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Seismic velocity and reflectivity images of subducted ridges beneath central Japan and its implication for mega-thrust earthquake

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There are significant variations in the size, especially lateral extensions, of the co-seismic rupture zones and inter-seismic locked zones. Obvious factors controlling them are still unsolved questions, even though several geophysical studies have suggested possible candidates of structural factors. In the summer of 2001 we acquired onshore-offshore integrated seismic data at the edge of the rupture zone of the 1944 Tonankai earthquake in the eastern Nankai Trough. The wide-angle seismic profile is designed as 477 km long profile in total; 262 km onshore and 215 km offshore. Five 500 kg and one 100 kg explosion sources were shot onshore, while 187.5 L air gun array was shot at every 100 m interval offshore. 391 land seismic stations and 70 ocean-bottom stations were recorded the seismic signal both from the land explosions and the air-gun array. Qualities of data are generally good. We can trace first arrivals from the air-gun array more than 250 km offsets. Remarkably high amplitude reflection phase is also clearly observed onshore part of the profile.

A joint refraction and reflection tomography is applied for the all observed first arrivals and remarkable reflection phases to obtained seismic velocity image as well as reflector geometry. The travel time tomography in cooperating with reflection phases provide a deeper seismic velocity image where the refraction arrivals do not sample. In order to obtain a seismic reflectivity image, we also applied pre-stack depth migration for the offshore data, while only NMO correction is applied for the onshore data.

From the both seismic velocity and reflectivity images, we successfully obtain two trough-parallel ridge systems offshore, i.e. cyclic ridge subduction, with thickness of 13-20 km and wavelength of 35-50 km. This remarkable feature is recognized from iso-velocity contours in the seismic velocity image and reflectors in the seismic reflectivity image, i.e., the iso-velocity contour of 4-7 km/s shows repeated broader and narrower width and the reflectors show bulges at the same positions. The deeper ridge is located at immediately seaward of the coast line. From the reflectivity image of onshore part, the top of subducted crust is traced down to 45 km. A weak reflector interpreted as Moho of the subducted crust can be also recognized several km below the top of the subducting crust. The reflector corresponding to the top of the subducted crust seems to be undulated. Although the geometry of this reflector contains large uncertainty, it may indicate another ridge system beneath the Tokai district.

By comparing the location of the subducted ridge and an inter-seismic locked zone estimated by GPS data, it is recognized that the offshore deeper subducted ridge, which is subducted beneath the backstop of the present day accretion process, is located exactly at the inter-seismic locked zone. From these results, we conclude that the rupture during the 1944 Tonankai earthquake did not extend to the east due to strongly locking caused by the ongoing cyclic ridge subduction; i.e., this study strongly support an evidence of the 'subducted seamount-strongly locking' hypothesis where a large scale ridge or seamount is subducted beneath a backstop in an accretion dominant subduction zone. The locked region may rupture when accumulating stress exceeds the critical strength of locking. This idea could explain why the recurrence interval of the great earthquake in the Tokai segment is longer or more obscure than the other segments. We also propose that the subducted convex shape would not produce strong coupling when the convex is located under young accretionary sediment, presumably a weaker material.