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Laboratory and field studies of rock fault dynamic deformation laws and their application to far-field block motion triggering

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The possibility of triggering large earthquakes and fluctuations in seismicity, volcanic eruptions, and other dynamic events by tidal deformations, remote earthquakes and powerful underground explosions has long been speculated about. However, it has only emerged as a significant scientific research topic in the last decade and as such, is one of the Earth science's new frontiers. This emergence was promoted by the Landers earthquake (28.06.1992, M=7.3), which was followed immediately by dramatically increased seismicity rates at distances of more than 1250 km. Since 1992 additional examples of dynamic triggering have been documented, suggesting it is a common and important phenomenon. Although it is widely accepted that the transient, oscillatory seismic waves were the causative triggering agent, the physical mechanisms involved remain significant topics of research.

We study the dynamic rheologic response of rock discontinuities in model and field tests during the dynamic loading. We apply the new seismic technique, which is based on the registration of dynamic parameters of seismic waves in the vicinity of a fault or a fracture and the analysis of amplitude ratio and dominant periods of waves of different types interacting with the fault *in situ*. We use seismic data on underground explosions in a wide yield range – from several grams to 150 kilotons of TNT. It allows us to estimate the normal and shear stiffnesses of a discontinuity. Stifnesses of various discontinuities from artificial cracks to large fault zones are estimated for a wide range of deformation wave intensities. Average normal and shear stiffnesses decrease with the increase of fault length (L) proportionally to $L^{-0.4}$. It is shown that for all types of discontinuities the non-linear type of the rheologic relation is observed down to the

strains of about $\sim 10^{-9}$ (10^{-3} microstrain).

The non-linear deformation properties of rock discontinuities and their effect on accumulation of residual deformations is analyzed. It is shown that the accumulation of interblock deformations at a stressed contact under low-intensity dynamic disturbances, which is not allowed by the Coulomb's criterion, is the direct consequence of the non-linear "stress-strain" diagram. The effect of gradual increase of contact's stiffness during repeating cycles of loading and unloading can lead to the fading of the process. It means that the threshold of the effective vibration action on a fault zone can be reached only by excitations, noticeably exceeding the intensity of background seismic noise. During large cumulative displacements contact stiffness starts to decrease due to the decrease of the running contact strength, which results in the increase of the deformation rate and, as a consequence, in the dynamic instability. Parameters are found that control realization of different deformation regimes – from gradual accumulation of deformation to a dynamic failure.

We demonstrate experimentally that dynamic pulses can trigger long-term slow motions along a preliminarily stressed fault. Interblock displacement accumulated during this slow motion can, at certain conditions, noticeably exceed the value of residual deformation that originates just after the action of a dynamic pulse. This effect may be of a great significance in formulation of the basic laws of fault zones evolution. This work was supported by RFBR grants 04-05-65027 and 05-05-64588.