別紙４

報告番号	※　　　　　　　第　　号

主　論　文　の　要　旨

論文題目　Tectonic deformation and earthquake hazard in Northwestern Vietnam inferred from GPS observations
（GPS 観測に基づくベトナム北西部の造構性地殻変動と地震ハザードの研究）

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論　文　内　容　の　要　旨

Northwestern Vietnam (NWV) is the most seismically active region in Vietnam with a complicated geological structure, dominated by many active faults, such as the Dien Bien Phu Fault (DBPF), the Son La Fault (SLF), and the Da River Fault (DRF). I utilize GPS measurements in order to clarify the tectonic affiliation of NWV and constrain crustal deformation across the major faults as well as its implications for the earthquake hazard.

In this study, a dense GPS network with 22 campaign sites concentrated on the DBPF, SLF, and DRF zones in NWV occupied from 2001 to 2012 is utilized to resolve the small relative motions along the faults, as well as to better understand tectonic loading processes in this region, which has not been thoroughly studied. Horizontal velocity is accurately estimated at each GPS site in ITRF2008 by fitting a linear trend to each coordinate time series. During this procedure, coseismic offsets caused by three great earthquakes, the 2004 Sumatra (M9.1), the 2008 Wenchan (M7.9), and the 2011 Tohoku (M9.0) earthquakes, are taken into account because even coseismic offsets from very distant earthquakes may be significant in an area like NWV where tectonic deformation rate is small. Theoretical calculation of coseismic displacement with an elastic sphere model shows that the horizontal displacements in NWV from the 2008 Wenchuan earthquake are less than 1 mm and so insignificant. While, the 2004 Sumatra earthquake caused

southwestward movement of about 15 mm and the 2011 Tohoku earthquake moved the area in the opposite direction, by 1.2 mm to the east and 0.5 mm to the north. Therefore, only the calculated coseismic offsets caused by the 2004 Sumatra and the 2011 Tohoku earthquakes are taken into consideration.

Along these fault zones, the present-day relative movements have been geodetically estimated in previous studies, however they are less adequately estimated due to the sparse distribution as well as the short time span of GPS sites. Through an analysis with the dense GPS network data in NWV, it is recognized that the left- and right-lateral motions take place across the DBPF and SLF-DRF zones, respectively, which is consistent with geological studies. In addition, spatial variation of the fault slip-rate along the DBPF is geodetically revealed for the first time. By applying dislocation models to displacement patterns across these fault zones, the locking depth and the slip rate of the DBPF are estimated as 15.3 ± 9.8 km and 1.8 ± 0.3 mm/yr, respectively. A shallow locking depth (with a large uncertainty) and a right-lateral slip rate of about 1.0 ± 0.6 mm/yr are estimated for SLF and DRF. As for the DBPF, 91% of hypocenters are located shallower than 15.3 km, which is comparable to the GPS-derived locking depth. Thus the GPS and seismological observations consistently suggest the effective thickness of the locked zones.

For the earthquake potential assessment, the strain rates, moment accumulation rates, possible magnitude of seismic events and their recurrence intervals are estimated for DBPF, SLF, and DRF by applying empirical relationship regressions to the estimated fault slip rates and the locking depths. This study recognizes that earthquakes with maximum magnitude as large as 6.0 could happen in the middle part of SLF and DRF zones, while the DBPF zone could have events with a magnitude probably reaching 6.7.

The strain rate field is calculated from the velocity filed. As a result, the study indicates that NWV is a deformation zone with the strain rate of 2.42×10^{-8} per year. The principal compressive strain rate axes gradually change from the NW-SE direction to the N-S direction in the areas from west to east. This corresponds well with tectonic deformation during the Pliocene - Quaternary times with the predominately sub-longitude compressive stress field reflected by the long-term geological survey. The estimate principal strain rate axes are compatible with source mechanisms of nearby earthquakes.

Before this study, NWV was originally considered to be a part of the Eurasian plate. With increasing number of precise geodetic observation, it turned out that the NWV forms a border between the South China block (SC) and the Sundaland block (SU). The Red River Fault (RRF) in NWV has been regarded as the northeastern tectonic boundary between SC and SU accommodating right-lateral shear strain. This study clearly states that NWV is in a transition zone between SC, SU, and the Baoshan sub-block (BS), although its motion is close to, but slightly different from, that of SC. Significant effect from BS in the tectonic deformation in NWV is first identified through precise geodetic measurements referring to the global reference frame. As a result of this study, the RRF is considered to be the northeastern end of the transition zone. Thus, by using the dense GPS observation network in NWV, the thesis provides a new insight into large-scale tectonics in Southeast Asia. The relative motion between SC and SU is partly accommodated by the NW-SE trending fault zones such as SLF, DRF, and RRF, but other faults to the south of the current study area in central Vietnam could be also responsible. However, because of the slow relative motion between the SU and SC blocks and the scarcity of precise space geodetic measurement, the actual extent of the transition zone to the south is still uncertain. The thesis suggests that it is necessary to expand the GPS network to the south of the current study area in order to clarify the deformation accommodation style between SC and SU.