Uplift of the Hidaka Collisional Orogen, Hokkaido, Japan Inferred from Stratigraphy and Thermochronology

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ABSTRACT

This paper reviews the stratigraphic and thermochronologic data concerning the exhumation history of the Hidaka collisional orogen, Hokkaido, Japan. The Neogene sedimentary record of foreland basin suggests that the topographic uplift of the orogen occurred in the Middle Miocene. The first occurrence of large amount of orogen-sourced granite clasts has been found in the Middle Miocene turbidites around 15 Ma. These granite clasts are S-type monzogranite-granodiorite, and show the Paleogene biotite K-Ar ages of 29–46 Ma. These data suggest that they are originated from Paleogene granitic plutons emplaced in the shallow part of the Hidaka crust. On the other hand, the overlying Late Miocene deposits contain clasts of metamorphic rocks and tonalite which are characterized by Miocene biotite K-Ar ages of 16–19 Ma. These clasts of syn-uplift reset ages represent exhumation of the middle part of the crust.

The present-day outcrops of the crystalline core zone of the Hidaka orogen show that the upper and middle crustal rocks have Paleogene and Miocene biotite K-Ar ages, respectively. Thus, the diachronic change of detrital materials in the foreland basin together with the above-mentioned thermochronologic contrast simply responds to a normal exhumation of the orogen. To explain the change of detrital assemblages, it was suggested that the different areas of the Hidaka orogen have undergone a significant denudation through two uplift events at Middle and Late Miocene. Our data, however, show a successive exhumation occurred in the southern Hidaka orogen where deep-seated crustal rocks now crop out.

Keywords: Stratigraphy, Thermochronology, Uplift, Hidaka collisional orogen, Hokkaido

INTRODUCTION

The Hidaka orogen, Hokkaido, northern Japan, was first developed along the Eurasian - Okhotsk plate boundary and later at a collision zone between the Northeast Japan and Kuril arcs (Fig. 1). The degree of exhumation is quite different between the northern and southern areas of the orogen. The metamorphic and plutonic rocks are distributed only in the southern area of the orogen, while several small plutons (mainly of granite) are emplaced into the Cretaceous - early Paleogene clastic rocks in the

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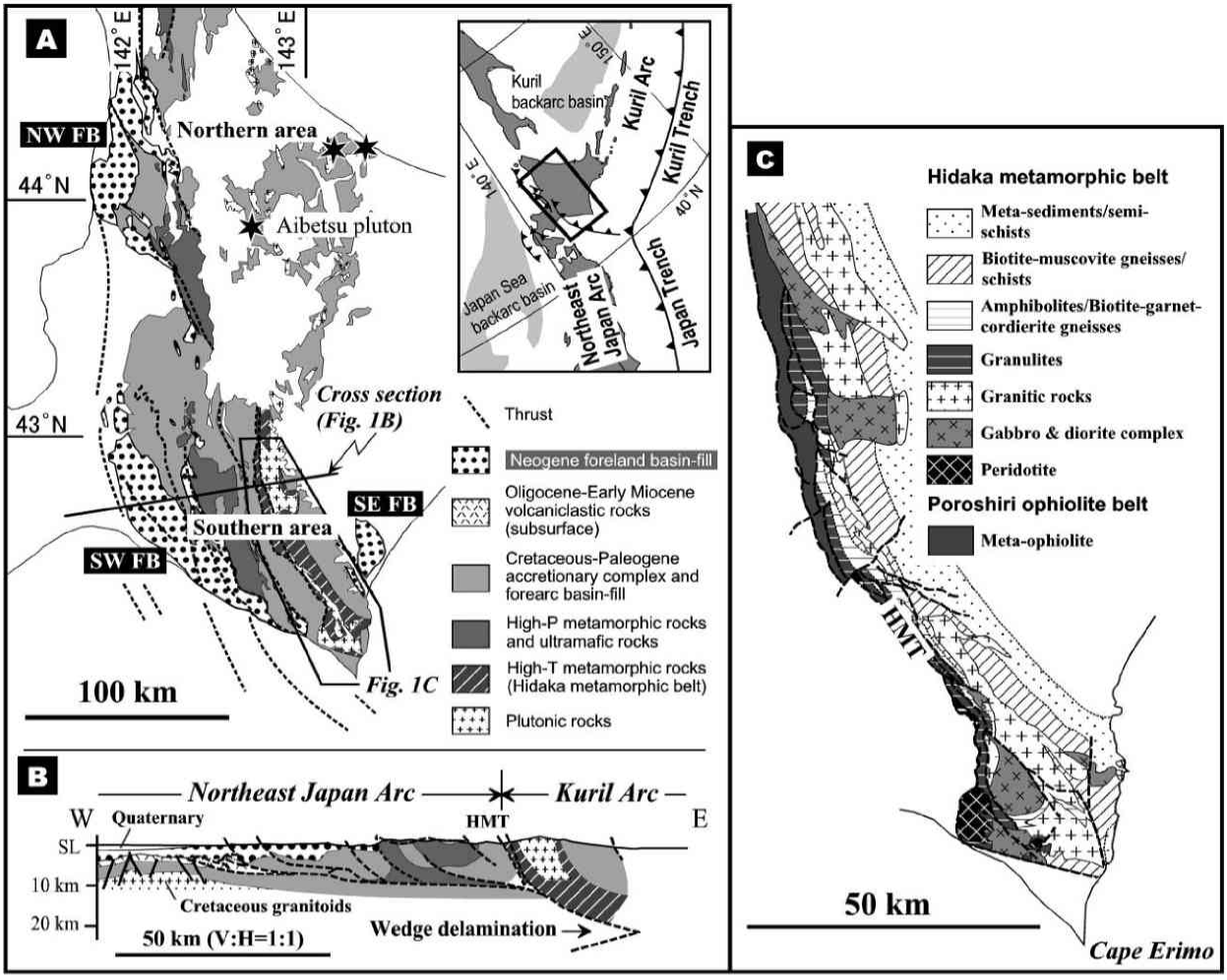

Fig. 1 (A) Simplified geologic map and (B) cross section of the central Hokkaido [15]. Black stars are Eocene granitic plutons. NW FB: northwestern foreland basin, SW FB: southwestern foreland basin, SE FB: southeastern foreland basin. (C) Detailed geologic map showing the distribution of metamorphic and plutonic rocks in the core zone of the Hidaka orogen [4].

northern area (Fig. 1A, C).

Miyasaka et al. (1986) proposed the uplift and exhumation history of the Hidaka orogen based on the petrographic analysis of conglomerates in foreland basins together with some sedimentologic evidence [1]. Their study suggested two different uplift stages in the Hidaka orogeny. The first uplift occurred in the northern area during the Middle Miocene. In this stage, the shallow crustal rocks (granite and non-metamorphosed rocks) were eroded. The southern area was still under sea water during the Middle Miocene from the evidence of existence of shallow marine clastics. Later, the uplift of the southern area took place during the Late Miocene, and it caused a rapid input of the middle crustal detritus (clasts of metamorphic rocks and tonalite) into the foreland basins. Regardless of significant erosion supposed during the Middle Miocene, no outcrops of middle to deep crustal rocks in the northern area raises question to the two uplift stages supposed by Miyasaka et al. (1986). In addition, the age of the "Middle Miocene" shallow marine deposits covering the southern area of the orogen has been newly proposed to be Early Miocene [2]. Following these points of view and detrital thermochronology, we conclude here that the significant uplift and exhumation of the orogen was progressed mainly in the southern area rather than the northern area through a single uplift event during the Miocene time.

GEOLOGIC OUTLINE OF THE HIDAKA OROGEN

The Hidaka orogen was developed at first along

the Eurasian - Okhotsk plate boundary. The boundary was transformed later to collision zone between the Northeast Japan and the Kuril arcs especially in the southern area as a result of the opening of the Japan Sea and Kuril backarc basins (Fig. 1A). The orogen shows west-vergent fold-thrust belt in the southern area (Fig. 1B). The crystalline core zone and the overlying sedimentary rocks crop out on the hanging wall of the Hidaka Main Thrust (HMT), and constitute a typical arc crustal sequence of 23 km in thickness extending to the lower crustal rocks [3, 4] (Fig. 1B, C). The deep-seated rocks of granulite-facies are distributed along the HMT, and the metamorphic grade decreases eastward (Fig. 1C). The metamorphic rocks are closely associated with mafic to felsic plutons including a large amount of S-type granitoids. Tonalites and granites are emplaced in the middle and upper crustal sequences, respectively [3, 4]. Especially the tonalites occurr as sheet-like plutons of up to 5 km in thickness.

The thick arc crust (Hidaka crust) was formed in relation to the mafic magmatic underplating and the following amalgamation of the Eurasian and Okhotsk plates in the early Tertiary [5]. The peak metamorphism and the resultant crustal anatexis occurred at 55–56 Ma according to the Rb/Sr whole rock isochron ages [6]. The timing of tonalite emplacement were slightly later than the peak metamorphism [5]. Thus, the metamorphism and plutonism took place considerably earlier than the Miocene uplift which is probably associated with the openings of the Japan Sea and Kuril back arc basins. Cooling ages of the crystalline core zone have been determined by various techniques, including biotite K-Ar, zircon fission-track, and whole rock-biotite Rb/Sr isochron methods during the last decade [7–11]. The thermochronologic data show zonal distribution of syn-orogenic (syn-uplift) reset ages (10–20 Ma) in the west and pre-orogenic (pre-uplift) cooling ages (29–44 Ma) in the east.

STRATIGRAPHY AND DETRITAL THERMOCHRONOLOGY OF FORELAND BASIN-FILLS

Sedimentology and Petrography

Thick Neogene sediments, of up to 5000 m, have been deposited in both the western and eastern margins of the Hidaka orogen (Fig. 1A). The basins are N-S trending foreland basins developed through the northern to southern area of the orogen during the early Middle Miocene. The lower half of the basin-fills consists of thickly accumulated turbidites on the basin-floor with abundant monzogranite-granodiorite and hornfels clasts [12]. The deposition of turbidites started at 15 Ma (Middle Miocene), and it marks the first occurrence of a large amount of orogen-sourced detritus in the stratigraphic record (Fig. 2).

The upper half of the basin-fills consists of gravelly fan delta deposits including clasts of schist and tonalite. The Middle Miocene turbidites are widely distributed throughout foreland basins in the northern to southern orogen, whereas the development of fan deltas is restricted to the southern area of the orogen during the Late Miocene to Pliocene (Fig. 2).

Detrital Thermochronology

The Middle Miocene turbidites throughout the north and south foreland basins contain granite clasts of Paleogene biotite K-Ar ages (Fig. 2). The monzogranite clasts in the southern basins yield biotite K-Ar ages of 43–46 Ma [10, 12]. Our new data on granodiorite clasts in the northwestern basin also represent biotite K-Ar ages of 29, 38, and 40 Ma [13] (Fig. 2). On the other hand, Late Miocene fan delta deposits in the southwestern basin contain tonalite and schist clasts showing syn-uplift K-Ar ages of the Middle Miocene (16–19 Ma), although the granodiorite-tonalite clasts still exhibit older biotite K-Ar ages of 33–34 Ma in the southeastern area [10] (Fig. 2). The tonalite clasts having syn-uplift biotite K-Ar ages of 16 Ma are first recognized in the Pleistocene alluvial terrace deposits in the southeastern foreland basin (Fig. 2). Thus, the thermochronologic data of the granitic rock clasts in the foreland basins show a normal exhumation of the orogen, although the clasts with syn-uplift reset age occurred earlier on the western side than on the eastern side.

DISCUSSION AND CONCLUSION

The Middle Miocene turbidites distributed in the central Hokkaido contain numerous granite clasts of Paleogene biotite K-Ar ages (especially Eocene, 38–46 Ma). However, granitic plutons exhibiting Eocene biotite K-Ar age are exposed only in the narrow zone of the northeastern area of the Hidaka orogen which is far from the foreland basins (Fig. 1A). The granitic pluton in northwestern area of the orogen (the Aibetsu pluton), which located quite far from the southern basins, also has 46 Ma biotite K-Ar age [13] (Fig. 1A). Low degree of exhumation of the orogen in the northern area and limited number

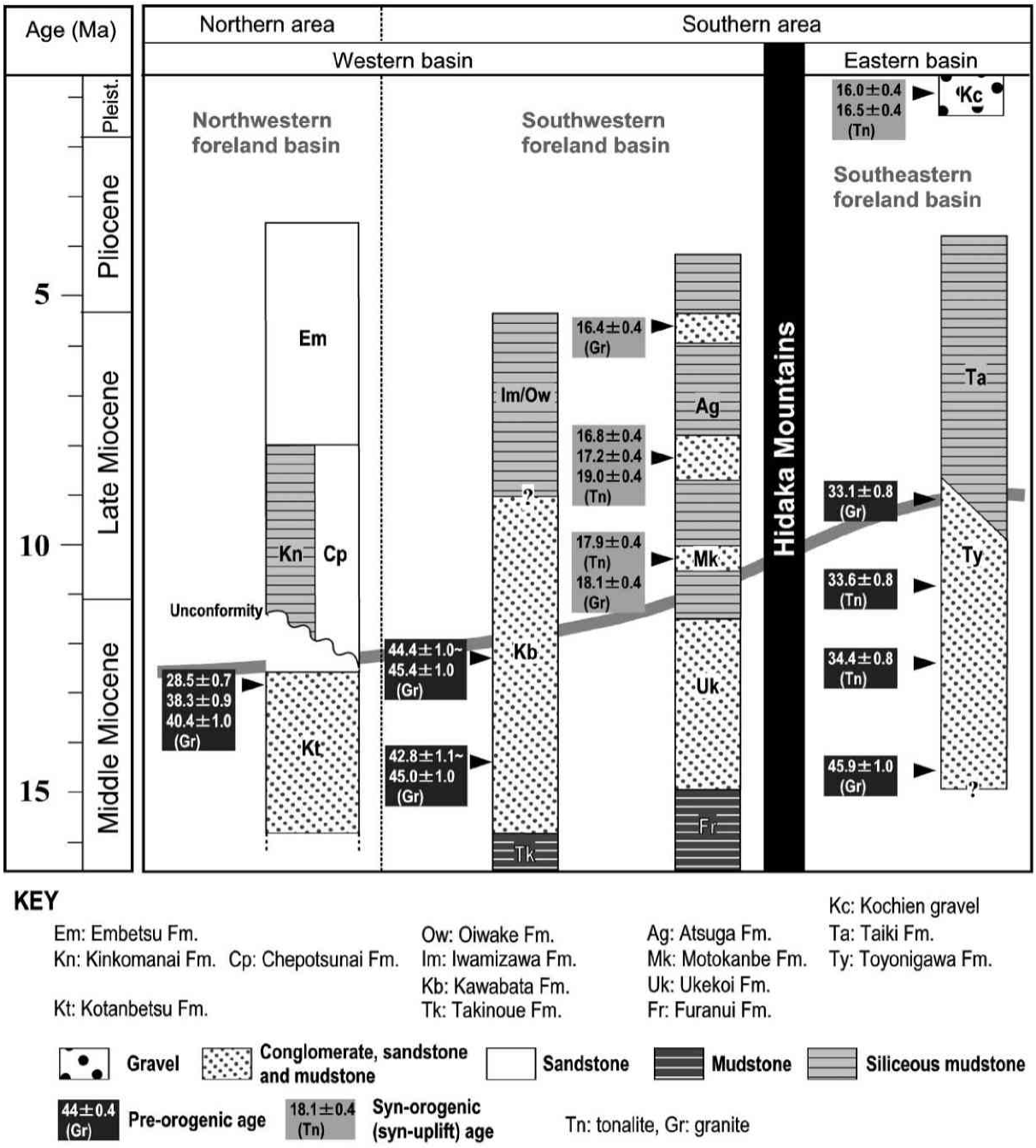

Fig. 2 Spatio-temporal distribution of granitoid clasts in the foreland basins, and their biotite K-Ar ages in Ma.

of the Paleogene granitic plutons emplaced there suggest that the northern Hidaka orogen was not the source area of the Middle Miocene detritus. The new age of Eocene for the Aibetsu pluton suggests that Eocene granitic plutons were previously distributed widely in the shallow crustal sequence of the southern Hidaka orogen, although they are not found now due to intense exhumation and erosion. Namely, the Eocene granitic plutons exposed in the northern Hidaka orogen are not much affected by erosion and therefore they are not considered to have been the source of the large amount of granite clasts appeared in the Middle Miocene turbidites.

The chronological proximity of the Eocene biotite K-Ar ages of the granitic plutons/clasts to the peak age of the Hidaka metamorphism at 55–56 Ma sug-

gests that the Eocene ages represent the cooling ages slightly postdating the emplacement of felsic magma into the shallow crustal sequence. On the other hand, the tonalite and metamorphic rocks constituting middle crust had been at temperatures higher than the closure temperature of biotite K-Ar system (ca. 300°C) until the Middle Miocene. Hence, they were reset when the significant uplift began in the early Middle Miocene and eroded during Late Miocene.

The diachronic change of the detrital materials in the foreland basins [1] and their thermochronologic ages responded to the normal exhumation of the Hidaka orogen especially in its southern part. Some researchers suggested two uplift stages of the Hidaka orogen during Middle and Late Miocene, respectively, to explain the change of detrital assemblages. Our data, however, show a successive exhumation in the southern Hidaka orogen. The orogen-sourced coarse detritus were widely distributed from north to south in the Middle Miocene turbidites and later restricted to the Late Miocene to Pliocene fan delta deposits in the southern area (Fig. 2). This distributional trend of detritus probably resulted from right-lateral transpressional movement in the collision zone [14], and it also does not explained by the spatio-temporal shift of uplifted area.

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