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VIII ВСЕРОССИЙСКАЯ НАУЧНО-ПРАКТИЧЕСКАЯ КОНФЕРЕНЦИЯ С МЕЖДУНАРОДНЫМ УЧАСТИЕМ, ПОСВЯЩЕННАЯ 50-ЛЕТИЮ ОСНОВАНИЯ ИНСТИТУТА ХИМИИ НЕФТИ

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DIFFERENT FAULT SLIP MODES - GOVERNING, EVOLUTION AND TRANSFORMATION

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The work presents a brief summary of fundamental results obtained in IDG RAS in investigating the mechanics of sliding along faults and fractures. Some of these results had been obtained in teamworks and discussions with the group of scientists and specialists headed by S.G.Psakhie.

The methodological base of activities in this direction was to divide the problem into the structural and mechanical constituents, and the main task was to elaborate a phenomenological model of the phenomenon [1].

The structural constituent was constructed on the base of in situ investigations of regularities of localizing slip events in space and time, and geological and tectonic conditions of their emergence. The results of geological description of exhumed fault segments, the data on deep drilling in fault zones, the detailed investigations of locations of seismic sources, spotted with high accuracy, all these results assert an extremely high degree of localization of coseismic displacements.

Conditions of emergence and evolution of different fault deformation modes testify probable macro-structural differences of fault segments, at which different slip modes do realize. The degree of localization of surface manifestations is noticeably higher in the segments of the Earth's crust where "normal" earthquakes occur. Fault splitting, expansion of zones of dynamic influence, maximal values of the fractal dimension of crack system are specific for the zones of slow slip events.

At the meso-scale the highest sliding velocities in releasing the excessive stresses correspond to the minimal fractal dimension, that is to fillers with maximal order. The sliding mode strongly depends on the matter and granular composition of the geomaterial in the sliding zone, the shape of granules, their electrochemical interaction, presence of fluid and its properties. Occurrence of even thin films of fluid at the grain surfaces leads to increasing probability of realizing the "stick-slip" mode and an increase of the stress drop under constant static strength. At high deformation rates the fluid penetrates into the contact zone between filler grains and stabilizes sliding. The higher the viscosity of the fluid is, the lower is the deformation rate at which sliding stabilizes.

Laboratory, numerical and field experiments constituted the base of the mechanical part of the model. All possible sliding modes were realized in laboratory, from creep to dynamic failure. Experiments on triggering the contact zone (injecting water or a surface-active agent, vibrating the interblock contact, acting by electrical pulses) have demonstrated that even a weak external disturbance can trigger a "prepared" contact [2], however, in order to change the slip mode and decrease the cumulative value of radiated seismic energy, a change of the matter composition of the sliding zone is needed, for example, by injecting fluid with special properties. The aim should be not to lower the excessive stress, as it was thought previously, but to decrease the shear stiffness of the fault zone.

It was experimentally proven that small variations of the percentage of materials exhibiting properties of velocity strengthening and velocity weakening in the fault principal slip zone may result in significant variation of the share of seismic energy radiated during a fault slip event [3]. Tests simulated different modes of interblock sliding, scaled kinetic energy of those modes varied by several orders of magnitude, while differences in contact strength and shear stress drop remained relatively small. The obtained results led to the conclusion that the earthquake radiation efficiency and the fault slip mode are governed by the ratio of two parameters — maximum fault slip-weakening rate and shear stiffness of the enclosing massif.

Briefly, the main points of the phenomenological model are as follows:

- Movements along faults make a continuum of slip modes – from earthquakes to slow slip events and steady creep;
- Irrespective of P-T conditions, tectonics, material composition of a fault, watering, pore pressure, etc., the regularities of origination, development and transformation of slip modes on a fault are controlled by the ratio between the shear stiffness of the fault and the one of the surrounding rock mass;

- The most probable mechanism that controls in broad limits the portion of energy radiated in a slippage on a fault, is the drastic decrease of the shear stiffness of a certain fault section as a result of a different, in comparison to other sections or other faults, material composition of the principal slip zone, a sub-lithostatic level of pore pressure, and some other mechanical, geological and geochemical processes. The mentioned characteristics can alter gradually in time and space. The laws of changing stiffness with scale are defined by several hierarchical levels, inside which changing parameters of earthquakes with scale obey to different laws;
- Slip along a fault is a heterogeneous process. The values of radiated energy and released seismic moment change during rupture propagation. This heterogeneity is produced, alongside with other reasons, by different values of the shear stiffness at different fault sections. The seismogenic rupture always nucleates at a fault section with unstable friction and high stiffness, which rapidly decreases just before the rupture starts. This decrease of stiffness may manifest in the spectrum of low-frequency ambient noise. Stable or conditionally stable fault segments can be the sections that brake or event stop the rupture.

The ideas developed were applied to determine a principal possibility to artificially transform the deformation regime of a section of a small fault into a slow deformation mode with low share of seismic wave radiation, for example, to provide safe mining. Judging by the obtained results, the magnitude of earthquakes sensitive to anthropogenic effects is limited and according to expert judgment can hardly exceed the value of M~6-6.5.

1. Kocharyan G.G. Geomechanics of Faults. Moscow, GEOS publishers, 2016, 424p. (in Russian).
2. Kocharyan G.G., Ostapchuk A.A., Pavlov D.V., Markov V.K. The Effects of Weak Dynamic Pulses on the Slip Dynamics of a Laboratory Fault // Bulletin of the Seismological Society of America. 2018. V.108 (5B). P. 2983–2992.
3. Kocharyan G.G., Novikov V.A., Ostapchuk A.A., Pavlov D.V. A study of different fault slip modes governed by the gouge material composition in laboratory experiments // Geophysical Journal International. 2017. V. 208. P. 521–528.