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主　論　文　の　要　旨

論文題目　Crustal Movements in Colombia based on GPS Space Geodesy with the GeoRED Network

（GeoRED 観測網の GPS 宇宙測地観測に基づくコロンビアの地殻変動）

氏　　名　MORA PÁEZ　Héctor

論　文　内　容　の　要　旨

The northwestern corner of South America, the southeastern of Central America and the Caribbean plate correspond to a wide plate convergence boundary. The tectonic and volcanic activity in this zone is a result of the interaction of the oceanic Cocos, Nazca and Caribbean plates, and the continental South American plate as well as the North Andean, Maracaibo, Chocó and Panamá blocks wedged in between, as was exposed by various studies. This highly complex tectono-dynamic situation of intense intraplate deformation is observed in a high density of faults, most of which are considered active or potentially active over northwestern South America and southeastern Central America. Also, the seismicity is spread over a broad area across the wide plate boundary in northwestern South America, Central America, and southwestern Caribbean, whose complexity was referred as a “Wide Plate Margin”. This, coupled with a potential of large magnitude megathrust and tsunami events related to the Pacific subduction zone, means that a high percentage of Colombia’s population lives under a constant threat of unannounced large magnitude earthquakes and tsunamis, with a potential of inflicting great damage in terms of loss of lives and destruction of infrastructure.

Given the tectonic complexity in the mentioned region and the high possibility of occurrence of large earthquakes and tsunamis as well as volcanic eruptions among other hazards of geological origin, systematic studies to establish a monitoring system for the current situation of crustal deformation using space geodesy techniques is of great importance. In Colombia, the establishment of an adequate network of GPS stations covering the entire Colombian territory, named GeoRED project, has begun to contribute to the understanding of the crustal dynamic processes. During the last decade, the main focus and efforts have been directed to the design and installation of the network. Generation of a steadily increasing stream of data has permitted, until to date, to construct a sufficiently detailed velocity field that is capable of registering the process of tectonic escape of the North Andean Block.

Using data from 60 permanent GPS stations from Colombia, Ecuador, Panama, Costa Rica and Venezuela, located on the Nazca, South American, Cocos and Caribbean plates, a new velocity field was estimated in ITRF2008.

By combining the velocity data obtained in this study and those in Ecuador, a new comprehensive model of the North Andean Block (NAB) was estimated, with a motion estimate of 8.6 ± 1.0 mm/yr with respect to the South American plate (SOAM) in the N60°E direction. This NAB velocity can be resolved into a margin-parallel component of 8.1 ± 0.7 mm/yr and a margin-normal component of 4.3 ± 0.6 mm/yr, assuming an average trend of N35°E of the NAB-SOAM margin based on the general direction of the eastern edge of the Eastern Cordillera in Colombia between latitudes 1° and 7° N. Various mechanisms responsible for the tectonic escape of the NAB are considered such as the collision of the Carnegie ridge, the rapid oblique convergence of the Nazca plate along the Colombia-Ecuador trench, and the high coupling at the Nazca-NAB subduction plate interface. Among them, the last two are clearly demonstrated with GPS results.

The GPS velocity field allows to observe the oblique subduction of the Nazca plate at a rate of 54.1 ± 0.4 mm/yr in N87°E direction with respect to the South American plate, based on two GPS stations. Given the limited number of GPS stations located on the Nazca plate, a GPS station of the GeoRED network on the Malpelo Island (Colombia), the only island in the northern part of the Nazca plate, allows refining the motion of the Nazca plate. Velocity vectors at stations located on the Pacific coast of Colombia reflect clear evidence of strain accumulation on the Nazca subduction zone.

The oblique convergence of the Caribbean plate with respect to the South America plate is represented by the velocity of stations installed in Colombian islands located on the Caribbean plate. The velocities of those stations are 17.6 ± 0.6 mm/yr in the S100°E direction with respect to the South American plate. This plate motion is probably absorbed at the South Caribbean Deformed Belt, which is a submarine prism that was formed at the interface between oceanic material that is subducting in the basins of Colombia and Venezuela, and arc terranes along the northern edge of the South American plate.

There is geodetic evidence of the active collision between the Panama block and NAB. Although the Atrato-Uraba Fault Zone is a candidate location of the boundary, the collision boundary is diffused over a wide area in the range of 200 to 300 km. This feature is reflected in the east components of the velocities with respect to NAB. In order to distinguish the effect of the Nazca plate or the Panama block, an analysis was performed using a velocity diagram, finding a combined effect of the subduction of the Nazca plate and the collision of Panama at BASO station (6.203°N,77.393°W). But it is not possible to distinguish which of the two effects is more representative.

In southwestern Colombia, GPS velocities obtained from GeoRED network were significantly different from those observed in 1990's. Postseismic deformation associated with the M_w 8.2 earthquake on December 12, 1979 is considered to be a candidate mechanism for this difference and a viscoelastic relaxation effect due to this earthquake was evaluated for 40 years after the occurrence of the earthquake using the viscoelastic-gravitational dislocation theory. It is concluded that the postseismic effect was significant in 1990's when the first space geodetic measurements were conducted in Colombia while the effect has faded out in 2010's, resulting in a significant velocity changes in southwestern Colombia. The consistency between the observation and the model implies that the mantle viscosity along the Nazca subduction is around 10^{19} Pa・s, consistent with other major subduction zones.

From the velocity field obtained in this dissertation, a margin-normal shortening across the Eastern Cordillera of Colombia is estimated less than 4.1 mm/yr. This observation is not consistent with paleobotanical studies of the uplift history of the Eastern Cordillera that suggest a rapid uplift (7 km) and shortening (120 km) during the last 10 Ma. As an alternative scenario regarding mountain building and shortening in the Eastern Cordillera of Colombia due to the collision of the Panama block, a "broken indenter" model for the Panama-Choco arc is proposed. The model considers that the Choco arc has been recently (1-2 Ma) accreted to the NAB and the shortening as well as the uplift rate at the Eastern Cordillera drastically decreased.