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Extracting tectonic information from cosmogenic exposure ages along bedrock scarps using synthetic and natural data

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Cosmogenic surface exposure dating is a powerful tool for reconstructing long term slip histories on active faults and extracting earthquake recurrence intervals (e.g. Benedetti et al., GRL, v.29, 2002). Extensional faults are particularly amenable to this type of study because they commonly produce a striated bedrock scarp, exhumed by faulting, that can be directly dated. Bedrock scarps in limestone can be sampled to obtain the concentration of cosmogenic 36Cl, produced primarily through interactions of cosmic ray secondary neutrons and muons with Ca within the scarp limestone. To first order the production rate decreases exponentially with depth beneath the ground surface. Because each normal-faulting earthquake uplifts a new portion of the scarp above the surface, the 36Cl concentration along the scarp is the sum of that 36Cl produced below the surface prior to the earthquake and that accumulated above the surface after the earthquake. For a scarp being seismically exhumed, the characteristic profile is therefore a series of exponentials with discontinuities marking the timing of each earthquake. The number of events, their timing and the magnitude of the associated slip strongly influence the shape of 36Cl profile.

Existing methods for extracting paleo-earthquakes from these data are based on a forward modelling approach and have shown that slip events $\geq$0.5m ($\geq$ Magnitude 6.0) are well resolved by fully sampling the height of the exposed bedrock scarp. A forward model for 36Cl accumulation generates 36Cl concentration versus fault height for different potential fault slip histories, which is then compared with the measured 36Cl concentrations. The best fit scenario(s) are then ranked using the Aikake Information Criterion (AIC), which is sensitive to the goodness of fit as well as the number of parameters included in the model. A key feature of published results using this approach is that slip events of several meters have, in several cases, been inferred that are too large given the dimensions and intraplate tectonic setting of the studied normal faults. In contrast, in this study, we transform the 36Cl concentration versus height data into a linear form. For a given set of fault slip events, event timings are determined using least squares inversion of the linearised data. By searching all possible combinations of slip event size (ranging from the sampling interval to the total scarp height), and using a range of different statistical measures for the goodness of fit, we rank the best fit scenario(s). By applying this approach to synthetic 36Cl profiles, generated using a numerical fault growth model, we are able to show that the AIC strongly favours inversions with a small number of large slip events, while other statistical measures may be used to extract more detailed information about the true slip history (which for the synthetic data is known). We use the conclusions drawn from our analysis of the synthetic data to guide our inversion of published real 36Cl concentration data to determine whether the inferred »1m slip events might have an alternative explanation.