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Origin of a foreland-dipping seismogenic zone and its basal decollement in southwestern Taiwan

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ABSTRACT

An unusual foreland-dipping seismicity band has been identified at a depth between 7 and 25 km beneath the Coastal Plain, a foreland basin, in southwestern Taiwan. This seismogenic zone is closely associated with abrupt changes in Vp/Vs based on our new high-resolution seismic tomography. Rocks with high Vp/Vs ratios of up to 1.84 were found directly above the inclined seismicity band. Below it, the Vp/Vs ratio dramatically drops to about 1.72–1.78. We found that this change may result from illite-bearing slates transforming to muscovite-bearing phyllite/mica-schist. Previous studies suggested that the frictional instability regime for illite–quartz gouge and muscovite–quartz gouge falls in the range of 250–500 °C. We calculated the isotherms based on regional heat flow data and found that the foreland-dipping seismicity band can well be bounded between the 250 °C and 500 °C isotherms. In addition, in the same temperature range wet illite/hydromuscovite would transform to muscovite and release water. This dehydration may elevate pore pressure and facilitate the formation of an incipient decollement at the base of the seismicity band in front of the mountain belt. The hypothesis that such a decollement exists is supported by the existence of a corresponding zone of low resistivity and also by the geometry of the earthquake of October 22, 1999. The latter clearly shows a fault branched off the basal decollement with an angle about 45°. This finding implies that the effective friction coefficient of the basal decollement is at least 23% less than that of the overlying rocks.

1. Introduction

The formation of a basal decollement is fundamentally important in revealing the mechanics of mountain building. The geometry of a basal decollement and the strength contrast between the basal decollement and the overlying mountain belt may affect the internal structural styles and morphology of the mountain belt (Davis et al., 1983; Dahlen, 1990). The Seismic expression of an active decollement often exhibits a hinterland-dipping band of microearthquakes beneath the mountain belt, where the decollement is at the base of the seismicity band (Carena et al., 2002; Mouthereau and Petit, 2003). The mechanisms responsible for the generation of a seismicity band beneath an active mountain belt may be complex, involving the intrinsic frictional properties of the fault-zone materials, the geometry of the fault surface and the pressure and temperature conditions (Rubin et al., 1999).

The formation of a decollement beneath a seismicity band may vary between different geological settings. Some decollements are associated with intrinsic low strength lithology such as rock salts, talc, smectite, and illite (Davis and Engelder, 1985; Davis and Mosher, 2015; Tesei et al., 2015). Often, excess pore pressure may be responsible for the formation of a weak decollement (Suppe and Witteke, 1977). Dehydration is one of the processes that elevates pore pressure in a decollement, such as the transition from gypsum to anhydrite in the Alps (Ko et al., 1997; Sonnete et al., 2014), and from saponite to chlorite in the Naikai Trough (Kameda et al., 2017).

While the decollement beneath a mountain belt is usually hinterland-dipping (e.g., Carena et al., 2002; Suppe, 2007), a number of studies have shown that opposed dipping decollement may occur close to or in front of the deformation front (e.g., Zapata and Allmendinger, 1996; Cristallin and Ramos, 2000; Barnes and Nicol, 2004). The mechanics behind the formation of an opposite-vergence decollement beneath a foreland basin remain unclear. In this study, we report a foreland-dipping seismic band associated with a drastic change in Vp/Vs ratio at depths between 7 and 25 km under the Coastal Plain (a foreland basin) in southwestern Taiwan, which has never been paid attention before. The questions addressed in this study include (1) Why is the seismic band foreland-dipping? (2) Why is the seismicity confined to a particular depth range? (3) Why is the seismicity band closely re-

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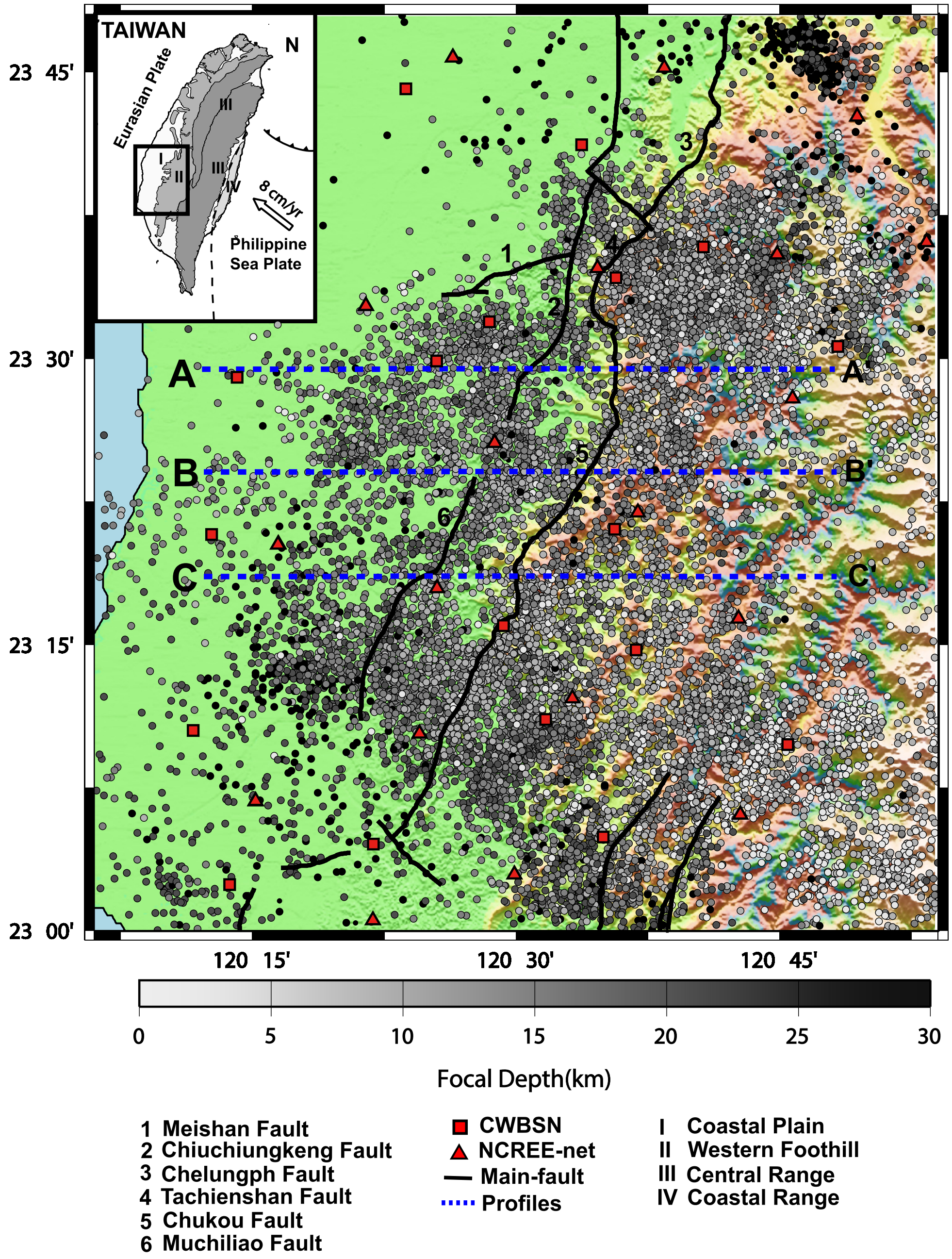

Fig. 1. Map of the study area. The rectangles depict the Central Weather Bureau Seismic Network (CWBSN) and the triangles depict the seismic network deployed by the National Center for Research and Earthquake Engineering (NCREE). The dots denote the earthquakes occurred during 2003–2015, and the black lines denote active faults.

lated to the abrupt change in Vp/Vs ratio? The relation between the decollement and the seismicity band as well as the possible strength contrast between the decollement and its overlying rocks are also discussed.

2. Seismic tomography

We collected the arrival time data of P and S waves recorded by the Central Weather Bureau Seismic Network (CWBSN) and National Center for Research and Earthquake Engineering (NCREE) in Taiwan from the period 2003 to 2015 (Fig. 1). The 3D seismic velocity inversion code (Simulps2000) employed was originally developed by Thurber (1983) and later modified by Eberhart-Phillips and Michael (1998). Fig. 1 shows our study area. 13,988 events were selected in the study area with more than six readings of the P- and S-wave first arrivals for each event. We also set a constraint that the ERH (error in horizontal components) and ERZ (error in vertical component) were less than 5 km and 10 km, respectively calculated by the code Hypo71 (Lee and Lahr, 1975). In total, 127,591 P-wave and 121,797 S-wave arrival times were chosen for 3D seismic velocity inversion.

The size of the horizontal mesh of the model is 5 km × 5 km and non-uniform vertical grid spacing was employed. The detailed model mesh design and the model resolution are described and shown in Supplementary Material. We chose an *a priori* 1-D P-velocity model of Yeh et al. (2013) as a starting model. Fig. 2 shows three cross sections from our velocity inversion results. Interestingly, beneath the Coastal Plain, a foreland-dipping seismicity band was found to be located in the region showing a drastic change in the Vp/Vs ratio. Above the seismicity band, the Vp/Vs ratio is about 1.80–1.84 with relatively low P-wave velocities, and below it, the Vp/Vs ratio drops to 1.72–1.78 with relatively high P-wave veloci-