# Contemporary stress field in the Hokkaido Wadati-Benioff zone by inversion of earthquake focal mechanisms – evidence for tearing of the subducting slab

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The study addresses the space distribution of the stress field in the Hokkaido Wadati-Benioff zone based on homogeneous data of earthquake focal mechanisms and the inverse technique by Gephart and Forsyth (1984). The data set used consists of 259 focal mechanism solutions (FMS) listed in the Japan Meteorological Agency Annual Seismological Bulletin, (JMA) and Kosuga et al. (1996) for shallow and intermediate depth earthquakes. The epicentral map of the selected events is shown in fig. 1. The space distribution of the selected earthquakes relatively to the trench axis (across and along the trench) is shown in fig. 2 a, b for five segments across the trench. The detailed analysis of the space distribution of orientation of P (compression) and T (extension) axes of FMS allowed the outlining of two WBZ subvolumes, upper and lower, for which we applied the stress inversion and evaluated the stress field parameters.

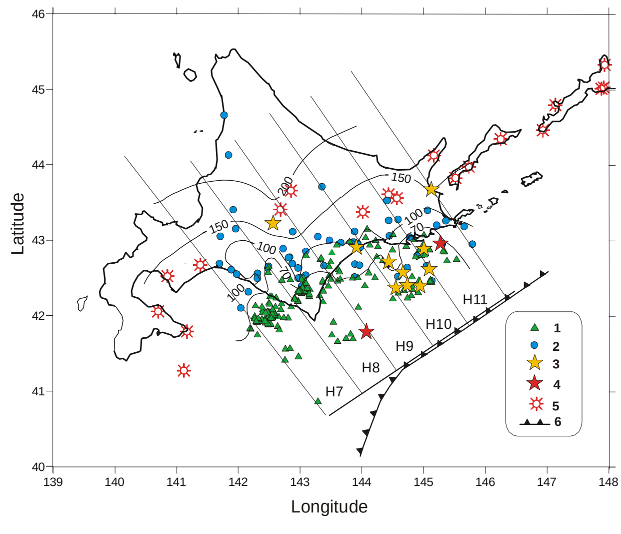


Fig. 1. Epicentral map of earthquakes with available focal mechanisms used for determining the stress field parameters in the Wadati-Benioff zone beneath Hokkaido Island. The epicenters are marked by different symbols depending on the subvolumes of the WBZ they belong to: 1 - the upper WBZ subvolume; 2 - the lower WBZ subvolume; 3 - earthquakes of magnitude 6.0≤Md ≤6.9; 4 - earthquakes of magnitude 7.0≤Md≤8.0; 5 - active volcanoes; 6 - trench axis. The solid lines are the contours of 70 km, 100 km, 150 km and 200 km hypocentral depth and show the dip trend of the WBZ.

A characteristic feature of the two WBZ subvolumes outlined beneath Hokkaido is that the upper subvolume overlies the lower one everywhere but in the southern part of the island (see fig. 2a). The results of the stress inversion are shown in fig. 3. The orientations of the maximum and minimum compressive stresses in the upper subvolume of the Hokkaido WBZ, considered relatively to the local slab geometry, show close to strike normal $\sigma_1$ and down dipping $\sigma_3$. The stress field in the lower WBZ subvolume is characterized by strike aligned $\sigma_3$ dipping north at about 50°, $\sigma_1$ trends SE being strike normal beneath the southern part of the island and slab normal beneath its northern part. The orientations of P and T in the upper WBZ subvolume in central Hokkaido (segment H9) differ significantly from these in the upper WBZ volumes to the south and to the north but are similar to those in the lower subvolume here. The stress inversion results indicate homogeneous stress field in the upper and lower WBZ subvolumes beneath central Hokkaido (segment H9). The orientation of the minimum compression here (strike aligned, trending north) is close to the orientations of $\sigma_3$ in the southern and northern lower parts of the Hokkaido WBZ, while $\sigma_1$ is dipping steeply to WSW. These stress directions, if considered kinematically, indicate that the preferred

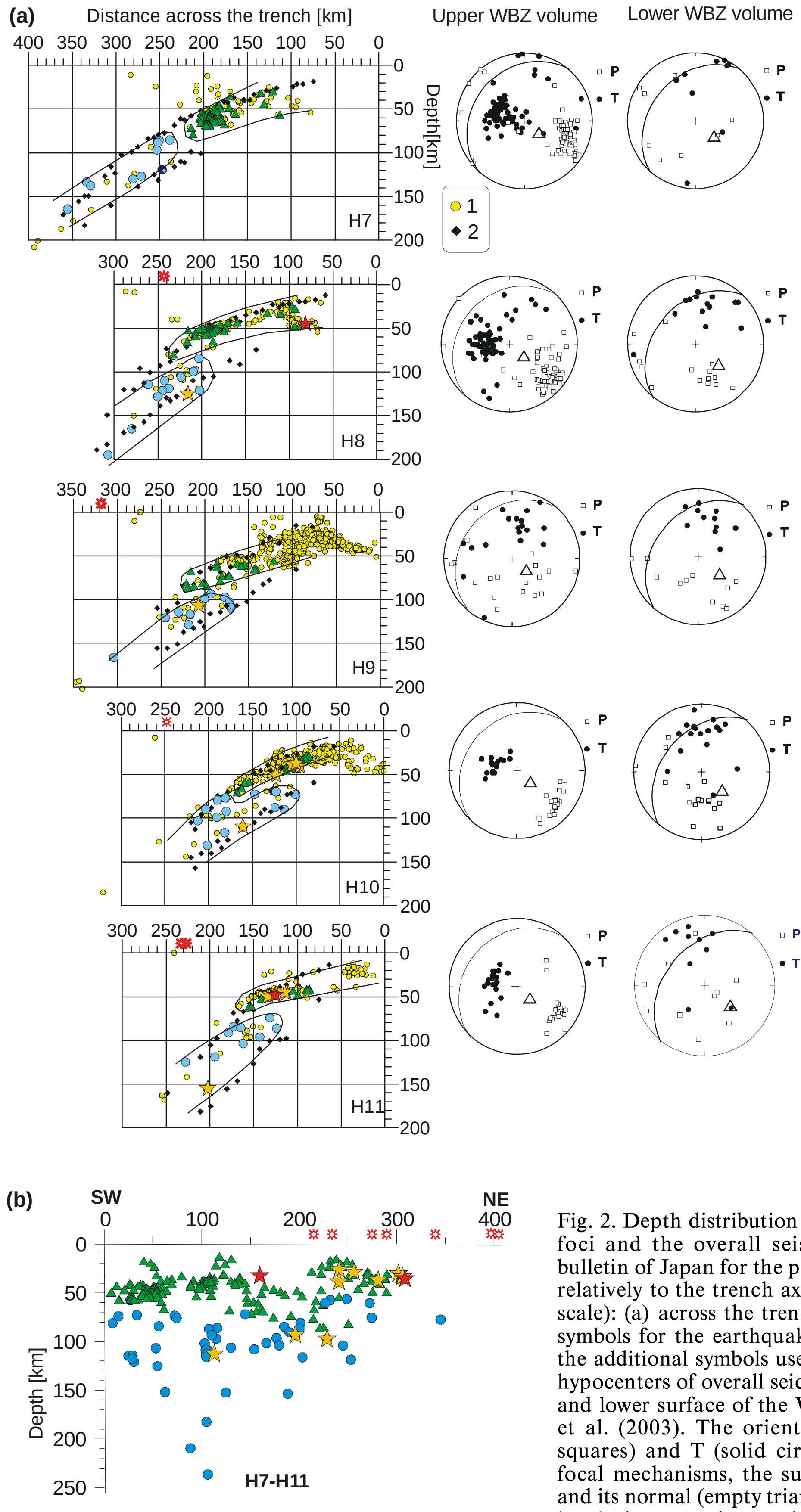


Fig. 2. Depth distribution of the considered earthquake foci and the overall seismicity (JMA seismological bulletin of Japan for the period 2002-2006) to true scale relatively to the trench axis (vertical scale = horizontal scale): (a) across the trench; (b) along the trench. The symbols for the earthquake hypocenters as in figure 1, the additional symbols used are as follows: 1 - the JMA hypocenters of overall seicmicity; 2 - limits of the upper and lower surface of the WBZ according to Katsumata et al. (2003). The orientations of the P (small open squares) and T (solid circles) axes of the earthquake focal mechanisms, the subducting plate (heavy curve) and its normal (empty triangle) are projected onto lower hemisphere equal-area plots for each WBZ subvolume.

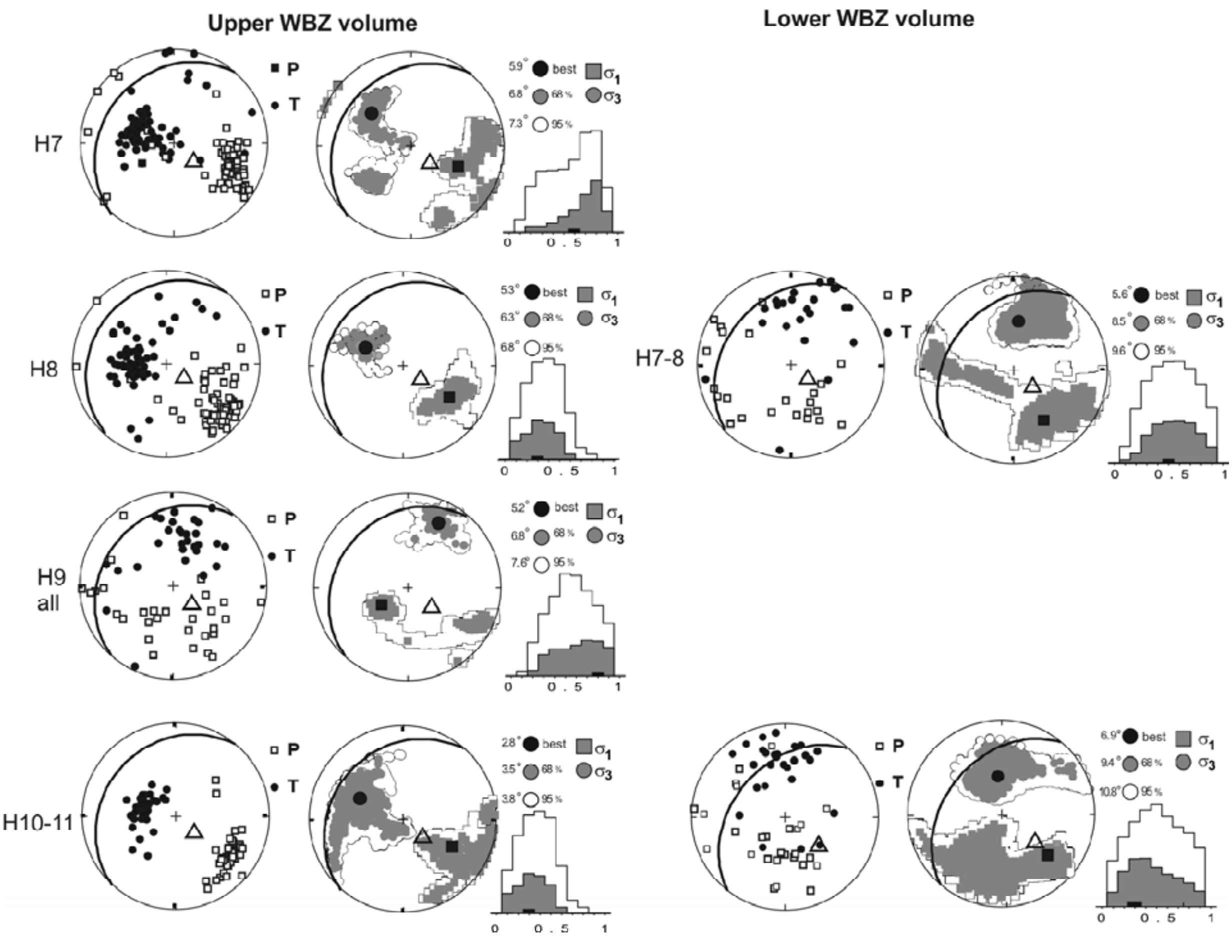


Fig. 3. Depth distribution of the directions of principal stresses in the Hokkaido Wadati-Benioff zone as determined by the stress orientation inversion: the left column depicts the orientations of P and T axes of the focal mechanisms of each data set; the right column shows the directions of the corresponding best-fit maximum $\sigma_1$ and minimum $\sigma_3$ compressive stresses (large solid squares and circles, respectively), as well as their 68% and 95% confidence ranges. The histograms show the distribution of the number of tested stress models within the 68% and 95% confidence ranges relative to the stress ratio R, the best-fitting stress model is indicated by black. The projection of the subducting slab and its normal are denoted by a heavy curve and an empty triangle, respectively. All directions are projected onto lower hemisphere equal-area plot.

faulting occurs at plane that is almost vertical and perpendicular to the strike of the slab (the strike of the trench) with the northern wall moving down and the southern one moving up. The stress regime is of general extension in all the considered subvolumes in the Hokkaido WBZ (Guiraud et al., 1989).

The results of this study clearly indicate for different orientations of the principle stresses in the upper and lower subvolumes of the Hokkaido WBZ. Another new founding of this study is a deformation zone (DZ) located beneath central Hokkaido, which perturbs the stress field in the upper WBZ subvolume. This DZ is perpendicular to the slab's strike and is cutting through the slab, the stresses in the upper and lower subvolumes of it are of similar orientation. The directions of the best-fit stress model in the DZ suggest that its northern wall moves down while its southern wall moves up. We suppose that this new found deformation zone represents a crack or a tear cutting through the entire slab.

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