Early Eocene rapid exhumation in the north Nima area: Insights into the development of the Tibetan Plateau

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1. Introduction and motivation

The formation and evolution of the Tibetan Plateau is critical to understanding large-scale crustal deformation processes, and how plateau development has influenced global climate. Yet how and when the Tibetan plateau formed remains controversial. Thrust faulting in the central Tibetan Plateau indicates that at least 50% upper shortening occurred before India-Asian collision (Kapp et al., 2007). Using low-temperature thermochronology studies, Rohrmann et al. (2012) proposed that localized plateau growth started in the Late Cretaceous, accelerating in Central Tibet by 45 Ma, and then spreading north and south over 1000 km. This hypothesis is put forward based on thermal histories derived from a relatively limited dataset from samples located in central Tibet, that may not fully capture the plateau's exhumation history (Fig. 1).

Nima area, located within the Bangong-Nujiang suture zone in central Tibet, records a pre-collisional and post-collisional deformational history. Our rationale is to undertake a low temperature thermochronology study on basin conglomerate clasts from a region where source and sink is well tied together, and this can be found in the well-mapped region of Nima area (DeCelles et al., 2007). Thus Nima area is an ideal place to fill in questions and gaps. In this study, we combine zircon U-Pb, apatite (U-Th)/He (AHe) and fission track (AFT) techniques on granite and sandstone clasts in Late Cretaceous to Oligocene conglomerates in the North Nima Basin and Xiabie granite basement in the adjacent thrust fault hanging wall, to elucidate the deformation history of the central Tibet.

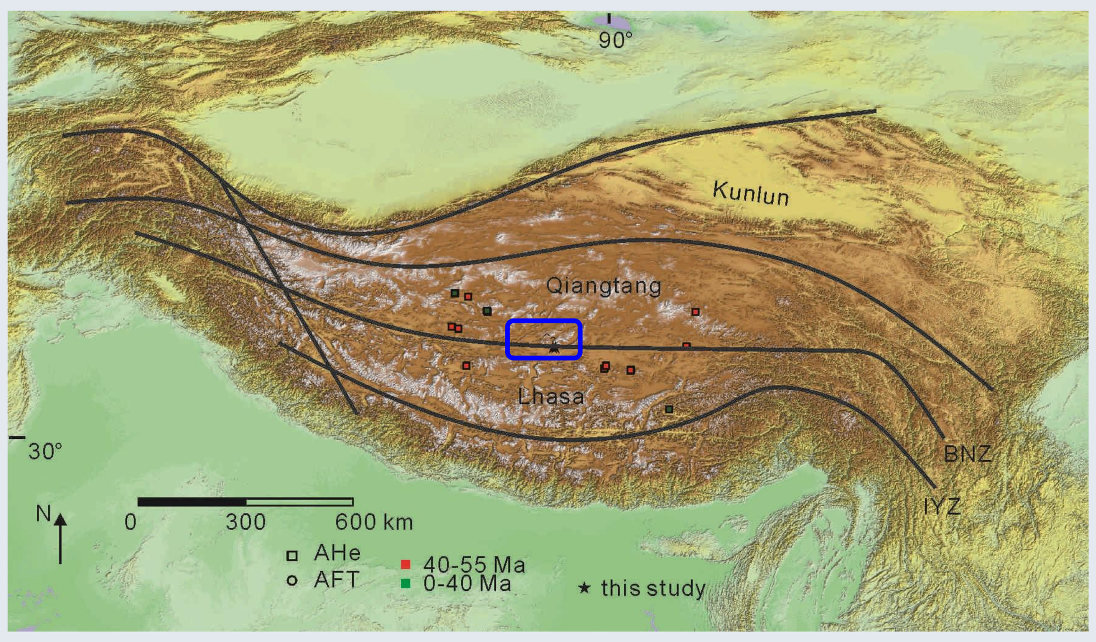
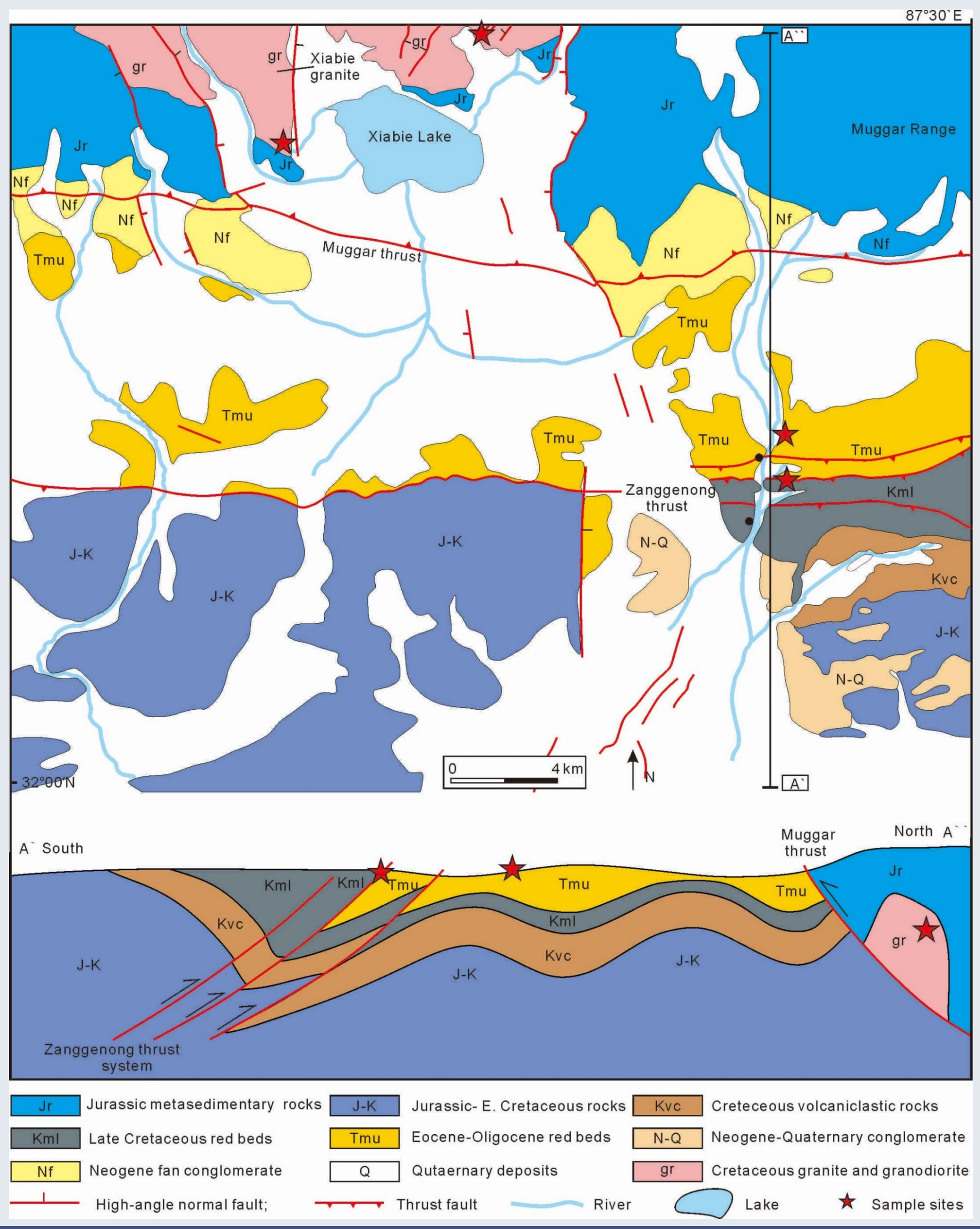


Fig. 1 The distribution of thermochronology data from Rohrmann et al. (2012) and our study area (the blue box shows the location of Nima area) on the Tibetan Plateau

2. Geological background

The North Nima region (Fig. 2) contains a sedimentary succession and basement granites that span Jurassic to Cenozoic (Kapp et al. 2007; DeCelles et al. 2007). The Muggar Thrust, which separates the Xiabie granite and Jurassic-Lower Cretaceous marine rocks in the hanging wall from Late Cretaceous to Cenozoic sediments of the Northern Nima Basin in the footwall, is part of a regional system of N-dipping thrust faults that have been named the Shiquanhe-Gaize-Amdo Thrust (SGAT) system along the Banggong-Nujiang suture (Kapp et al., 2007).



Cretaceous-Cenozoic rocks in the North Nima Basin are almost exclusively non-marine including alluvial fan, braided streams, and ephemeral lacustrine environments.

We collected granitoid and sandstone clasts from Late Cretaceous to Oligocene conglomerate beds of the Nima Basin (The depositional age determined by spore and pollen, DeCelles et al., 2007), and Xiabie granite in the hanging wall of basin-bounding Muggar Thrust. We carried out zircon U-Pb, AHe and AFT analysis on those conglomerates clasts and Xiabie granite.

Fig. 2 Geological map of North Nima, modified from Kapp et al. (2007).

3. Zircon U-Pb data

Four granitoid conglomerate clasts (N1-C4 to C6, N4-C1) from North Nima Basin yield zircon U-Pb ages of 114.6 - 122.9 Ma, based on weighted average ages of $^{206}Pb/^{238}U$ (Fig. 3). The Xiabie granite from the hanging wall of the basin-bounding Mughar Thrust to the north of North Nima Basin yields zircon U-Pb age of 119 ± 2.2 Ma, similar to Kapp et al., (2007). In addition, southward paleoflow and recycled orogenic provenance indicated the main source area of North Nima Basin is north of the study area in the hanging wall of the Muggar Thrust, consisting of Jurassic argillaceous rocks and Early Cretaceous granites (DeCelles et al., 2007). Thus the granitoid clasts from conglomerate beds are likely derived from the Xiabie pluton, implying a short source to sink distance.

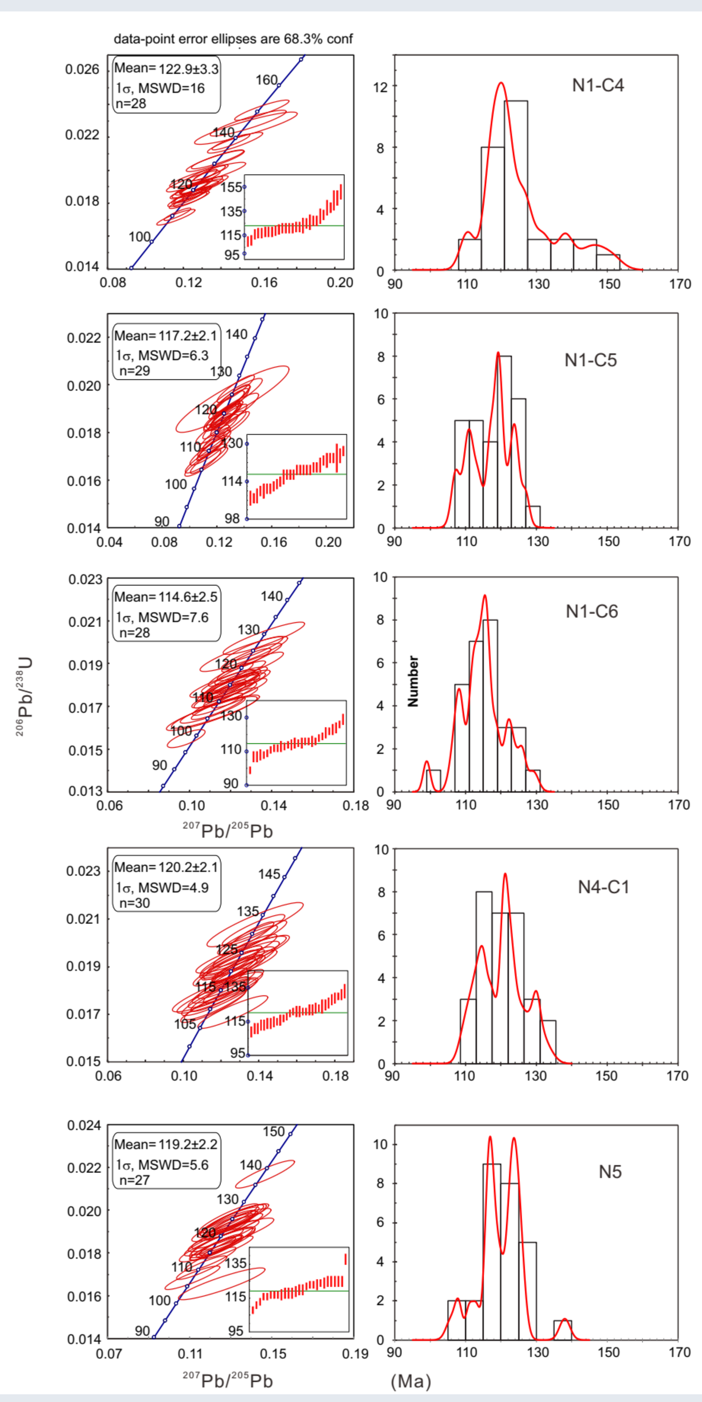
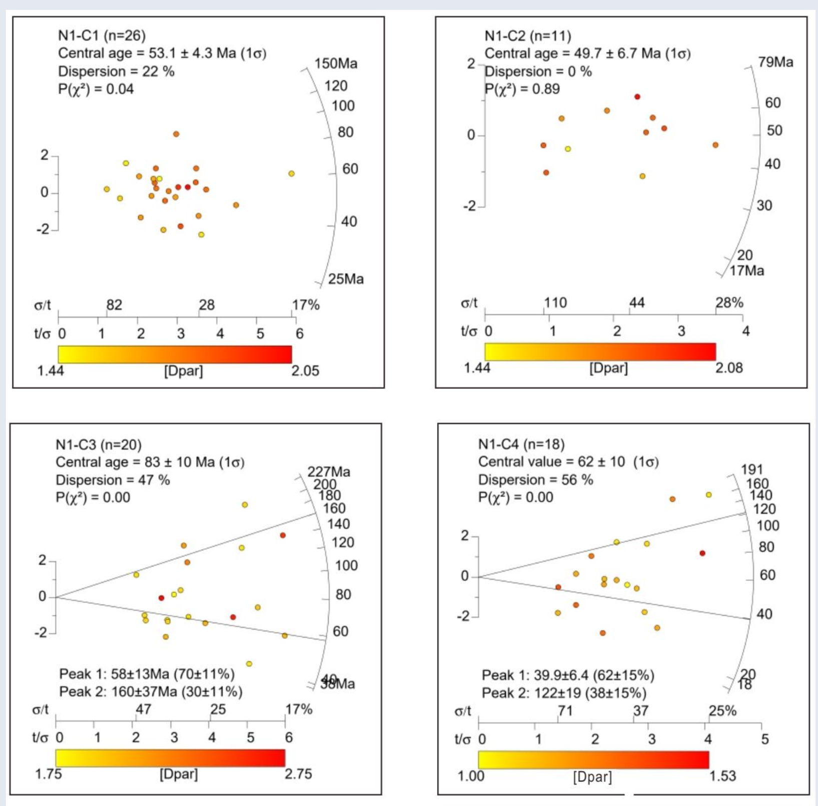
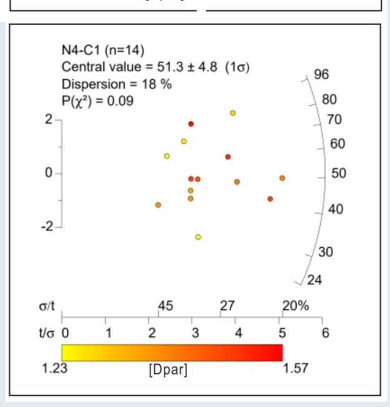


Fig. 3 U-Pb concordia plot of granite clasts in North Nima Basin and Xiabie granite

4. Apatite Fission track data

Three granitoid clasts from Late Cretaceous conglomerates yield AFT ages ranging from 33.6 ± 3.0 Ma to 77.2 ± 15.1 Ma. AFT ages of 3 sandstone clasts from Late Cretaceous conglomerates range from 49.7 ± 6.7 Ma to 83 ± 10 Ma. One granitoid clast from Oligocene conglomerates yield an AFT age of 51.3 ± 4.8 Ma (Fig. 4). D-par range from 1.1 to 2.0 μm. The single grain ages are reported in Figure 4, using radial plots. For the sandstone clasts, which failed the chi-square test ($P(\chi^2)<0.05$), we divide the distribution into several populations, based on the age cluster. For example, sample N1-C3 has two peaks, one is 58 ± 13Ma, another is 160 ± 37 Ma, although no significant relationship is observed between D-par and age cluster (Fig. 4).





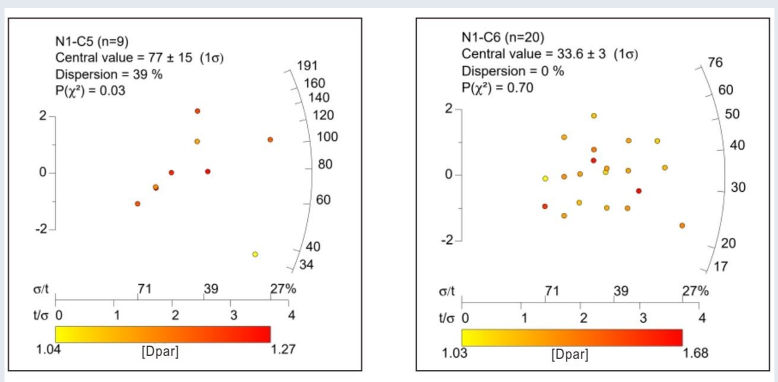


Fig.4 AFT radial plot in North Nima Basin. Drawing with isoplot R software (Vermeesch et al., 2018).

In the graphs, x axis (σ/t) is measures precision; y axis in the left is standardised estimate, and age distribution in the right.

5. Apatite (U-Th)/He data

Single-grain apatite (U-Th)/He ages were determined from 14 samples (Fig. 5). Six granitoid clasts from Late Cretaceous strata yield uncorrected AHe ages of 16.1 to 46.5 Ma. Three granitoid clasts from Oligocene strata yield uncorrected AHe ages of 13.4-42.9 Ma. Two granites from the Xiabie pluton yield uncorrected AHe ages ranging from 29.6-49.8 Ma (Fig. 5). Three sandstone clasts from Late Cretaceous conglomerates yield uncorrected AHe ages ranging from 8.7-29.1 Ma.

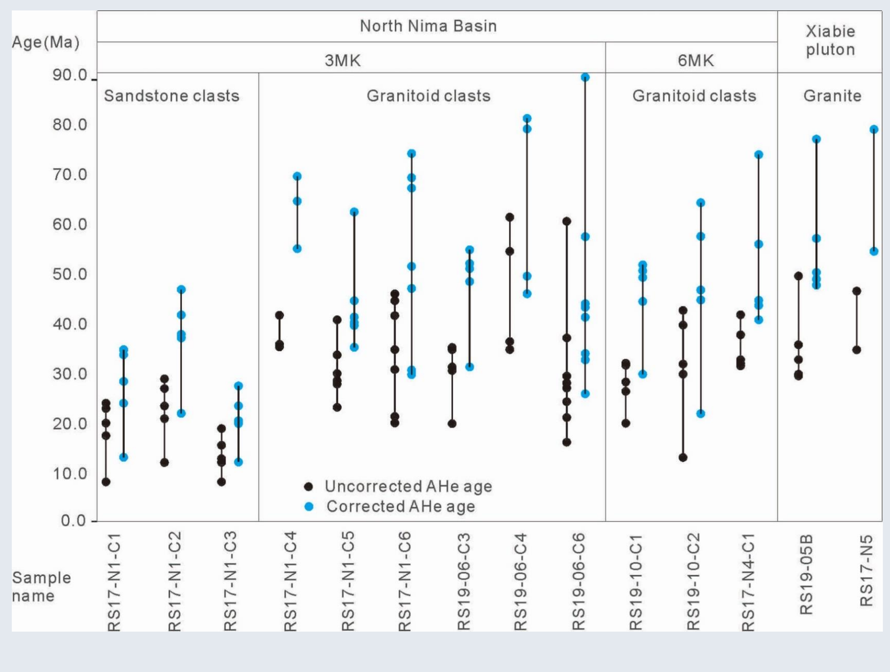


Fig.5 AHe ages distribution in North Nima Basin and Xiabie granite

6. Thermal histories

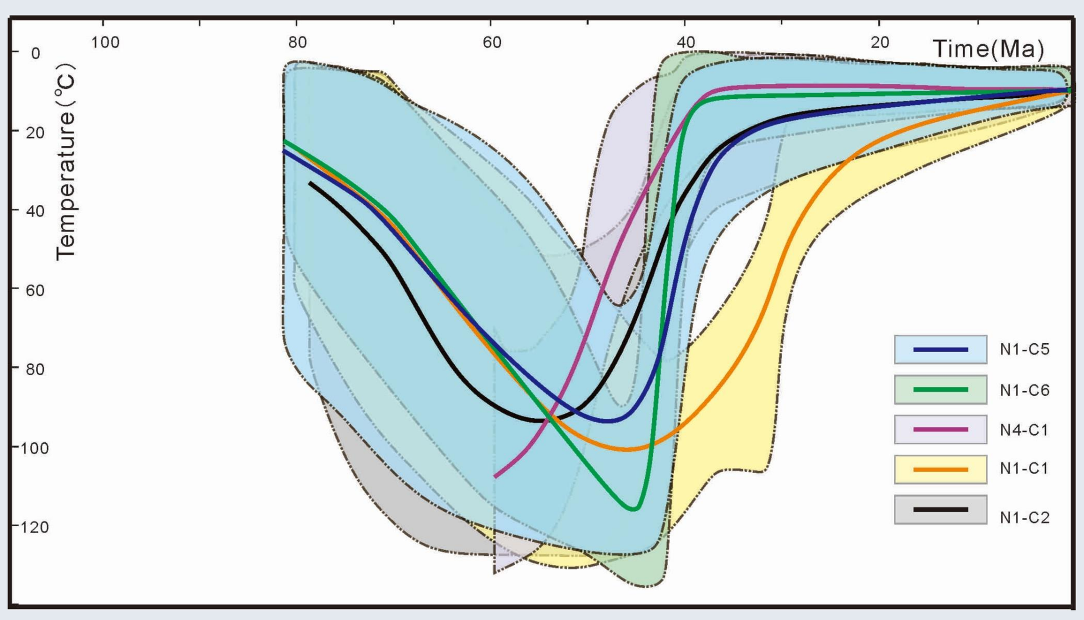


Fig.6 Cooling history of produced by QTQT software (both AHe and AFT data used ; Gallagher et al., 2012)

The granitoid and sandstone clasts from Late Cretaceous-Oligocene conglomerates reveal similar thermal histories: rapid cooling from 100±20°C to 30±10°C at ~45 Ma (Fig. 6). Assuming a paleo-geothermal gradient of 25° C/km the average erosional exhumation rate is 0.025-0.008 mm/yr since the transition to slow cooling at 40 Ma.

7. Implications

Rohrmann et al. (2012) proposed that regionally extensive plateau growth had occurred by 45 Ma. This is based on a majority of AHe ages being within the range of 55-43 Ma, although it was not documented in the thermal modelling. Our new thermal modelling now provides a robust conclusion on the timing of exhumation, pinpointing it at 40±5 Ma.

Reference:

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