thaw and rainfall have a significant influence on rockfall triggering. Moreover it appears that the rockfall frequency is higher the days following a freezing day than the freezing days themselves, suggesting that failure is due mainly to the thermal dilatation of ice during thawing periods, rather than to ice formation.