Variations of $b$-values at the western edge of the Ryukyu Subduction Zone, north-east Taiwan

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ABSTRACT

Using earthquakes relocated in north-east Taiwan, we estimated $b$-value distribution along a cross-section located near the Ryukyu slab edge, and four $b$-value anomalous areas are evidenced: (1) a high $b$-value body lying on top of a low $V_p$, low $V_S$ and high $V_p/V_S$ sausage-like body was considered as a region of enhanced partial melt or water supply above which seismicity occurs; (2) beneath the Ilan Plain, an anomalous area characterized by $b$-values slightly higher than 1.1 might give evidence to the magma conduits to the Kueishantao Island; (3) above the Ryukyu Wadati-Benioff zone, at depths ranging from 90 to 110 km, a high $b$-value anomaly might correspond to the depth where dehydration occurs in the subducting oceanic plate; and (4) a low $b$-value area located within the Ryukyu slab, at depths ranging from 70 to 90 km, might be linked to the compressive mechanisms shown by focal mechanisms and the bending of the subducting plate.

Data and method

Relocation of the earthquakes recorded by the Central Weather Bureau (CWB) from December 1990 to May 1999 in northern Taiwan has been performed by Lin et al. (2004). 3370 earthquakes located north of 23.5°N were relocated with the SIMUL2000 program (Thurber and Eberhart-Phillips, 1999) (Fig. 1).

The distribution of earthquakes is not homogeneous in northern Taiwan. Most of the earthquakes are associated with the Ryukyu slab while the shallow seismicity around the Ilan Plain is linked to the backarc opening and the left-lateral motion along the Lishan Fault (Fig. 1). We thus decided to apply the $b$-value calculation along a cross-section located near the Ryukyu slab edge (Figs 1 and 2a).

Along this cross-section, the earth-
Spacing to ensure that a change in than windows with constant width in each sample are preferred rather in cylinder-shaped volumes with varying radii to sample a constant number of radii to sample a constant number ofinder-shaped volumes with varying in function of depth with a 5k m dow was used to analyze the horizontal axis. A sliding spatial win-pling volumes are cylinders around a dergately to the cross-section. Sam-

de selected and projected perpen-
dicularly to the cross-section. The final number of events in each cylinder was a compromise between the spatial resolution and the smoothing effect of large windows and we used 100 events as in similar studies (Wiener and Benoit, 1996; Power et al., 1998). The resolution is thus a function of cylinder radii (Fig. 2g).

The completeness of the earthquake catalogue, i.e. the estimation of the so-called threshold magnitude Mc is critical. In general, the Mc magnitude of a data set is obtained from an $M - \log N$ diagram (cumulative number of events vs. magnitude); we adjusted a straight line to the data, and, following Habermann (1983), we defined Mc as the magnitude below which the distribution departs from the linear regression line (e.g. 3.1 in Fig. 2h). Once Mc values are computed, b-values are calculated at every grid node by using weighted least squares methods (Bender, 1983) (Fig. 2h).

Results and discussion

The resolution of b-values is high (radii < 10 km) around the top of the subducting slab and within the overlying crust and lithosphere (Fig. 2f,g). Only b-values calculated from cylinders with a radius less than 30 km are displayed in Fig. 2f. We chose 30 km as a maximum value to limit the amount of smoothing between grid nodes and to maintain uniformity in the cylinder size. We focus the following discussion on the areas where the spatial resolution is smaller than 20 km (Fig. 2f,g) to ensure that the observed b-value variation represents the real local tectonic structure.

Three areas of high b-value are observed: the largest one is located on top of the low $V_P$, low $V_S$ and high $V_P/V_S$ sausage-like body at depths ranging from 0 to 40 km (1 in Fig. 2f). If the sausage-like body is linked to melt and/or $H_2O$ enriched material (Lin et al., 2004), earthquakes are rather expected to occur around this body. The high b-value feature might be linked to earthquakes produced at the boundary between the sausage-like body and the overlying lithosphere. Within this feature, the highest b-values (~1.5) are observed close to the surface, south of the Ilan Plain. Anomalous heat provided by the rising magma might affect the upper brittle crust and trigger the hydrothermal process near the surface, causing these large b-values.

In the upper crust (0–10 km) near Kueishantao Island, b-values are slightly higher than 1.1 (2 in Fig. 2f). They correspond to the region of the feeding channel imaged by tomo-

ographic results (north-rising red dashed contours in Fig. 2c–g). As Kueishantao Island magma supply may rise up from the lower crust to the surface through numerous conduits, the whole region may be characterized by b-values higher than 1.0. b-values higher than 1.0 are observed between depths of 90 and 110 km, above the Wadati-Benioff zone (3 in Fig. 2f). They are 20% higher than in the adjacent volumes of the wedge. The widely accepted
concept that dehydration of subducting oceanic crust at about 100 km providing fluids which migrate in the overlying mantle (Gill, 1981; Arculus, 1994) may be at the origin of the increase in pore pressure and decrease in the effective stress. Such dehydration processes in subduction zones linked to high b-values were already reported in Alaska, New Zealand and north Japan (Wiemer and Benoit, 1996; Wyss et al., 2001). We consequently suggest that this high b-value region might correspond to the depth where the dehydration process of the subducting oceanic PH plate occurs.

Significantly low b-values are also found within the subducting slab, at depths ranging from 70 to 90 km (4 in Fig. 2f). After earthquakes relocation, Chou et al. (2006) showed that the western extremity of the Ryukyu slab was folded beneath the Ilan Plain at 50–100 km depth, as a result of the collision between the EU and PH lithospheres (Fig. 2b). Horizontal compressive mechanisms were also determined in this area (Kao et al., 1998). According to several laboratory experiments and field studies, a link between low b-values and a rise of ambient stress was proposed (Scholz, 1968; Lahaie and Grasso, 1999; Gibowicz and Lasocki, 2001). We consequently suggest that the low b-values observed within the Ryukyu slab might be because of the compressive mechanisms detected in the portion of folding slab located in the area of convergence between the PH and EU plates. These compressive mechanisms do not exist everywhere in the subducted slab (Kao et al., 1998), and it might be the reason why the low b-value distribution pattern is not observed along the entire slab.

Conclusions

b-values determined along the cross-section located in the vicinity of the Ryukyu slab edge by using Central Weather Bureau relocated earthquakes located within 15 km on each side of the cross-section provide new insights into the convergence area of the PH and EU plates: (1) high b-values lies on top of the low Vp, low Vs and high Vp/Vs sausage-like body, a region of increased partial melting or water supply, suggesting that regions surrounding magma chambers are seismogenic; (2) the magma feeding channel rising from the sausage-like body to the Kueishantao Island is also characterized by b-values slightly higher than 1.1, suggesting that the magma may rise through numerous conduits; (3) above the Ryukyu Wadati-Benioff zone, at depths ranging from 90 to 110 km, the high b-values might correspond to the depth of dehydration of the subducting oceanic crust; and (4) the low b-value region located within the slab, at depths ranging from 70 to 90 km might be linked to the existence of compressive mechanisms evidenced by focal mechanisms and the folding of the Ryukyu slab extremity.

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References


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