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Fluid transport property of sediments near the plate boundary fault at Japan Trench

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The 2011 Tohoku earthquake (Mw 9.0) produced huge fault slip (~50m) on the shallow portion of plate boundary fault. On the basis of previous studies of the rheology of subduction faults and historical observations of seismicity, neither large Mw 9.0 earthquakes near the Japan Trench, nor rupture of the shallow portion of the subduction thrust were anticipated. Thus, questions remain about the dynamic processes during the earthquake, which can be addressed though evaluation of physical properties of the fault zone. Fluid transport properties of fault zones influence pore fluid pressures and how fluids migrate at depth. Permeability of fault rocks and surrounding sediments directly influences (1) the efficiency of the thermal pressurization process during coseismic faulting and (2) the evolution process of pore fluid pressure generated by the chemical dehydration reactions of the subducting sediments along a plate boundary. These processes consequently affect fault dynamics. Thus, we have measured hydraulic property of core samples around the plate boundary materials recovered from the Japan Trench during IODP expedition 343 (JFAST), performing laboratory tests on mudstones from the hanging wall near the plate boundary fault zone (Lithological Unit 4, 714 mbsf and 785 mbsf). Permeability and porosity were measured at confining pressures of 0 to 30 MPa and pore pressures of 0.2 to 0.8 MPa at room temperatures (about 20 degree Celsius). Permeability was determined by a steady-state flow method with NaCl solution (35 per-mil) and distilled water as a pore fluid.

Permeability and porosity for mudstone from 713 mbsf are $3*10^{-17}$ m^2 and 43%, respectively, at 1 MPa effective pressure. These parameters decrease to $2*10^{-18}$ m^2 and 30% with increasing effective pressure to 10 MPa. Specific storage shows from $5*10^{-8}$ to $1*10^{-8}$ Pa^{-1}. A sample from 785 mbsf has measured permeability of $7*10^{-17}$ m^2 and porosity of 40% at 1 MPa effective pressure and $5*10^{-18}$ m^2 and 31% at 10 MPa effective pressure. For both samples, permeability decreased exponentially with a decrease of porosity. Permeabilities at conditions comparable to the in-situ depth (ranging from 10^{-17} m^2 to 10^{-18} m^2) are therefore low enough that processes (1) and (2) are expected to occur. We will model these processes more specifically considering the friction properties of the plate boundary fault, temperature structure at depth and shear-induced permeability change.

Keywords: permeability, JFAST, Tohoku Earthquake, IODP Expedition 343