Tectonic Features of a Triple-Plate Junction in Hokkaido Using Local Seismic Tomography

So Gu Kim Department of Earth and Marine Sciences, Hanyang University
Hyung-Sub Bae Department of Earth and Marine Sciences, Hanyang University
Sang-Pyo Pak Department of Earth and Marine Sciences, Hanyang University

Abstract

The three-dimensional Tomography developed by Kim and Bae(2004) was applied to 64,024 P and 64,618 S wave arrival times observed at 238 seismic stations for 4050 local earthquakes in the depth range from 0 to 300 km in and around Hokkaido, Japan. High and low velocity zones for Vp/Vs were clearly imaged in and around Hokkaido. The upper seismic planes of the double seismic zone (DSZ) were found in the subducted Pacific Plate beneath Hokkaido at depth of 40- 80 km, which produced high seismicity around Hokkaido. The findings of high Vp/Vs anomalies beneath the Moho discontinuity supports an evidence of a surface triple-collision hypothesis prepared by Moriya(1994) that the Kuril Arc(Okhotsk Plate or North American Plate) is colliding against the NE Japanese Arc(Amurian Plate or Eurasian Plate), along and beneath the Hidaka Mountain Range, and at the same time the Pacific Plate is subducting into these two plates, making an equilibrium of tectonic forces along the Hikada Mountain Range (HMR) corner and the central tectonic axis(142~143E) in Hokkaido. The low Vp and Vs were also found in east and west along the central tectonic axis in which the focal mechanism represents the extensional forces. These phenomena are also consistent with low Bouguer gravity anomalies in this region. It is understood why most of great earthquakes occurred outside Hokkaido where the balance of tectonic forces are breaking from the triple junction of three tectonic forces in Hokkaido.

일본 홋카이도와 그 주변 지역의 238개의 관측소에서 관측한 깊이 0~300Km내에서 일어난 4050개의 지진 중 P파 64,024개와 S파 64,618개를 Kim과 Bae(2004)에 의해 개발된 3 성분 토모그래피에 이용하였다. Vp/Vs의 속도 이상대가 홋카이도와 그 주변 지역에서 명확하게 나타났다. Double Seismic Zone(DSZ)의 Seismic Planes는, 홋카이도 주변에서 지진 위험도가 높게 나타나는, 40~80Km의 깊이에서 홋카이도 아래로 태평양판이 섭입하는 것이 발견되었다. 모호 불연속면 아래에서 높은 Vp/Vs 이상대의 발견은 Moriya(1994)에 의해 제안된, 쿠릴 열도(Okhotsk Plate 혹은 North American Plate)가 NE 일본 열도(Amurian Plate 혹은 Eurasian Plate)와 충돌하고, 동시에 태평양판이 홋카이도의 Central Tectonic Axis(142°~143°E)와 Hikada Mountain Range(HMR) Corner를 따라 지체구조력의 균형을 이루는 두 개의 판 아래로 섭입하고 있는, 표면 삼중 충돌 가설의 증거이다. 낮은 Vp와 Vs는 장력을 나타내는 지진 메커니즘의 표현인

Central Tectonic Axis을 따라 동쪽과 서쪽에서 발견되었다. 이들 현상은 이 지역에서의 낮은 부게 중력 이상값과 일치한다. 이것은 왜 큰 지진의 대부분이 홋카이도의 3개의 지체구조력의 3중 접합점에 의해 지체구조력의 균형이 깨어지는, 홋카이도 바깥쪽에서 일어나는지 알 수 있다.

1. Introduction

The data set was provided by Institute of Seismology and Volcanology (ISV), Hokkaido University in the period of 1998-2003. 64,024 from 68,531 P-wave arrival times and 64,618 from 68,531 S-wave arrival times were utilized from 238 stations, for 4050 local earthquakes after relocation, in a depth of 0-300 km in and around Hokkaido. The data set was truncated at 7.0 by using the difference between observed and theoretical travel times for P and S-wave travel time data. The analyzed number of shallow-focus earthquakes ($0 \le h < 70$ km) and deep-focus earthquakes ($70 \le h \le 300$ km) were 2,730 and 1,320, respectively. The magnitude range was selected as M 3.0 for shallow-focus earthquakes and M 2.0 for deep-focus earthquakes.

Miyamachi and Moriya (1984) applied the 3D inversion method to P-wave travel time data in Hokkaido. They surveyed 781 travel times observed at 21 seismic stations for 61 local earthquakes in a depth of 0 to 150 km in the area of the Hidaka Mountain Rannge (HMR). They found that the P- wave velocity in a "low-velocity zone"(LVZ) with a thickness of 20-25km, extending to 10-6 5km and dipping 60°NE was 10 % slower than the surrounding region. The suggested that the LVZ was a subducted crust resulting from the collision between NE Japan and the Kuril Arc. Miyamachi et al. (1999) applied a new inverse method developed by Miyamachi (1994) toa data set of 8,400 P and 4,500 S wave travel times observed at 52 seismic stations for 349 local earthquakes. They presented the shape of the Moho discontinuity and the upper boundary of the Pacific Plate with P and S-wave velocities at a depth of 0 to 160 km in and around the Hokkaido area. The purpose of this study is to verify the tectonic features of a triple plate junction in Hokkaido via a more detailed and higher resolution three dimensional tomography using a larger and more accurate data set

2. Results and Discussion

Figure. 1 shows profile lines and distribution of earthquakes and seismic station. Closed triangles and closed circles, and open circles indicate seismic station, deep focus earthquakes, and shallow-focus earthquakes, respectively. They are 4050 earthquakes and 238 stations. The subduction features of the Pacific Plate with the double seismic zone(DSZ) were estimated as high Vp/Vs(≥ 1.8) at profiles (a-a'), (b-b'), (c-c') at depth of 40 - 80 km in the upper seismic plane that produces a high seismic activity. Also high Vp/Vs implies that the high seismicity is related to the hydration due to earthquake rupturing process. High Vp/Vs values at profile (b-b') was clearly imaged in HMR at depth of 0-10 km, which are very agreeable with other studies(e.g. Miyamachi and Morita(1984), Katsumata et, al 2004). The high Vp/Vs near HMR is due to the collision of the NE Japan and the Kuril arcs, and also the Pacific

Plate, which result in the uplifting processing in this region. The low velocity zones(LVZ) of P-and S-wave velocities were found at the eastern part along the HMR and the Central Hokkaido.The high Vp and Vs were also observed at profiles (c-c') and (d-d') of the subducting plate beneath the eastern Hokkaido of the Pacific Ocean and especially very high Vs is related to the deep lithosphere block of high specific gravity.

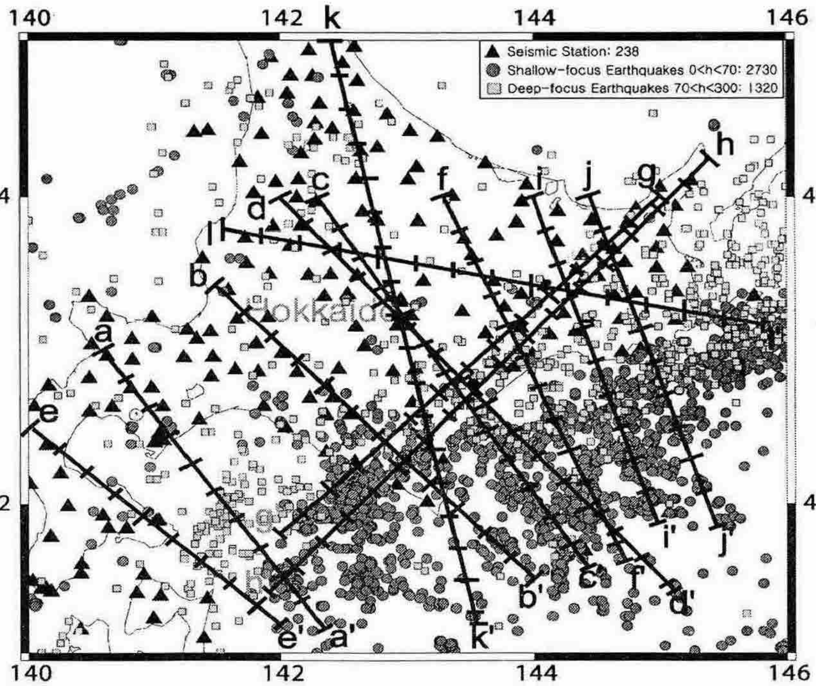

Figure 1. Profile lines

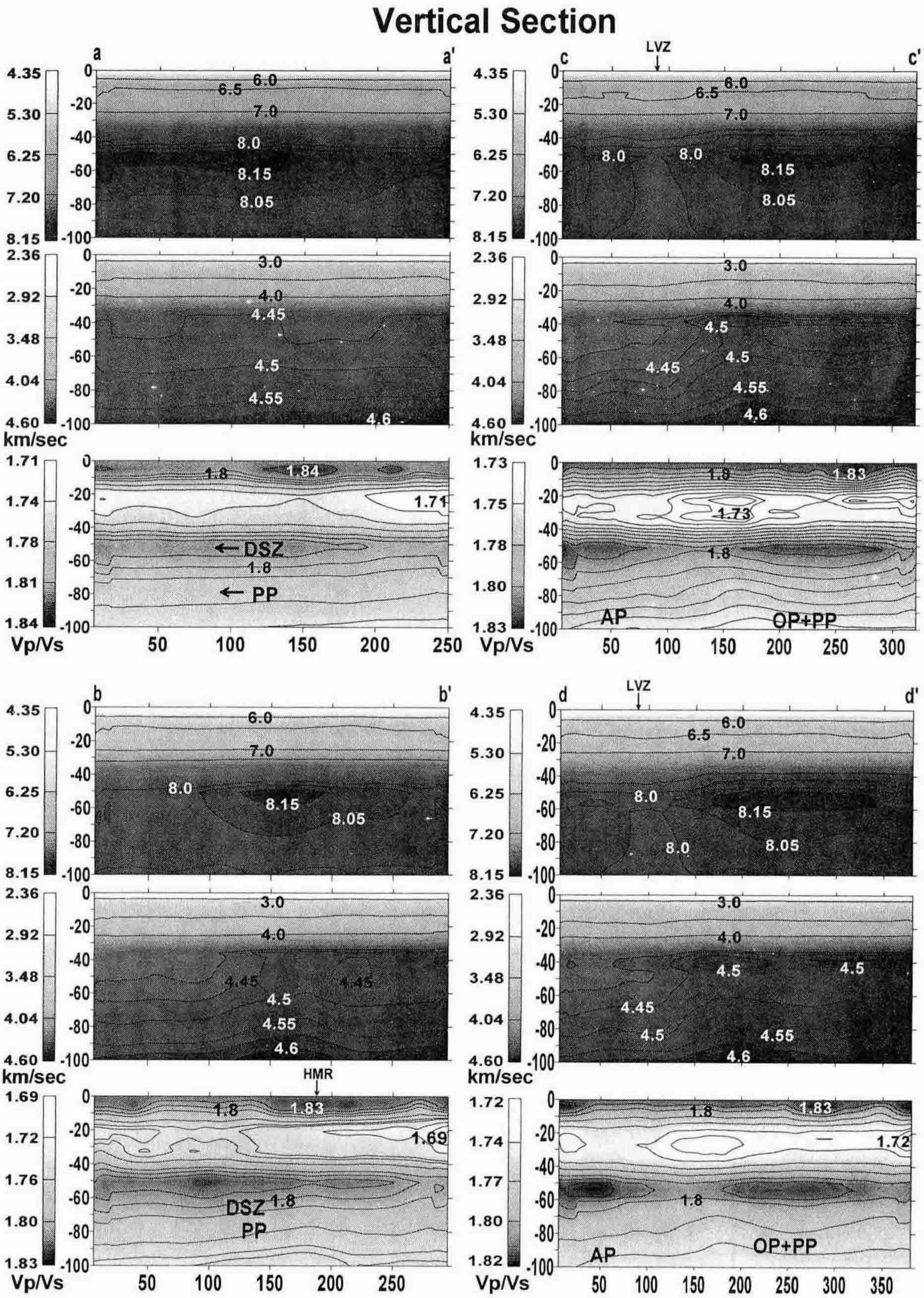

Figure 2. Vertical section of profile lines (a-a'), (b-b'), (c-c'), (d-d')

Acknowledgements

This study was supported by the Korea Meteorological Administration(KMA) and Hanyang University.

Reference

Bijwaard, H., W. Spakman and E. R. Engdahl (1998). Closing gap between regional and global travel time tomography, J. Geophys. Res., 103, 30055-30078.

DeMets, C., R. G. Gordon, D. F. Argus and S. Stein(1994). Effect of recent revisions to the geomagnetic reversal time scale on estimation of current plate motions, Geophys. Res. Lett. 21, 2191-2194.

Katsumata, K., N. Wada and M. Kasahara(2003). Newly imaged shape of the subducting Pacific plate beneath the Hokkaido corner, Japna-Kurile arc-arc junction, J. Geophys. Res. 108, ESE, 5.1-5.23.

Kim, S. G., E. Erdenedalai and P. H. Park(2004). The seismic activity of the Korean Peninsula surrounded by high earthquake countries, J. of Seismology, 8(1), 91-103.

Kim, S. G., M. Kasahara, H. Bae, M. Ichianagi, S. Horiuchi, and H. Negishi(2004).

Study of magma body changes and volcanic activities in Mt. Usu and Tokachi-dake, Hokkaido, Japan using state-of-the-art seismological technique, the Japan Seismological Society, October 9-11, 2004,

Fukuoka, Japan. Kubo, A., E. Fukuyama, H. Kawai, K. Nonomura (2002). NIED seismic moment tensor catalogue for regional earthquakes around Japan: quality test and application, Tectonophys., 356, 23-48.

Miyamachi, H. and T. Moriya(1984). Velocity structure beneath the Hidaka Mountains in Hokkaido, Japan, J. Phys. Earth. 32, 13-42.

Miyamachi, H., M. Kasahara, S. Suzuki, K. Tanaka and A. Hasegawa(1994). Seismic velocity structure in the crust and upper mantle beneath northern Japan, J. Phys. Earth. 42, 269-301.

Miyamachi, H(1994). A method for determination of the three-dimensional seismic velocity structure from local earthquake data, J. Phys. Earth. 42, 239-262.

Moriya, T(1999). Triple collision of Kurile and Northern Honshu crusts and Pacific Plate beneath the southern Hidaka Mountains, Hokkaido, Japan, Abstracts of 1999 Japan Earth and Planetary Science Joint Meeting, Sk-021.

Morita, Y. and H. Hamaguchi(1984). Automatic detection of onset time of seismic waves and its confidence interval using the autoregressive model fitting(in Japanese), J. Seismol. Soc. Japan. 37, 281-293.

Pulliam, R. J., D. W. Vasco and L. R. Johnson (1993). Tomographic inversion for mantle P wave velocity structure based on the minimization of l2 and l1norms of International Seismological Centre travel times residuals, J. Geophys. Res., 98(B1), 669-734.

Roecker,S.W.(1993). Tomography in zones of collision: practical considerations and examples.

In: H.M. Iyer and K. Hirahara(Editors), Seismic Tomography, Theory and Practice, Chapman and Hall, London, 584-612.

Stein, S.(1987). Introduction to Seismology Earthquakes and Earth Structure, Northwestern Univ. Press, 521 p

Takahashi, H., M. Kasahara, F. Kimata, S. Miura, K. Heki, T. Seno, T. Kato, Vasilenko, A. vashchenko, v. Bahtiarov, V. Levin, E. Gordeev, F. Korchagin, and M. Gerasimenko(1999). Velocity field of around the Sea of Okhotsk and Sea of Japan regions determined from a new continuous GPS network data, Geophys. Res. Lett. 26, 2533-2536.

Tarantola, A. (1987). Inverse Problem Theory: Method for Data Fitting and Model Parameter Estimation, Elsevier, 613 p.

Yamamoto, A.(2004). Bouguer gravity map of Hokkaido, unpublished map.

Yamamoto, A.(2004). Dense Clustering of Latest Cenozoic Caldera-like Basibs of Central Hokkaido, Japan, Evidenced by Graveimetric Study, Jour. Fac. Sci. Hokkaido Univ., Ser. VII (Geophysics), 12(2), 75-9