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Triggering of earthquake swarms following the 2011 Tohoku megathrust earthquake

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Earthquake swarms, often interpreted to result from fluids invading the brittle seismogenic zone, have seismicity patterns that are significantly different from an aftershock sequence. Following the Mw 9.0 Tohoku-Oki earthquake, an unusual, shallow normal-faulting swarm sequence occurred near the Pacific coast in the southeastern Tohoku district. An integrated approach combining geophysical and geochemical methods was utilized to establish the presence of aqueous fluids around the seismic source region and their derivation. Magnetotelluric inversion defined an anomalous conductor with a width of 20 km and clearly visible to depths of more than 20 km, extending to the base of the crust. Independent geophysical observations, including seismic, strongly support the suggestion that fluid-filled porous materials and fluids associated with slab dehydration are present in the convergent plate boundary. In order to provide geochemical constraints on the source of the fluids triggering the swarm activity, new helium isotope data were acquired from gas and water samples around the seismic source region. The observed 3He/4He ratios in these samples are significantly lower than the atmospheric value of 1.4x10-6, indicating that the mantle helium contribution is less than 10% of the total helium. Plausible sources of the fluids can be attributed to waters produced by dehydration of accreted deep-sea sediments and/or seawater-altered volcanic rocks, rather than dehydration reactions in the subducted oceanic crust and/or hydrated mantle below the fore-arc mantle wedge. The swarm sequence would have been triggered by stress changes associated with the Tohoku-Oki earthquake, enhanced by vertical metamorphic fluid expulsion from the reaction zone.