Detection of aquifer at the subduction zone and/or in the crust by means of seismic refraction/wide-angle reflection method

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1. Introduction

In recent years, the importance of aquifer in the crust and mantle has been recognized to understand the geophysical and geological phenomena such as earthquake generation, volcanism, faults etc. In the subduction zone, aquifer layer near the plate boundary was found by deep sea drilling in Barbados. The thickness of aquifer is ~20m, and the aquifer was also identified as seismically bright layer (decollement) with negative polarity by 3D seismic reflection records. Because aquifer might have very low Vp, the decollement is explained by low velocity layer(LVZ) above the subducting plate. Fujie et al. (2002) found a bright reflector by refraction/wide-angle reflection method in the subduction zone of Japan Trench. They interpreted the bright reflector by extremely low velocity material such as aquifer. To obtain seismological knowledge on presence of aquifer at subduction, we performed waveform simulation using refraction/wide-angle reflection method.

2. Waveform simulation and travel time calculation

We examined the refraction/wide-angle reflection phases in the subduction zone. In the model, the trench axis located at x =100km at the center of the model, an oceanic plate subdducts beneath the forearc basin between 0 and 100 km. The oceanic crust with 7km subducts. The zone between 100 and 200km is pure oceanic region. The thickness of forearc basin is thinning toward the trench axis. Above the subducting plate, 500 m thick aquifer (soft sediments) with 1.6-2.2km/s is placed. Vp at just top of the oceanic mantle is 8.0km/s.

We used the integrated method to analyze crustal structure study (Kasahara et al., 2007). The seismograms and travel times were calculated by 2D-FDM (Larsetn,200) and graph method (Kubota et al., 2005), respectively. Assuming appropriate Vp, Vs, density and Q values, we computed shot-gather records using 4Hz Richker wavelet explosive sources placed in the ocean bottom and receivers at 30 m below the sea surface. Grid spaces in x and z are 30m, and time step is 2ms. Receivers are placed on ocean bottom. The size of model is 200km x 100km.

3. Results

At all locations, we can recognize the strong reflection from the decollement with negative polarity due to the negative impedance contrast. Two way time of decollement reflection at 0-offset varies with the depth of decollement.

1) At 100km from the trench axis, clear reflection from the decollement at 6km below the ocean bottom and PmP from the subducting oceanic Moho are identified. Reflection from the decollment has large amplitude between offset distance of 0 and 30km, but PmP does large amplitude between30-50km. Pn traveling in the oceanic mantle has clear appearance. 2)At 50 km, characteristics of shot gather records have similar characteristics of ones at 100km case. 3) At 100km(trench axis), waveforms at distance greater than 100km are similar to the seismic records at typical oceanic crust. Large Pg and PmP are identified. Pn is seen for both side of trench axis. Reflection from PmP around 0-offset is weak, but it has very large amplitude at 20-40km by wide-angle reflection.

4. Discussion and conclusion

We evaluated the effect of LVZ (decollement) such as aquifer (or soft sediments) along the subuction zone using refraction/wide-angle reflection synthetic seismograms. Very strong wide-angle reflection is identified from 0-offset to a few ten km distance. The thickness of LVZ used is a little thick (0.5km), it corresponds to 125m if 16 Hz wavelet is used. Negative polarity can tell that reflecting layer is low velocity compared to the upper layer. Even if a layer is not pure aquifer, we can expect strong seismic reflection from the target layer.

This simulation suggests that refraction/wide-angle reflection method is useful to identify an aquifer in the crust if it exists at shallower than ~10 km beneath the ocean bottom and continuous layer with thickness of several 10m ~100m.