Temporal changes in coherence and phase of elastic P wave transmitting through fracturing Westerly granite

Nana Yoshimitsu[1]; Hironori Kawakata[1]; Naoki Takahashi[2]; Manabu Takahashi[3]

[1] Ritsumeikan Univ.; [2] Sumitomo Mitsui Construction; [3] GSJ

The amplitude and velocity of elastic waves that transmit through a rock sample have been known to change before the peak stress (e.g. Lockner et al., 1977, JGR). The velocity would change when cracks open or close during loading. Unfortunately, we could not know detailed image of cracks from the previous studies because of narrow band recordings.

Yoshimitsu et al. (2008, ASC) observed transmitting P wave under triaxial compression test to know the development of crack heterogeneities in a rock sample during the faulting process including after the peak stress. They used a newly developped system of broadband recording of elastic waves by Kawakata et al. (2007, SSJ). A cylindrical sample of intact Westerly granite that was 50 mm in diameter by 100 mm long was loaded. A confining pressure of 80 MPa was maintained under dry condition at ambient temperature. P-wave type piezoelectric transducers (sensitive range; 200 - 800 kHz) were attached within upper and lower end pieces. They repeatedly applied 50-V pulses to the upper transducer every 1/40 s, and transmitting waves corresponding to the pulse onsets were recorded at the lower transducer for 2 ms at 100 MS/s. The S/N values of recorded waves were high enough in 100 - 1000 kHz. They estimated temporal change in frequency dependent attenuation. After the dilatancy started, waves attenuated in all frequency range. Further loading up to 80 % of strength made waves attenuate in specific frequency ranges. After the peak stress level was attained, wave components only in lower frequency were attenuated. At the same time, peak-to-peak amplitude of the first arrivals decreased in an almost constant rate after the dilatancy started, and drastically decreased just after the peak stress. Velocity also decreased in an almost constant rate after the dilatancy started. It kept almost constant velocity after the peak stress. From these results, they discussed the process of crack generation and fault growth.

In this study, we estimated frequency dependent velocity change by cross-spectral analysis, using the same experimental data as Yoshimitsu et al. (2008, ASC). The analyzed time window was 0.197 ms from 0.027 ms before the P wave arrival not to contain clear reflected wave and analyzed frequency range was 100 - 1000 kHz. We calculated temporal changes in coherences and phase using wave pairs one of which was obtained 50 s later than the other.

The wave coherence was kept to be nearly 1.0 in almost whole analyzed frequency range. Lag time calculated from phase was always positive (less than 2 microsec in a whole frequency range) before the peak stress, while no clear delay was found after the peak stress.

From our results and the results of Yoshimitsu et al. (2008, ASC), it is suggested that both first arrival time and frequency dependent lag time of elastic P wave transmitting parallel to the axis of maximum compression kept constant after the peak stress. It is also indicated that first arrival time and phase of transmitting P wave are much less sensitive for fracture growth than spectral amplitude and first wave amplitude in such a wave path.