Contemporary stress field in the Wadati-Benioff zone beneath North Honshu and the Hokkaido corner by inversion of earthquake focal mechanisms – evidences for 3-planar distribution of the stresses

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The study addresses the space distribution of the stress field in the Wadati-Benioff zone beneath North Honshu (NH) and the Hokkaido corner (HC) based on homogeneous data of earthquake focal mechanisms and the inverse technique by Gephart and Forsyth (1984). The data set used consists of 612 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 seven 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 three planar structures in the WBZ for which we applied the stress inversion and evaluated the stress field parameters.

The stress field in Plane 1, low-angle thrust faults, is characterized by shallow dipping and close to strike normal maximum compression **σ1** and down dipping minimum compression **σ3**. Plane 2, the upper surface of the WBZ below 60~70 km in NH and HC, is under slab parallel **σ1** and close to slab normal **σ3** all along NH, while in HC the minimum compression rotates counterclockwise at about 30° relatively to the slab normal. Plane 3, the lower surface of the WBZ, is characterized by close to slab normal **σ1** and close to slab parallel **σ3**. The stress

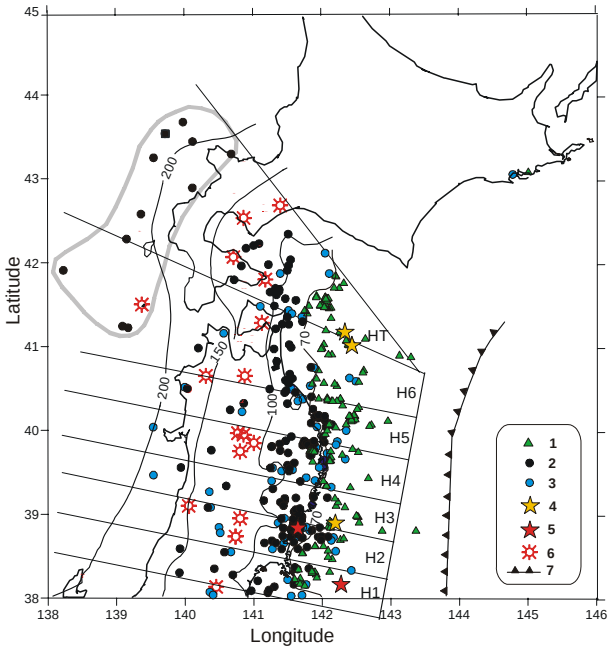


Fig. 1. Epicentral map of earthquakes with available focal mechanisms used for determining the stress field parameters in the Wadati-Benioff zone beneath North Honshu and Hokkaido corner. The epicenters are marked by different symbols depending on the subvolumes of the WBZ they belong to: 1 - Plane 1 (low-angle thrust events); 2 - Plane 2 (the upper surface of the WBZ) and the deep earthquakes; 3 - Plane 3 (the lower surface of the WBZ); 4 - earthquakes of magnitude in the range 6.0≤Md≤6.9; 5 - earthquakes of magnitude in the range 7.0≤Md≤8.0; 6 - active volcanoes; 7 - 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.

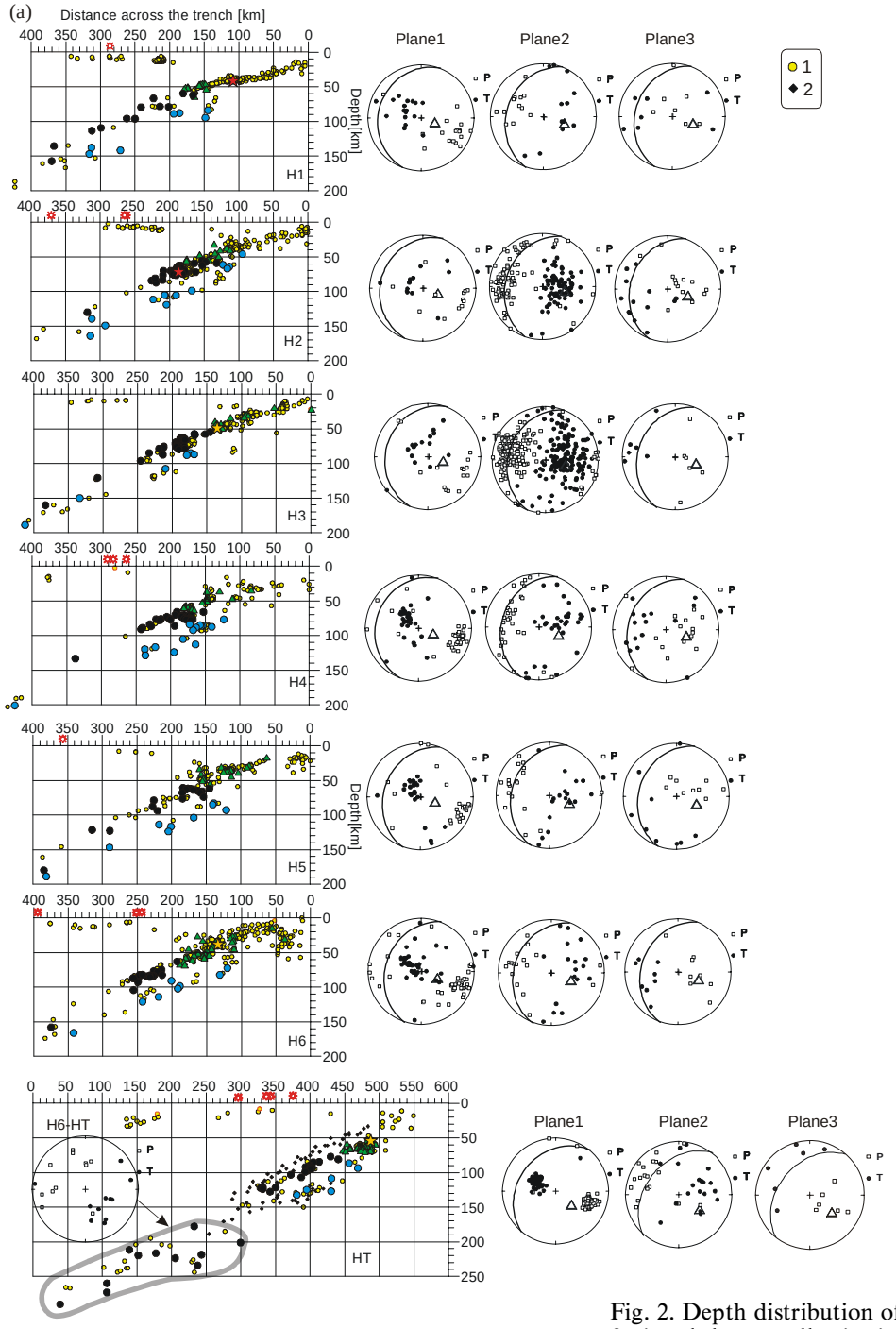


Fig. 2. Depth distribution of the considered earthquake foci and the overall seismicity (JMA seismological bulletin of Japan for the period 2002-2006) to true scale relatively to the trench axis (vertical scale = horizontal scale): (a) across the trench; (b) along the trench. The symbols for the earthquake 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.

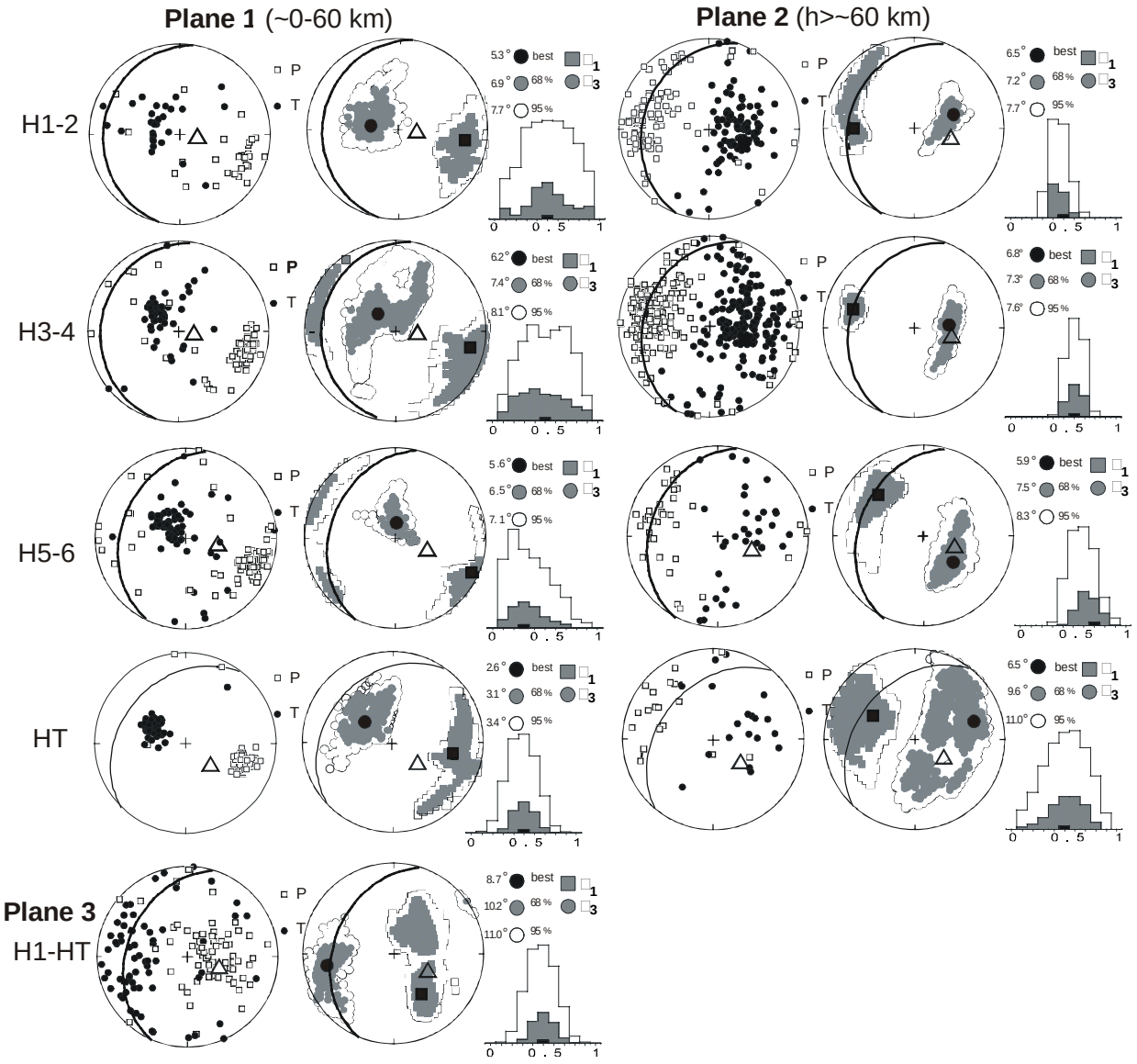


Fig. 3. Depth distribution of the directions of principal stresses in the Nort Honshu and the Hokkaido corner Wadati-Benioff zone as determined by the stress orientation inversion: the left column depicts the orientations of P and T axes of the focal mechanisms of each data set; the right column shows the directions of the corresponding best-fit maximum σ_1 and minimum σ_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.

regime in Plane 1 is of general compression everywhere but in segment HT, beneath the Hokkaido corner, where it is of general extension (Guiraud, 1989). The stress regime in Plane 2 is of general compression, and in Plane 3- of pure extension.

Previous studies on stresses in the study area were based on analysis of earthquake FMS or composite FMS for small and microearthquakes (e.g., Umino, Hasegawa, 1975; Hasegawa et al., 1983; Kosuga et al., 1996). It was found that the WBZ beneath NH and HC has two-planar structure with predominant down dip extension in the upper plane and down dip compression in the lower one. Seno and Pongsawat (1981) found that the WBZ beneath Miyagi Prefecture in NH has a 3-planar structure that consists of a shallow thrust zone and the so-called double-planed seismic zone. Recently, Igarashi et al. (2001) have shown that the 3-planar seismic structure is

continuous throughout northeastern Japan. The results of our study based on stress inversion of FMS clearly indicate 3-planar distribution of stresses in the WBZ beneath North Honshu and the Hokkaido corner.

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