Application of fractal model of electrical and elastic properties of porous rock to Hirabayashi borehole data

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To investigate microstructure of fault core and damaged zones, a fractal model for elastic and electrical properties of porous rock was applied to logging data of the Hirabayashi borehole, a 746 m deep borehole penetrating the Nojima fault, the main fault responsible for the Kobe earthquake at 1995. The main advantage of the present model against other theoretical models is to describe both elastic and electrical properties of rock with a single model for a wide range of microstructures including 3D grains and pore anisotropy and various degrees of pore interconnection. Dependencies of the conductivity and the seismic velocities against the porosity were simulated for all zones detected by core analysis: from the outside fault zone (152-426 m) to the upper and lower damaged zones (426-611 m and 641-746 m respectively) and the fault core zone (611-641 m). An interesting feature is that while the average fracture frequency observed by Fullbore Formation MicroImager (FMI) in the outside fault zone (4.2 fracture/meter) is 3-5% more than in the upper damaged and core zones (3.99 and 4.08) and only 12.5% less than the average fracture frequency throughout the whole fault zone (4.8 fracture/meter), the resistivity and seismic velocities in the fault zone are remarkably lower. This seeming discrepancy was explained by increasing number of microcracks that might be not detected by FMI. The seismic velocities and resistivity measured by logging at the depth 152-426 m were simulated under assumption, that porosity of microcracks is 0.7 – 6%. At upper and lower damaged zones the experimental data were simulated with porosity of microcrackes of 4.8- 16%. Throughout the depths of fault core 624-642 m the contribution to porosity with open generation was estimated to be more than 16%. The laboratory measurements of porosity in the core samples, which are taken from the different depth, show 0.69% for the depth 152-426m, 2.29% for the upper and lower damaged zones and 16.9% of porosity for the Hirabayashi fault core. The results of laboratory measurements are consistent with simulation results for outside the fault zone and the fault core. The lower value of laboratory measured porosity throughout the upper and lower damaged zone can be explained with different scale of measurements. The simulation results are compared with O'Connell and Budiansky diagram and it is shown, that the suggested model gives means to distinguish whether the large aspect ratio or partial saturation is the reason of low growth of the compressional velocity with the shear one. The suggested theoretical model of physical properties of porous rock can be useful for revelation of unknown parameters of porous media using the measured ones.