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Measurements and mechanisms investigation of seismic wave attenuation for frequencies between 1 and 100 Hz

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Seismic wave attenuation at low frequencies in the earth crust has been explained by partial saturation as well as permeability models. We present results obtained by the Broad Band Attenuation Vessel (BBAV) which measures seismic wave attenuation using the sub-resonance method in the frequency range 0.01 - 100 Hz. The apparatus also allows the investigation of attenuation mechanisms related to fluid flow by means of five pore pressure sensors placed in the specimen. This allows continuous local measurements of pore pressure changes generated by stress field changes.

Measurements were performed on 76 mm diameter, 250 mm long, 20% porosity, and ~500 mD permeability Berea sandstone samples. The confining pressure was varied between 0 and 20 MPa, and the specimens were saturated with water between 0% and 90%. Attenuation measurements show dependence with saturation. For instance, when samples are at dry conditions they exhibit attenuation values around 0.01, the same sample saturated with 90% water shows attenuation values between 0.018 and 0.028 across the entire frequency range. Attenuation is also confining pressure dependent. For instance, variations of confining pressure ranging between 0 and 8 MPa lead to quality factors between 40 and 10 at 60 Hz and 60% water saturation. Best fits on these measurements reveal that the corner frequency of the attenuation mechanism decreases from ~800 to ~200 Hz with increasing confining pressure.

Using calibration measurements with Aluminum the possibility of apparatus resonances can be ruled out. Local pore pressure measurements corroborate this observation showing pore pressure evolution as a function of saturation.

The results are discussed and interpreted in light of known attenuation mechanisms for partially saturated rocks (patchy saturation and squirt flow). We rule out the possibility of patchy saturation occurrence, but squirt flow would offer an explanation. The confining pressure dependence could be the result of crack closure which produces the corner frequency shift. Crack closure in similar samples and conditions (i.e. Berea sandstone at confining pressure less than 20 MPa) was also observed using ultrasonic tests.