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Lithosphere failure cycle parameters: estimations, variations, nature

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Statistical estimates of seismic parameters obtained on various scales have traditionally been compared solely on the basis of the Gutenberg–Richter law, i.e., the power-law size distribution of seismic sources. The earthquake distribution in space and time is considered uniform within the spatiotemporal "elementary" cells used for the estimates. The roughness of this approach is quite obvious, because at least the spatial inhomogeneity of seismicity is obvious. This fact often leads to the so-called scale effect and actually makes it possible to compare results on markedly different scales (e.g., derived from in situ and laboratory experiments) only qualitatively. The research of the last few decades indicates that another statistical property of the seismic regime: statistical self-similarity in space, i.e., fractality of its geometric structure. Fractal objects are characterized by the dependence of their average density on the scale of averaging, and it is this dependence that explains many scale effects arising in various natural sciences when estimates are transferred from one scale to another.

Modern ideas of the physics of failure rest on fracture mechanics and the kinetics of the system of defects developing on various scales in a stress field. These ideas involve several key parameters controlling the development of the failure process. One such parameter is the average time between two successive acts of fracture in the same region of the medium, or the duration of the failure cycle. In fracture mechanics, it is determined by the time during which one or more adjacent cracks attain an unstable state. This time is commonly assumed to depend on the rate of stress increase, the ultimate strength of the medium, and the degree of crack interaction. In the kinetic theory of strength, this parameter is referred to as the durability, or long-term strength. Its value is a function of the applied stresses and the structural parameter, which depends in particular on the defectiveness of the medium. Irrespective of the physical interpretation (mechanical or kinetic), the failure cycle duration can be regarded as a characteristic of the intensity of the failure process. In seismology, the failure cycle duration is associated with the earthquake recurrence. However, the recurrence in its classical interpretation characterizes the average earthquake recurrence interval in a certain region that is usually much larger than the volume of the medium fractured during an earthquake. The failure cycle duration, as it is understood here, is defined by the average recurrence interval of fracture of the same portion of the medium.

The generalised frequency-magnitude relation, combining the energy- and space-domain scaling laws of seismicity and known as unified scaling law too, allows to estimate the duration of the lithosphere failure cycle from data of earthquake catalogues for a limited time interval.

The estimates of the duration of the lithosphere failure cycle are obtained and mapped from the instrumental data of the seismological catalogues for regions representing general kinds of tectonic structure: subduction, shear fracture and ocean rift zones. The range of variation of cycle durability from region to region is about one and half – two orders (from hundreds years to ten thousand years). Variations of cycle durability within regions are about two orders. The average regional cycle durability is generally controlled by the velocity of tectonic deformations. However, significant range of variations for cycle durability within relatively small regions points to significant un-uniformity of distribution of deformation velocity and strength within regions.

The durability of failure cycle does not depend on the size of failure area (on the earthquake size). It means, that intensity of the failure process on different spatial scales is approximately the same, i.e. the probability of the failure of medium elements is distributed uniformly on their sizes. Such situation take place when stress field is matched with strength "field". There are at least two physical scenarios for this situation, supported by the laboratorial experiments.

Time variations of failure cycle parameters for aftershock sequences testify that redistribution of failure intensity on sizes take place in common with decreasing of level of failure intensity (Omori law). From the physical point of view it can be explained as result of certain mismatching of distribution of stresses and strength and, consequently, deviation of the probability of the failure of medium elements from uniform distribution. We suppose that this mechanism in not only specific for aftershocks but plays role in dynamics of seismic process.

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