論文内容の要旨

論文題目

Multiple collision and subduction structure of the Izu-Bonin arc revealed by integrated analysis of active and passive source seismic data

（制御震源・自然地震データの統合解析に基づく伊豆小笠原弧多重衝突・沈み込み様式の解明）

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The Japanese Islands are composed of several island arcs along the subduction zones developed in the eastern side of the Asian Continent. The NE Japan arc is overriding the subducted Pacific plate, while the Philippine Sea plate (PSP) is subducted beneath the SW Japan arc. The Izu-Bonin arc (IBA), the intraoceanic volcanic arc located south of the Honshu arc, has been developed in the eastern part of the PSP associated with the subduction of the Pacific plate. Since the middle Miocene, this volcanic arc has been colliding with the Honshu arc in central Japan associated with the northwestward motion of the PSP and back arc opening of the Sea of Japan. This collision process is responsible for an extremely complex crustal structure of the Izu collision zone (ICZ).

The collision process of the IBA is known as “multiple collision” where several crustal fragments derived from the IBA including the Koma Mountains, the Misaka Mountains, the Tanzawa Mountains and the Izu peninsula, were accreted onto the Honshu crust at different ages (e.g. Amano, 1991). These crustal blocks are separated by several tectonic boundaries represented by the Sone Hills Faults (SHF), the Tonoki-Aikawa Tectonic Line (TATL) and the Kozu-Matsuda Faults (KMF), respectively. The subduction zone associated with the PSP is also developed on both sides of the ICZ; the Sagami trough in the eastern side and the Suruga trough in the western side. Although collision and subduction structure of the IBA has been elucidated for some parts of the ICZ by the previous geological/geophysical researches, the whole crustal structure including the Misaka, Tanzawa and Izu blocks together with the subducted PSP has not been elucidated as yet. Furthermore,

there are almost no studies describing physical property of the slab beneath the ICZ despite its great importance for understanding the features of the subducted island arc crust.

This thesis aims to reveal the whole structure formed by the multiple collision and subduction ongoing in the ICZ and to establish the model of crustal deformation process in this region. This study is also expected to contribute to understand seismic activity in the collision zone because the mechanism of earthquake generation is strongly controlled by structural heterogeneity. For these purposes, the information on the following three aspects are inevitably important; (1) configurations of collision boundaries and slab, (2) structural relationship between collision part and subduction part of the IBA, and (3) physical property of the subducted part of the IBA. To achieve this goal, I performed integrated analysis of seismic data so far acquired in this region. I collected active source seismic data from five seismic experiments conducted in and around the ICZ. To these data sets, I applied intensive refraction/wide-angle reflection analysis to obtain fine-scale collision and subduction structure. Furthermore, passive source seismic data recorded in the seismic network densely distributed in the ICZ were also added in the tomographic analysis in order to map a deeper subduction structure as well as shallow structural variation in the southern part of the ICZ, for which active source data did not have enough resolving power.

Based on refraction/wide-angle reflection analyses for active source data, I revealed the collision and subduction structure in the eastern and western parts of the ICZ. The structural model in the eastern part is characterized by significant lateral velocity variation in the shallow crust and a north dipping reflector into the deep crust associated with the TATL, the collision boundary between the Kanto Mountains in the Honshu arc and the Tanzawa block in the IBA. From P wave velocity and geometry of reflectors, the Tanzawa block was delaminated from the subducted lower crust to form a wedge-like body thrusting between the upper and the lower crust of the Honshu arc.

In the western part, the fine-scale velocity structure in the shallow part was constructed from first arrivals and travel times of several reflection phases from the upper crustal levels. The deeper structure was mainly constrained from reflected waves from the slab. The obtained structure showed the prominent multiple collision system of the Misaka, Tanzawa and Izu block. The low velocity zones were well developed corresponding to the locations of the collision boundaries (SHF, TATL and KMF). The northernmost collision boundary (SHF) dips southward, which is in a clear contrast with northward dipping boundaries (TATL and KMF) in the middle and southern parts of the profile. The northernmost part of the IBA, namely the Misaka block, obducted onto the Honshu arc along the SHF. The upper parts of the Misaka and Tanzawa blocks were delaminated from the middle/lower crust. The Misaka block is bounded by the southward dipping SHF from the north and the northward dipping TATL from the south, forming a “pop-up” structure in the present compressional stress regime, while the Tanzawa block shows crustal stacking characterized by northward dipping boundaries. On the other hand, the whole crust of the Izu block was found to be subducted beneath the Tanzawa.

A north-dipping interface at 25-35 km depth deduced from the wide-angle reflection represents the top of subducted part of the IBA. The velocity just beneath this interface is 7.0-7.1 km/s, which corresponds to the lower crustal velocity of the IBA. The volume of the obducted/accreted parts of the IBA is much smaller than the total volume of the IBA which collided/subducted since 15Ma. This indicates that the middle part of the IBA have been stacked beneath the Honshu arc. Actually, the P wave velocity in a depth range of 15-35 km above the subducted lower crust is 6.7-6.9 km/s, which is comparable to that of the middle crust of the IBA.

The structure and physical condition of the subducted part of the IBA was revealed by amplitude modeling for active source data and seismic tomography analysis incorporating active and passive source data. The amplitude analysis of wide-angle reflection from the top of the subducted crust indicated that the impedance contrast between the overriding crust and the subducted lower crust is small. This is in a marked contrast with the case of Nankai subduction zone, where very strong reflection is generated by a low velocity layer on the top of the plate boundary. This low velocity layer is considered to be formed by the trapped water dehydrated from the oceanic lithosphere.

According to the combined analysis of the active source and passive source data, the middle/lower crust of the Izu block with P wave velocity of 6.5-7.0 km/s is subducted beneath the Tanzawa without delamination. The subducted middle crust is characterized by very high seismic activity. The Vp/Vs ratio of this part showed an intermediate value, indicating the composition of hornblende gabbro in dry condition (Nishimoto et al., 2008). The *b* value obtained for this seismicity showed a low value of 0.6-0.8. These results of the Vp/Vs ratio and the *b* value suggested low water content and poor dehydration reaction in the subducted IBA crust, which is consistent with the low impedance contrast at the top of the slab described above. Thus, it is concluded that the role of dehydrated fluid is not significant for this seismic activity.

Based on the new findings obtained in this study, I propose a new multiple collision and subduction model of the Misaka, Tanzawa and Izu blocks summarized by Figure 7.2. The northernmost Misaka block collided at 15-12 Ma, and its upper crust was delaminated from the descending middle/lower crust, and obducted onto the Honshu crust. The Tanzawa block experienced the similar process of delamination at 8-3 Ma. The collision form of the Tanzawa block is characterized by the crustal stacking with northward dipping boundaries. Considering mass balance of collision, a large portion of middle/lower crust of the Misaka and Tanzawa blocks were accreted beneath the Honshu arc and/or subducted into the mantle. In contrast with the Misaka and Tanzawa blocks, the whole crust of the Izu block is subducted at least beneath the Tanzawa block. The subduction process is closely related to the seismic activity because the remarkable seismicity occurs within the subducted middle/lower crust of the Izu block. This seismicity also implies a possibility that crustal delamination of the middle crust occurs beneath the Tanzawa block, and is currently propagating southeastward within the Izu block. High crack density within this part, which is supported by other studies, is another possibility for the high seismic activity.

The similar delamination structure was also found in other collision zones such as the Hidaka collision zone in NE Japan, (Iwasaki et al. 2004), the Ogasawara Plateau in the subduction zone of the Pacific plate (Takahashi et al., 2010b) and continent-continent collision such as the eastern Alps (TRANSALP Working Group, 2002) and the Pyrenees (Teixell, 1998). From the structural characteristics common to all the cases including the ICZ, it is indicated that colliding crusts are responsible for large amount of deformation, and crustal decoupling in the mid-crustal level is a common feature in the process of the collision regardless of its collision type. Furthermore, there exists a mechanically-weak interface in the crust universally, while the lower crust is structurally-coupled with the upper mantle. On the other hand, slight differences of the collision styles were also found in several aspects such as a dip angle of the detachment plane and the relationship with a brittle–ductile transition zones. These differences may arise from diverse physical properties such as strength profiles of the individual crust, thermal condition, crustal thickness and rock compositions.