Dense thermochronometric mapping in the NE Japan Arc: Constraint the uplift style of the mountains based on apatite fission-track (AFT) analysis

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Northeast (NE) Japan Arc is one of the most active mobile belts in the world, which is also known as a typical island arc because of the inland topographic alignment parallel to the Japan trench. The arc-parallel mountains are thought to have been formed by the E-W compression derived from the plate subduction (Takahashi 2006, Jour. Geogr.). After the termination of the extensional stress field related to the opening of the Sea of Japan (25–13.5 Ma), the NE Japan Arc was formed as an island arc through the three uplift events under the E-W compression (Sato 1994, JGR). Most of the topographic reliefs in the NE Japan Arc have been formed from the Pliocene to Quaternary (Yonekura et al. 2001, Tokyo Univ. Press) through the complex tectonic histories. However, few studies were conducted for quantitative investigations of the mountain buildings.

Thermochronometry is capable of reconstructing the time-temperature relations (namely, thermal history) of rocks based on radiometric ages and closure temperatures specific to the combination of the applied dating method and target mineral (hereafter, thermochronometer). For estimation of thermal history on the upper crust, such as the mountain building, low-temperature thermochronometers are useful, such as apatite and zircon (U-Th)/He and fission-track method (AHe, ZHe, AFT and ZFT, respectively).

Our research group has carried out thermochronometric investigations in NE Japan Arc for quantitative understanding of the mountain buildings. Sueoka et al. (2017, EPS) utilized He method and proposed arc-across contrasts of thermal histories and distribution of denudation rates in the southern NE Japan Arc among the fore-arc side, the Ou Backbone range (OBR), and the back-arc side. Besides, Fukuda et al. (2018, FT Res. Gr.) applied AFT analysis and thermal inverse calculations using HeFTy program (Ketcham 2005) to the same rock samples of Sueoka et al. (2017, EPS). The results are summarized as below. On the fore-arc side, denudation has been slow and stable (<0.05 mm/yr) since the Asia continent margin era, whereas the denudation/uplift rates might have got faster in the Quaternary. The amount of denudation was estimated at 1–2 km or less over the Cenozoic. In the OBR, the initiations of cooling episodes were estimated at several to 1 Ma, approximately corresponding to the onset of the present E-W compression. The denudation rates were computed from 0.1 to a few mm/yr. The AFT ages got younger from the mountain bases to the summits, which disagreed with the conventional uplift model of OBR, namely the tilted pop-up model (e.g., Nakajima 2013, INTECH), because faster denudation rates (younger ages) at the mountain bases are expected for the model. Hence, doming model (e.g., Hasegawa et al. 2005, Tectonophys.) is thought to be more plausible. On the back-arc side, the initiations of the cooling episodes were estimated at several to 1 Ma, coeval with the OBR, whereas the denudation rates were calculated at 0.1–1.0 mm/yr. This result might suggest a later uplift of the back-arc mountains than the previous studies suggested; the previous studies proposed that the crustal deformation was initiated at 5–3.5 Ma on the back-arc side, and then migrated to the OBR at 2–1 Ma (Sato 1994, JGR; Acocella et al. 2008, Tectonics). As described above, our results of the OBR and back-arc side disagree with the previous models, so further quantitative investigations based on thermochronometry are required.

In this presentation, we are planning to report new AFT ages and thermal inverse modeling results based on the dense thermochronometric mapping of the OBR and back-arc side in order to elucidate the plausible uplift model of mountains and tectonic model. AFT ages of 7.8–4.3 in the OBR and 39.6–3.6 Ma on the back-arc side were obtained. The AFT ages of OBR got younger toward the mountain ridge including the previous AFT ages, which supports the doming uplift model of OBR. New results of thermal inverse modeling indicate rapid cooling at >3 Ma, which also corroborated the interpretations by Fukuda et al. (2018, FT Res. Gr.), that is, the last cooling episodes on the back-arc side initiated after ~3 Ma concurrently with the OBR.

Future prospects are as below: (a) application of other thermochronometers, such as the AHe, ZHe and ZFT methods, (b) thermochronologic investigations in the northern NE Japan Arc, and (c) comparison of timing of the migration of the mountain uplift and uplift style of the mountains between the northern and southern parts of the NE Japan Arc.

Keywords: Thermochronology, NE Japan Arc, Fission-track method, Mountain building process, Uplift/denudation history