Paleogene syn-collisional leucogranite with rutile exsolution in garnet, southern Tibet

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Abstract

The Gangdese arc magmatism was active in response to the Mesozoic subduction of the Neo-Tethyan oceanic lithosphere and the Cenozoic collision between the Indian and Asian continents. The Paleocene Gangdese batholith in southern Tibet is intruded by several voluminous peraluminous leucogranites, with the origin of these leucogranites remaining controversial. In this study, we investigate a small garnet-bearing leucogranite intrusion in the Nyingchi Complex that represents the exposed lower crust of the Lhasa Terrane and underwent multi-stages of amphibolite- to granulite-facies metamorphism since the Cretaceous. Bulk-rock mineralogy and geochemistry display S-type granite signatures, indicating its anatexic origin. The center of the ˜300 m-wide pluton contains abundant garnet in a perthite-quartz matrix. The garnets, from core to rim, display stepwise concentrations of major and rare earth elements, indicating multiple stages of growth. The cores are featured by three groups of oriented needles of rutile, which are regarded as products of exsolution due to rapid decompression or cooling and have been found almost exclusively in extreme temperature and/or pressure conditions. The Ti-in-rutile temperatures range from 900 to 850 oC, consistent with the temperatures derived from the ternary feldspar thermometer. These rutile-rich garnet cores were likely seeded from the lower crustal resitites and incorporated in an upwelling of hot mantle-derived magma. The peritectic garnet mantle continued to grow in the melt at 800-650 oC, as suggested by the Zircon saturation temperature and the Ti-in-zircon thermometer. The diffusion profiles between the Ti-rich core and mantle yield a short ˜25 kyr duration of cooling from 870 °C to 700 °C, when the leucogranite magma migrated and emplaced. Zircons from the granite show complex textures; most of the cores and magmatic mantles yield U-Pb ages between 60 and 50 Ma, suggesting a syn-collisional origin of the melt. We speculate that the Paleogene slab roll-back and slab break-off would have resulted in enhanced asthenospheric corner flow and upwells, supplying a long-lived heat source for coeval crustal anatexis and metamorphism in southern Lhasa during the early phase of continental collision.

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1. Summary

- Bulk-rock mineralogy and geochemistry of the Nyingchi leucogranite display S-type granite signatures, indicating of an anatexic origin.
- Complex texture, geochemistry and geochronology in zircon and garnet, indicating multiple stages of melting and cooling events. Rutile needles in garnet core suggest a high-T lower crustal source. Garnet zoning records rapid cooling (<25 kyr) from 900 °C to 700 °C for leucogranite magma migration and emplacement.
- Paleogene slab roll-back and breakoff would have resulted in enhanced asthenospheric corner flow and upwells, supplying a long-lived heat source for coeval crustal anatexis in the lower crust.

2. Geologic background and geochoronology

- Fig. 1. Geological map of southern Tibet and vicinity of the sampling location in Nyingchi.
- Fig. 2. Bulk rock composition of the leucogranite suggests S-type granite origin.
- Fig. 3. Zircon U-Pb dates suggest complex cooling history.

Fig. 1

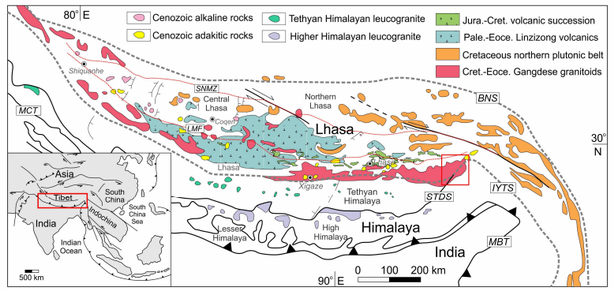


Fig. 2

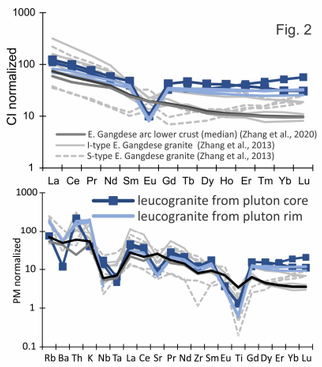
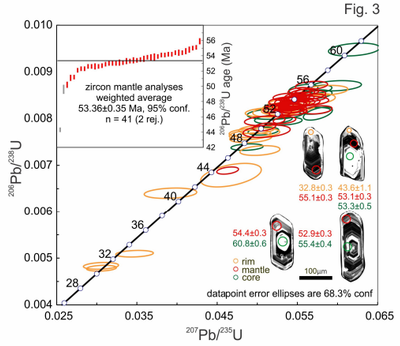


Fig. 3



3. Garnet geochemistry and multi-stage growth

- Garnet from the leucogranite display at lest three stages of growth based on their compositions (Fig. 4, 5). Garnet grainsfrom the core of the pluton is also featured with oriented needles of rutiles in the core, which is likely relics from the Gangdese lower crust material that underwent high temperature/pressure metamorphism but later brought up rapidly by leucogranite magma.

Fig. 4

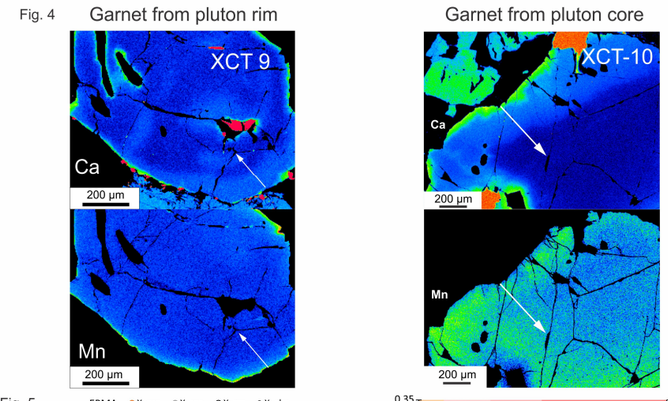
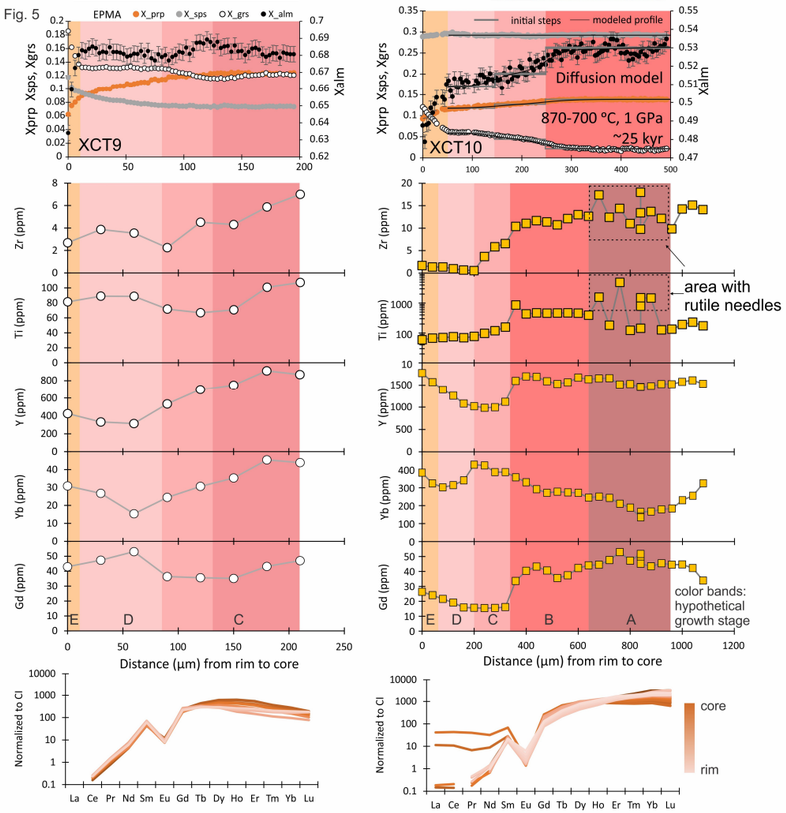


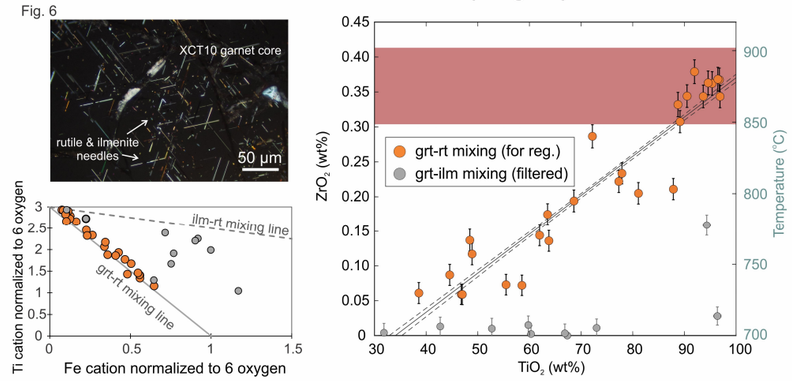
Fig. 5



4. (Ultra-)High-T lower crustal anatexis and rapid magma emplacement

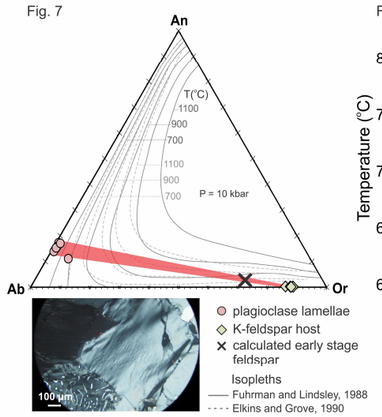
Zr-in-rutile thermometer: 880°C ± 25°C (Stage A)

Fig. 6



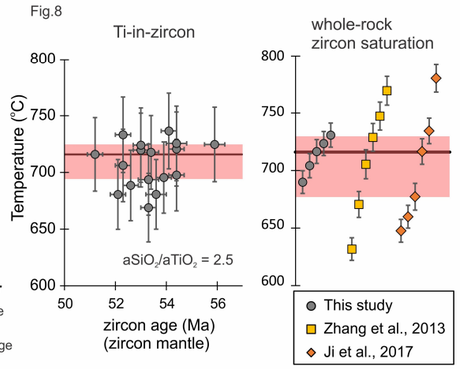
Ternary feldspar thermometer: ~850 °C (Stage B)

Fig. 7



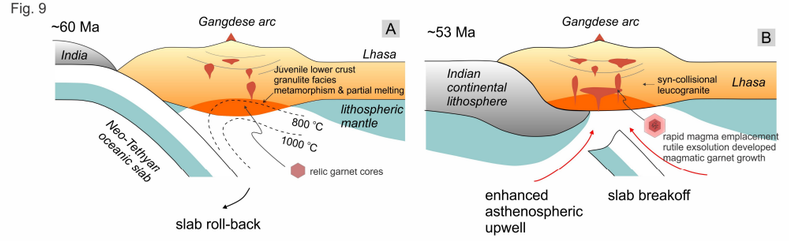
Zircon saturation and Ti-in-zircon thermometer: ~800-650 °C (Stage C-D)

Fig.8



5. Genetic model

Fig. 9



- The Paleogene slab roll-back and slab break-off before and during India-Asia collision would have resulted in enhanced asthenospheric corner flow and upwells, supplying a long-lived heat source for coeval crustal anatexis and metamorphism in southern Lhasa during the early phase of continental collision.