On the spatio-temporal distribution of acoustic emissions in two granitic rocks: the role of pre-existing cracks

Xinglin Lei[1], Kinichiro Kusunose[2], Osamu Nishizawa[3], Akio Cho[4], Takashi Satoh[3]

[1] Earthquake Res. Dept., [2] Geological Survey of Japan, [3] GSJ, [4] GSJ, AIST

http://www.gsj.go.jp/~lei/lei00.htm

Tsukuba granite (TG) and granitic porphyry (GP) samples were used in triaxial compression tests. GP contains rare pre-existed cracks, however, IG contains many cracks. A rapid data acquisition system was used to monitor the spatio-temporal distribution of acoustic emission (AE) during fault nucleation. In our tests, the two rocks showed significantly different behaviors. In GP, before the fault nucleation, AE activity was low and showed increasing b-values with increasing stress. But in TG, a large number of AEs were observed and showed short-term b-value anomalies - mutual fluctuations on a decreasing background. The short-term fluctuations of b-values are closely correlated with the spatio-temporal clustering and governed by the heterogeneously distributed pre-existing cracks in TG.

Laboratory studies have found that the magnitude-frequency relationship in earthquakes holds also for acoustic emission (AE) events generated by cracking in rock samples under stress. By using a fast data acquisition system to monitor the spatio-temporal distribution of AEs, we found that during fault nucleation b-value shows mutual change on a decreasing background, which was correlated with the hierarchy of faulting. The heterogeneities in a rock, including pre-existing cracks, grain boundaries and local strength distribution associated with rock-forming minerals, can be considered as the main reason for the hierarchy of faulting. In order to understand the role of heterogeneities at different scales, we conducted experimental studies using a rapid data acquisition system to monitor AEs. Here are the results of such experiments on two coarse-grained

The rapid AE monitoring system used in this study can record AE waveforms without major loss of events even when AEs occurred on the order of several thousand events per second, as is generally observed during fault nucleation in rocks. Therefore, it is possible to obtain complete data sets for time series and hypocenters. Here hypocenter data is a sub set of time series data, since the trigger threshold for waveform recording is higher than peak detection.

GP and TG showed a completely different fracturing process. First of all the strength of TG and GP under 60MPa confining pressure are 510MPa and 800Mpa, respectively. Pre-existing cracks decreased the failure strength of TG significantly. In TG, AE activity initiated at about 400 MPa and then increased rapidly with increasing stress. In GP, AE also initiated at about 400 MPa but showed rather low activity and increased slightly with increasing stress. Therefore, our results, demonstrate that pre-existing cracks are the most dominant factor of all heterogeneities that govern the faulting process.

The b-value increase in GP with increasing applied stress contradicts generally observed the negative correlation between b-value and stress intensity factor. Our finding may indicate that the mechanics of cracking is something else than crack growing and need more study. On the other hand, b-value of TG is more promising. In TG, the observed b-value minimum at the peak stress and the global minimum at the onset of dynamic failure. When AE increased rapidly our results showed short-term mutual fluctuations on a decreasing background. The double minimum model of Main et al. [Geophy. J. Int., 115, 367-380, 1993] can be extended to include the heterogeneity of pre-existing cracks in a rock. In such a case, self-organized hierarchy in fault nucleation cannot be disregarded. Furthermore, the subcritical growth of multiple larger cracks becomes easy to be generated simultaneously or alternately in multiple positions. Therefore, interactions between these larger cracks become important. Particularly near the dynamic fracturing, the interactions will be a main factor affecting the local stress distribution and thus also the K factors of the subcritical cracks. As a result, the total behavior will be a combination of the multiple double minimums, and therefore, apparently shows mutual fluctuations of the b-value.

In short, our experimental results show that: 1) pre-existing - particularly larger - cracks are the most important factors governing the faulting process, especially the nucleation; 2) mutual fluctuations of the b-value on a decreasing background, showing a close correlation with the alternate occurrence of clustering, is an important feature of fault development in rocks with pre-existing cracks.