Pore pressure measurement in the Kamioka mine, central Japan

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We developed a new technique to precisely measure pore pressure changes with a closed borehole well. The new measurements improve the frequency response of pore pressure observations compared to conventional techniques, which use water level measurements in open wells, by greatly reducing the water flow between the well and surrounding rocks. From 2002 to present, we monitored pore pressure changes of the host rock using four closed borehole wells drilled in the Mozumi and Atotsu tunnels in the Kamioka mine, central Japan. We analyzed the barometric response of the pore pressure change produced by loading and unloading of barometric pressure (at frequencies of 10^{-6} - 10^{-5} Hz) and the tidal response of the pore pressure change caused by crustal deformation associated with earth tides (at frequencies of 10^{-5} Hz). The hydroseismograms (pore pressure oscillations associated with passage of seismic waves at frequencies of 0.1 - 1 Hz) that were recorded for the large earthquakes including the 2002 Denali, the 2004 Kii-Hanto-Oki, 2004 Chuetsu, the 2004 Sumatra-Andaman Islands, 2005 Fukuoka-Seiho-Oki, 2005 northern Sumatra, 2006 and 2007 Kuril, 2007 Noto-Hanto-Oki, and 2007 Chuetsu-oki earthquakes, revealed that the radial component of ground velocity is proportional to the pore pressure. Three boreholes (MA, AC and K1) have flat frequency responses in this wide (barometric, tidal and seismic) range of frequencies. One borehole (K2) shows a seismic response comparable to the others, but negligible barometric and tidal responses. The difference of barometric and tidal response between boreholes implies that the hydraulic diffusivity of the volumes connected to the boreholes is different, and the degree of confinement has a frequency dependence that is controlled by the hydraulic diffusivity. The volume connected to MA, MC and K1 is confined for barometric, tidal and seismic frequencies and the volume connected to K2 is only confined for the seismic frequency range. The pore water around K2 drains to the water table for barometric and tidal frequency ranges. Based on these observations, we confirm that the pore pressure and deformation changes, in response to elastic stresses, are well described in terms of the theory of linear poroelasticity throughout a wide range of frequencies, with consideration of the variations of hydraulic diffusivity.