Crustal structure of the eastern Nankai Trough from Full Waveform Inversion of the dense Ocean Bottom Seismometers data

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The Nankai Through region is one of the best sites providing an excellent natural laboratory for studying factors controlling segmentation of the earthquake rupture zones in subduction systems. The area has a ~1300 year historical record of damaging earthquakes and is constantly under intense multidisciplinary scientific investigation. For this purpose enormous number of data are acquired in this region. Among them high quality seismic datasets, including multi-channel reflection seismic (MCS) and wide-angle reflection/refraction seismic (WARR) acquired using Ocean Bottom Seismometers (OBS), provide a great potential for seismic imaging.

Crustal-scale velocity models from 2D marine WARR surveys are usually built using ray-based methods. However their ability to resolve complex structures is limited by factors such as: OBS spacing, width of the Fresnel zone or interpreter's ability to distinguish and associate the picked phases with the model interfaces. From the other hand rapid development of the Full Waveform Inversion (FWI) methodology during last decade allows for automation of the crustal velocity model building in the unprecedented resolution, given that the sufficiently dense acquisitions are used. Additionally, potential of FWI stimulates not only development of the imaging algorithms –but also new acquisition technologies including growing pools of OBS instruments available to the academic community making it possible to acquire dense WARR OBS data in 3D.

Here we present multiscale, layer-stripping strategy for the semi-automatic, high resolution, crustal-scale imaging using FWI. We develop practical workflow including: (i) preprocessing focused on the improvement of the data coherency and boosting low frequencies; (ii) thorough and early stage QC starting from the analysis of the traveltime error in the initial model; (iii) final model validation procedures using source estimation, evaluation of the data fit with Dynamic Image Warping, correlation with PSDM image and the interpretation of crustal phases by the ray-tracing. We successfully apply this workflow to the 2D OBS dataset from the eastern Nankai Through acquired by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) involving 100 OBS uniformly deployed along a 100-km long profile recording air-gun shots extended along 140-km long profile with a 100 m spacing.

As a result we obtain velocity model of the complex subduction zone with clearly delineated shallow and deep structures. In particular in the backstop we observe large-scale stacked thrust sheets covered by sediments of forearc basin. These structures spatially extend to the area of accretionary prism forming Kodaiba and Tokai thrusts. Further into seaward direction we can point sequence of smaller thrusts delineating active wedge covered by slope basins and the thick layers of sediments in the trench. We observe local thickening of the oceanic crust corresponding to the subducting oceanic ridges as well as a sharp low-velocity zone (LVZ) atop the oceanic crust, which represent a damage fault zone created by one of these ridges colliding with the backstop. The top of the LVZ corresponds to a splay fault along which the co-seismic slip can occur during the next large earthquake in the area.

We show that with FWI one is able to retrieve a detailed information on the subduction zone structure that can be used as an input for other studies (e.g. geodynamical modeling). High resolution velocity models

accompanied by image from MCS data increase interpreter's ability not only in terms of structural interpretation but also help to understand formation processes. Our study presents great potential of the FWI as a semi-automatic method for better imaging of complex crustal targets being beyond the reach of the WARR or towed-streamer surveys. Further tests of FWI with decimated acquisitions reveal that even datasets with 5km OBS-spacing have potential to deliver satisfactory results in terms of imaging overall crustal structure.

Keywords: subduction zone, crustal-scale imaging, full waveform inversion, velocity model building, OBS data, Nankai Trough

