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Hypothesis of self-organized criticality and non double couple seismic sources

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The analysis of deformation process in earthquakes foci makes it possible to get a better insight into various aspects of faulting and earthquakes in real media. Seismic process depends on distribution of stresses in a volume of rocks. Qualitative analysis of the redistribution of stresses in an elastic medium with scaling organization of faults demonstrate that the inhomogenity of stresses near tips of such fault zones is altered drastically. It has been shown that of great importance are regional variations in the stress state caused by the processes of redistribution of crustal stresses during seismic activity in the region as well as by more distant seismogeodynamic processes on interplate boundaries. The hypothesis that seismicity may be considered as self-organized critical process (SOC) take into consideration multi-scale hierarchical structure of real geological medium and its heterogeneity. In result the SOC approach leads to rather well description of earthquakes statistics (first of all the Gutenberg – Richter law) but up to now it was not so helpful for understanding of individual EQ-triggering process at local scale level. On the other hand, current seismological observations suggest that the pattern of seismic waves from some earthquakes cannot be produced by slip along a planar fault surface. Other physical mechanism is required to explain the observed varieties of these non-double-couple earthquakes (NDC). The specific mechanisms underlying NDC are not always clear. The most common explanation currently is that these earthquakes are complex, with stress released on several non-parallel fault surfaces. Thus NDC sources are considered as a result of complicated fault geometry and its segmentation during the process of seismic rupture. As concerned the interaction mechanisms, the SOC approach also implies a possibility of collective (ensemble) interaction. The system in a state of SOC oscillates about a state of marginal stability with a series of slip events in much the same way that it is applied to 'avalanches'. We suggest that observed NDC events should be studied in terms of SOC methodology. Indeed, in the terms of SOC these NDC events treated as non-steady deformation may be taken as examples of chaotic flows in nature. We can further extend outlined above model and suggest that faults play a role similar to role played by slider blocks in the SOC model of seismicity. A wide variety of slider-block models can exhibit classic chaotic behavior as these have been reviewed by Turcotte (1999; Phys. Ea. Pl. Int., 111, 275–293). In these models, the slip of one fault plane could lead to the instability of either or both of the adjacent blocks, which would then be allowed to slip in a subsequent step or steps, until all blocks were again stable. As the redistribution involves only nearest neighbor blocks, it is a cellular-automata model. Redistribution can lead to further instabilities with the possibility of an 'avalanche' of slip events. Thus NDC event related with simultaneous complex faulting may be treated in terms of SOC as seismic 'avalanche'. Self-organized criticality may be realized only if the heterogeneity is high enough. To some extent, notions of heterogeneity and chaotization seem to be closely linked. The case then probability of simultaneous slidings of all faults in cluster becomes very high is a classic example of critical point behavior typical for percolation model, forest-fire model, multiplicative cascade model and other models that exhibit self-organized critical behavior. Acknowledgments. The USGS and Harvard University kindly provided access to their centroid-moment tensor data. This work was partly supported by RFBR, № 07-05-00436.