Geophysical Research Abstracts, Vol. 9, 05030, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-05030

Incremental growth of normal faults: insights from a laser-equipped analog experiment

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We conduct a laser-equipped analog experiment that allows monitoring quasi-continuously the growth process of a dense population of normal faults, in homogeneous conditions. Willing to bring insights on the way major slip events - earthquakes-repeat on faults to make them grow, we measure with great precision the incremental slip and length changes that the analog faults sustain as they grow. The analog faults are found to share common features with the natural ones, which the measurements allow to describe in detail. In particular, the faults develop and maintain over their growth slip profiles that are generally triangular and asymmetric. They grow through alternating phases of rapid lateral lengthening with little slip accumulation, and phases of long lasting slip accumulation with no or little lengthening. The mode of earthquake repeat is thus expected to be different depending on which growth phase a fault is going through, with characteristic earthquakes only possible during those phases when the fault length keeps constant. The incremental slip is found to be highly variable in both space (along the faults) and time. Slip rates on faults are thus as variable. In particular, short- and long-term slip rates are markedly different. We also infer that slip measurements at local spots of fault traces do not contain any clear information on the earthquake repeat mode. Finally, while the fault growth process is highly heterogeneous when considered at the scale of a few slip events, it appears amazingly homogeneous and self-similar at a longer time scale. This results likely from a feedback between stress heterogeneities and slip development. This also suggests that the long-term faulting process is primarily insensitive to the short-term heterogeneities that are rapidly smoothed or redistributed. We propose a new conceptual scenario of fault growth integrating the above observations.