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主 論 文 の 要 旨

論文題目 Tectonics and seismic potential along the Caribbean subduction zone in northwestern Colombia based on GeoRED GPS data

(GeoRED GPS データに基づくコロンビア北西部カリブ沈み込み帯のテクトニクスと地震ポテンシャル)

氏　　名 LIZARAZO Sindy Carolina

論 文 内 容 の 要 旨

The Caribbean coast of northwestern Colombia is a region where complex tectonic interactions are taking place between the main oceanic Caribbean plate and several continental blocks known as North Andean, Panamá, Maracaibo, and Bonaire blocks. The existence or lack of subduction of the Caribbean plate beneath the North Andean block margin has been a matter of debate given the absence of a well-defined Wadati-Benioff zone and shallow seismic (and tsunami) activity in instrumental and historical written records. As a result, studies to decipher the Caribbean's seismic/tsunami potential are far from sufficient, which translates into potentially ignored hazards that could have large impacts on the region. Then, it is essential to carry out analyses on this subject.

Existence of an earthquake cycle and seismic potential along a plate subduction zone can be identified through geodetic approaches. Recent dense precise GNSS observations around the world revealed significant strain accumulation during the interseismic period. I made use of the improved spatio-temporal dataset from the GeoRED project (GEOdesia: Red de Estudios de Deformación in Spanish) of the Geological Survey of Colombia (SGC) to determine interseismic velocities of 87 continuous GPS sites for the period 2008-2017 under the ITRF2014 reference frame. Based on these data, I described motion trends of interacting tectonic plates/blocks in Colombia, which shows general consistency with previous studies. Thanks to the improved spatial resolution of the network, a new tectonic affiliation in the northern part of the country named Macondo block is identified. This interpretation contradicts the previous tectonic framework and has important implications regarding the plate kinematics in northwestern Colombia with a very slow subduction of the Caribbean plate at about 7 mm/yr. In addition, a prevailing compressive pattern of deformation is revealed from horizontal displacement rates, which concentrate mostly along subduction and collision margins, including the Caribbean subduction zone with strain rates of ~65 nanostrain/yr.

The localized contraction at the Caribbean coast of Colombia is intriguing. In order to elucidate if it is due to an ignored seismic potential, an interplate coupling analysis is conducted by inverting 3-dimensional GPS data assuming an elastic half-space medium. The results revealed a locked region on the plate interface offshore Cartagena city, which could cause a M_w8.0 earthquake every ~600 yr based on the size of the locked region and the slow subduction velocity of the Caribbean plate with respect to the Macondo Block. This seismic event could potentially trigger a tsunami considering the shallowness of the asperity. This interpretation seems to be validated by the consideration of the Caribbean northwestern Colombia as one of the slowest subduction zones characterized by "invisible" megathrust earthquakes and tsunamis occurring over very long recurrence intervals and for which, there is a lack of historical records as well as geological studies. Although the model explains horizontal deformation, a remaining problem is the reproduction of vertical motions, in particular, the large coastal subsidence.

Assuming the Caribbean coast of Colombia is the locus of a future megathrust event that is approaching the final stage of the interseismic period, new modeling is conducted to improve overall data fitting, especially in the vertical component, by taking a regular recurrence of large earthquakes and viscoelastic relaxation of the asthenosphere into account, since it has been proved significant when the recurrence interval is much longer than the relaxation time. Also, the sensitivity of surface deformation to parameters such as the lithospheric thickness, the asthenospheric viscosity, and the earthquake recurrence interval is tested. This modeling attempt confirms the Caribbean subduction zone as a potential locus of a M_w8.1 type earthquake with a recurrence interval still consistent with the absence of historical records and previous estimates. It also reproduces observed velocities to a better degree than the elastic coupling model according to 3-dimensional WRMS values. In this regard, it is demonstrated that early postseismic effects following an earthquake play an important role in increasing interseismic coastal subsidence and then, have important implications regarding the correct interpretation of the geodetic data in terms of seismic and tsunami hazards. Coseismic and postseismic uplift at coastal regions are completely recovered in one earthquake cycle, suggesting that tectonic activity at the subduction interface does not leave a permanent signature in the coastal topography. Regarding the tested parameters, the lithospheric thickness acts as a controlling parameter of the deformation, but the viscosity or recurrence interval assumptions are insensitive and cannot be constrained from the available observation data.

Both the elastic and viscoelastic models conclude the Caribbean subduction zone can potentially generate a M_w8.0 – M_w8.1 earthquake possibly followed by a tsunami in northwestern Colombia for which there is no adequate hazard mitigation and management plans. Besides, if the event takes place in the near future, regional impacts would be devastating. Despite the fact there are no historical records, the absence of these events should not be taken lightly. The slow nature of the subduction zone produces megathrust over long recurrence times (several hundreds or thousands of years), which cause the earthquakes remain disguised in a seismic quiescence. It remains a challenge for forthcoming studies to integrate paleoseismology and paleotsunami information to corroborate the present dissertation hypothesis and to improve the seismic potential assessment in the Caribbean of Colombia. Additionally, reconciliation of short- and long-term strain inconsistency can be provided by acquiring new geodetic and geological data (older marine terraces) in order to reduce the uncertainties of each observation. Subsequent modeling is needed to solve the time scale discrepancy and to propose a full contemporary/long-term interpretation of the deformation signals.