# Improved depth imaging of Japan Trench forearc basin using seismic full waveform inversion and reverse time migration

*Ehsan Jamali Hondori[1], Chen Gou[1], Jin-Oh Park[1]

1. Department of Ocean Floor Geoscience, Atmosphere and Ocean Research Institute, The University of Tokyo

## Introduction

The Japan Trench forearc region is recognized with four distinguishable zones; a deep-sea terrace, a steep upper slope, a relatively flat middle slope, and a steeply rugged lower slope. Seismic images and ocean drilling results showed that Pliocene–Pleistocene and Miocene sediments overlie the Cretaceous continental framework in the deep-sea terrace and the upper slope, with an erosional unconformity between Cretaceous continental framework and Miocene sediments. This unconformity is observed as a high amplitude seismic reflection which makes it a prominent marker horizon. However, the strata above the unconformity are locally tilted and deformed by a number of normal faults. This makes the velocity model building and depth imaging challenging due to the complexity of the faulted sediments and deformed basin. We developed full waveform inversion (FWI) and reverse time migration (RTM) tools and applied them to the seismic reflection data in forearc basin of Japan Trench. FWI iteratively updates an initial velocity model by minimizing the misfit error between observed seismic data and synthetic data generated through wave equation solution. RTM can resolve steeply dipping reflectors, multipath events, and severe velocity contrasts for imaging.

## Data Acquisition

The 2D seismic data were acquired by JAMSTEC along line D13 using research vessel Kairei in May 2011, immediately after the 2011 Tohoku earthquake (M 9.0). The objective of the survey was to investigate the detailed crustal structure of the Japan Trench margin, especially near the epicentre of the 2011 event. A large volume (~130 litters) tuned air gun array with air pressure of 2000 psi was used as the seismic source with 50 m shot intervals and about 10 m towing depth. A 444-channel streamer with 12.5 m group spacing (~6 km maximum offset) was towed at a depth of 21 m to avoid collision with the floating obstacles brought to the ocean by the tsunami.

## Data Processing

Due to the relatively large towing depth of the receivers, a strong ghost reflection was recorded in the seismic data. Bubble oscillations also contaminated the data which could degrade the quality of the seismic images. Moreover, multiple reflections from the sea surface overlapped with the target primary reflections. We applied a series of preprocessing to the seismic data, including deghosting, debubble filtering, swell noise suppression, and surface related multiple elimination (SRME). It should be noted that although multiple reflections from the sea surface could be used in FWI, we removed these reflections from data by SRME and applied a Perfectly Matched Layer (PML) boundary condition on top of the model to reduce the nonlinearity of the FWI problem. Before applying FWI and RTM we developed a migration velocity model using layer stripping method for Kirchhoff prestack depth migration (KPSDM). A smoothed version of this velocity is also used as an initial velocity model for FWI. The shallowest part of the deep-sea terrace seemed to be a suitable candidate for FWI. Although a maximum depth of 5 km has been selected for modeling and inversion, FWI may not be able to improve the model at such a depth using the limited offsets (~6 km) available in the data. We applied a depth-variant smoothing operator on the preconditioned gradient of the misfit function. The larger smoothing window at deeper parts of the model helps to balance the amount of the velocity update while preserving the resolution at the shallower depths.

**Results**

We applied RTM on the selected dataset using FWI initial and final velocity models. The initial velocity model could not well image the steeply dipping reflectors in the severely faulted zone. Moreover, the Cretaceous unconformity was poorly imaged with considerable migration artifacts due to the inaccurate velocity model. On the other hand, the velocity model developed by FWI could properly image the faulted structure and the Cretaceous unconformity. The sharp boundary between sediments and continental framework below Cretaceous unconformity could be seen on the resulting velocity model.

**Acknowledgments**

The authors would like to thank JAMSTEC for providing the seismic data. We also thank Paradigm/Emerson (http://www.pdgm.com) for providing data processing software for KPSDM.

Keywords: full waveform inversion, reverse time migration, Japan Trench