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Rb-Sr Geochronology of the Rocks of the Himalayas, Eastern Nepal
Part II
The Age and the Origin of the Granite on the Higher Himalayas

By

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Abstract

Rb–Sr isotopic measurements are made on the Makalu granite, which is one of leucocratic granite occurring sporadically in the high range of the Himalayas. The granite is intruded between the Himalayan gneiss and the Tethyan sediments. In this study, Rb–Sr analyses have been made on both whole rock and small sliced rock.

The Rb–Sr isotopic analytical results on whole rock of the Makalu granite define the age of 92.7 ± 9.4 m.y. The analytical results on small slabs suggest that Sr isotopic redistribution occurred after the intrusion of the granite.

The initial $^{87}Sr/^{86}Sr$ ratio of the Makalu granite is 0.7433 ± 0.0019 and is remarkably high. Such high ratio indicates that the granite originated from the remelting or partial remelting of old crustal materials such as Himalayan gneiss.

I. Introduction

The Himalayas have been taken as a substantial example of continent-continent collision type mountains (Dewey and Bird, 1970). The previous geological studies have revealed that the range experienced at least two geologic episodes (Gansser, 1964; Wadia, 1975). The first one is attributed to the Precambrian metamorphism and the present Himalayan geologic feature evolved through the Cenozoic orogenic movement, which implies simultaneous tectonic, metamorphic and plutonic activities.

The remarkable tectonic characteristic of the range is the arrangement of thrust-fault systems (Gansser, 1964; Wadia, 1975). One of the major thrusts, the Main Central Thrust (MCT), which divides the overlying Himalayan gneiss from the southern metasediments, was active from Oligocene to Miocene (Mattauer, 1975). The tectonic movements had been accompanied by the metamorphic and plutonic activities in the Higher Himalayas (Le Fort, 1975). The 28 m.y. age of the Manaslu granite defined by Rb–Sr whole rock isochron would give an important constraint to the age of the metamorphism and plutonism (Hamet and Allégre, 1976). However, the time span of the metamorphism and plutonism is subject to much controversy. Vidal (1978) contested against the original emplacement of the leucocratic granite of the Higher Himalayas is in Miocene. BIRD (1978) also claimed that the granite would not only be produced by underthrusting of the continental crust.

This investigation aims to define the age of the granite by using Rb–Sr systematics. The age obtained would make clear the time span of the metamorphism and plutonism. The rock samples analysed were collected from the Khumbu region, eastern Nepal. The analyses were performed on whole rock samples. Moreover, small slabs were also analysed to elucidate the thermal history subsequent to the intrusion.

II. Geology

The geology of the studied area, the Khumbu region, is described by BORDET (1961), GANSSER (1964) and HASHIMOTO *et al.* (1973). The geologic maps are shown in Fig. 1 and Fig. 2.

Three types of the rocks occur in this area; the granite, the gneiss and the Tethyan sediments. The granite whose center is situated at the Mt. Makalu in the east end of this area extends westward. BORDET (1961) termed the granite the Makalu granite. It is leucocratic granite rich in muscovite, tourmaline and biotite. The granite is intruded into the gneiss and the Tethyan sediments. The massif appears as a large concordant sheet within the surrounding formations. The main body of the granite is foliated. The structure was supposed to be synchronous with the major deformations (Le FORT, 1975). The granites with the similar occurrence and mineral compositions occur sporadically in the Higher Himalayas (Fig. 1). They are supposed to be the same origin as suggested by Le FORT (1975).

The formations surrounding the granite are Himalayan gneiss and the Tethyan sediments. The Himalayan gneiss was Precambrian in origin and was affected again by the metamorphism later than Mesozoic (GANSSER, 1964; METHA, 1977). The other formation surrounding the granite is Tethyan sediments overlying the gneiss. The sediments extend far northward to the Tibetan Plateau and range from Cambrian to Eocene in age (GANNSER, 1964).

III. Results and Discussions

3–1) Analytical results

The analytical data on the whole rock samples of the Makalu granite are presented in Table 1 and plotted on Rb–Sr evolution diagram (Fig. 3). These points apparently give a single array which defines an age of 92.7 ± 9.4 m.y. with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7433 ± 0.0019. The result strongly implies that the granite has remained closed to Rb and Sr isotopes since that time, and the age can be correlated with the time of intrusion of the Makalu granite.

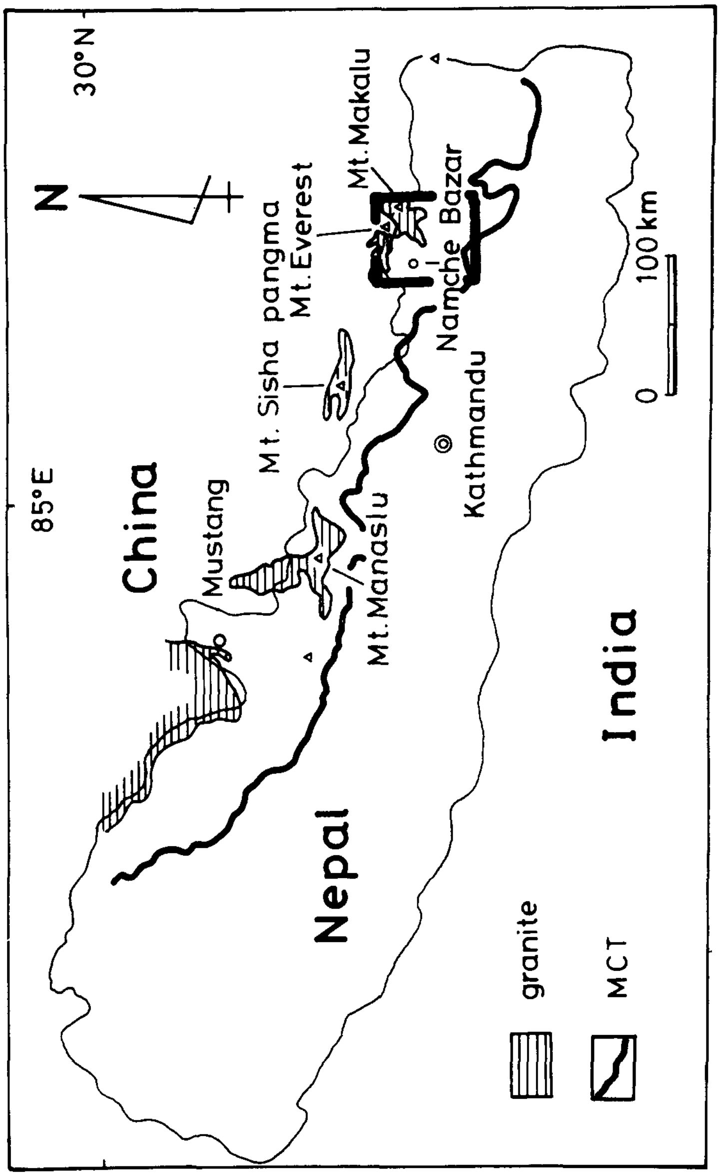

Fig. 1. Map showing the studied area and distribution of the granite, after BORDET (1961) and HASHIMOTO *et al.* (1973).

A whole rock sample, K–13, was chosen for preparing small slabs. Its mode is heterogeneous even within a hand specimen. The small slab specimens prepared are shown schematically in Fig. 4, with the variation of Rb and Sr contents among them.

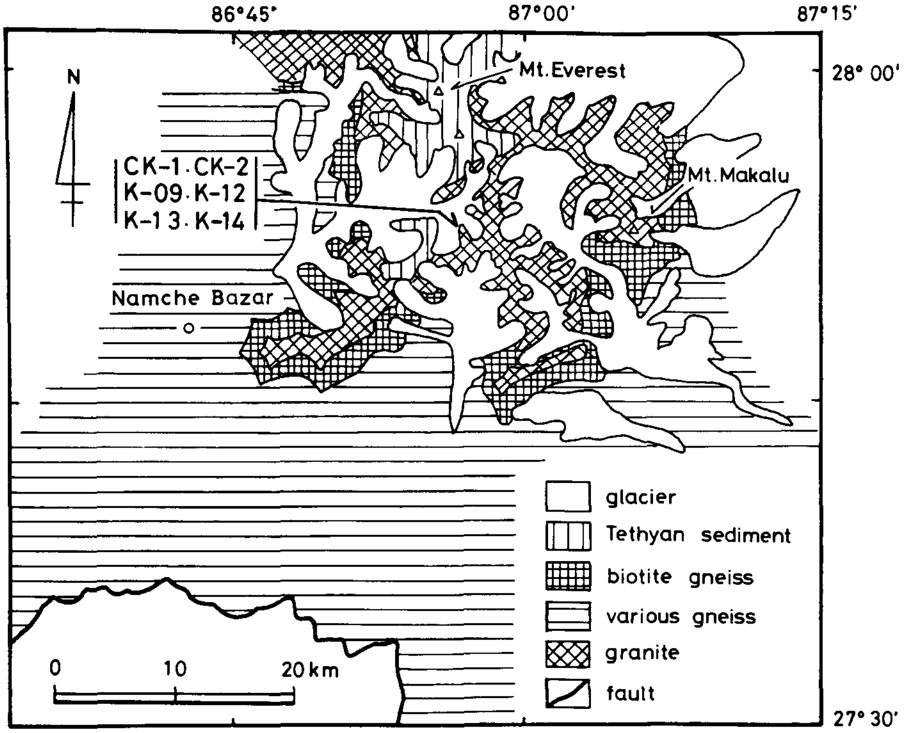

Fig. 2. Geologic map of the eastern Nepal, after BORDET (1961) and HASHIMOTO et al. (1973).

Table 1. The analytical data for whole rock of the Makalu granite

Sample No.	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr \pm 1\sigma$
CK-1	269.7	110.3	6.990	0.7510±0.0019
CK-2	401.9	48.25	24.25	0.7730±0.0028
K-09	361.6	78.98	12.91	0.7604±0.0040
K-12	381.0	76.09	14.58	0.7644±0.0017
K-13	390.5	72.78	15.62	0.7630±0.0039
K-14	446.0	129.8	10.44	0.7564±0.0030

The Rb-Sr analytical data on the small slabs of the Makalu granite (K-13) are given in Table 2 and also plotted in isochron diagram of Fig. 5. They fall in rather scattered range of $^{87}Rb/^{86}Sr$ due to heterogeneous distribution of micas and feldspar. However, $^{87}Sr/^{86}Sr$ ratios of these slabs show rather small variation. The plots form a single array, but this array does not give a meanigful age but a minus age. The result suggests that Sr isotopic reequilibration had occurred among the small slabs at relatively recent time.

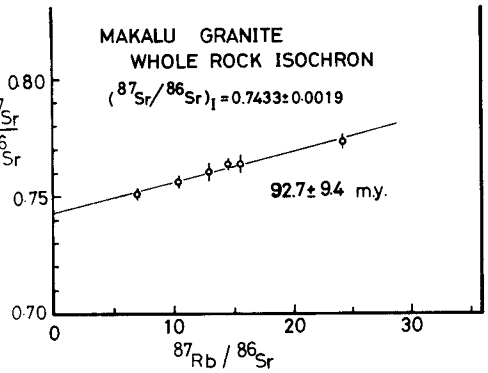

Fig. 3. Whole rock isochron of the Makalu granite. Vertical bar represents analytical error.

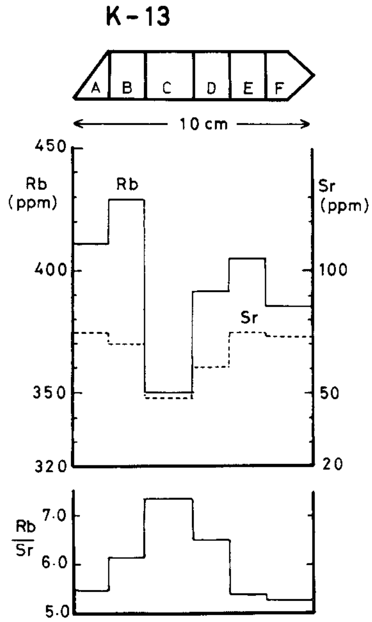

Fig. 4. Cross-section of the Makalu granite, (K–13), showing variations of the concentrations of Rb and Sr along a normal to the layering. The sections are about 1 cm square.

Table 2. The analytical data for small slab of the Makalu granite

Sample No.	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr \pm 1\sigma$
K–13–A	410.8	74.70	16.01	0.7638±0.0038
K–13–B	429.5	69.79	17.91	0.7660±0.0018
K–13–C	349.9	47.71	21.35	0.7630±0.0035
K–13–D	391.6	60.31	18.91	0.7639±0.0039
K–13–E	404.9	74.78	15.95	0.7650±0.0022
K–13–F	385.5	72.79	15.42	0.7669±0.0038

3–2) Age of the Himalayan granite

The massifs of the leucocratic granite similar to the Makalu granite sporadically occur in the Higher Himalayas. The granites are supposed to be syn- to post-orogenic granite by many authors (GANSSER, 1964; LE FORT, 1975). The ages of the granites are supposed to be same and to be later than Mesozoic (BORDET, 1961; LE FORT, 1975). The Rb–Sr isotopic study of the Manaslu granite, one of the leucocratic granite, gave a whole rock isochron age of 28 m.y. (HAMET and ALLÈGRE, 1976).

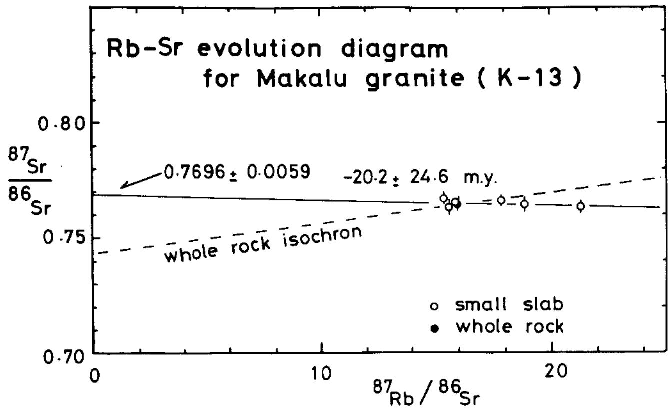

Fig. 5. Rb–Sr evolution disgram for the small slabs of the Makalu gramite (K–13). The dashed line is whole rock isochron. Vertical bar represents analytical error. closed circle; whole rock, ipen circle; small slab.

The present results of the Makalu granite give 92.7±9.4 m.y. age, which is evidently older than that of the Manaslu granite. This discrepancy needs some explanations. In Part I, it was postulated from the Rb–Sr systematics of the small slabs of the Himalayan gneiss that a metamorphism occurred in Tertiary age. If the Himalayan granites were pre-Tertiary origin, the granites would have been influenced thermally by the Tertiary metamorphism. This supposition may be supported by open system behavior of Rb–Sr systematics as suggested by the small slabs of the Makalu granite. The degree of the effect of the metamorphism may differ between the Makalu granite and the Manaslu granite; In the former the metamorphism caused the Sr isotopic redistribution only among the neighboring small slabs, i.e. in the scale of a few centimeters, but in the latter the event would have caused the Sr isotopic redistribution among the whole rocks, i.e. in the scale of a few hundred meters.

Le FORT (1975) postulated that the Tertiary metamorphism was caused mainly by the underthrusting of the crust along the MCT. The Makalu granite occurs geographically farther from the MCT than the Makalu granite as shown in Fig. 1. According to the postulation of Le FORT (1975), the Makalu granite may have been little influenced by the Tertiary metamorphism.

3–3) Suitability of the Himalayan gneiss as a source of the granite

One of the conspicuous characters of the Makalu granite is its high initial ^{87}Sr/^{86}Sr ratio of 0.7433±0.0019. The high ratio of 0.7408 was also reported from the whole rock isochron of the Manaslu granite (HAMET and ALLÉGRE, 1976). Such high ratio would indicate that the granite of the Higher Himalayas was originated by the remelting of the old crustal materials.

Le FORT (1973) supposed that the anatectic roots of the granite lay in a lower part of the Himalayan gneiss. The leucocratic granites of the Higher Himalayas have similar occurrences and mineral compositions to each other (HAGEN, 1969; Le FORT, 1975). Suitability of the Himalayan gneiss as a source materials of the granite is discussed based on the Sr isotopes as follows.

It is possible to estimate the source materials of the granite if the following assumptions are made: (1) Each rock unit has remained closed systems to Rb and Sr isotopes since emplacement, (2) The initial $^{87}Sr/^{86}Sr$ ratio for the granite is the $^{87}Sr/^{86}Sr$ ratio for the source material at the age of the granite, and (3) The average present-day $^{87}Sr/^{86}Sr$ ratio of whole rock sample from a particular rock unit represents the present-day $^{87}Sr/^{86}Sr$ ratio of that unit.

These assumptions imply that the average Rb/Sr and $^{87}Sr/^{86}Sr$ ratios of the whole rock are the Rb/Sr and $^{87}Sr/^{86}Sr$ ratio of the rock unit, and that the $^{87}Sr/^{86}Sr$ ratio of the anatectic granite is evolved from the Sr evolution of the source materials.

The least-squared initial $^{87}Sr/^{86}Sr$ ratios and ages and the average present-day

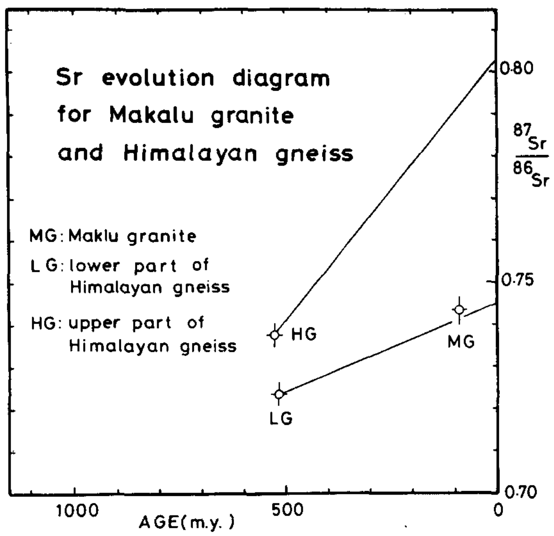

Fig. 6. $^{87}Sr/^{86}Sr$ evolution diagram for the Himalayn gneiss and the Makalu granite. The initial $^{87}Sr/^{86}Sr$ ratios and the ages of the Himalayan gneiss are quoted from Part I. MG; Makalu granite, LG; lower part of the lower Himalayan gneiss (Barun gneiss and Irkhua geniss), HG; upper part of the Himalayan gneiss (Barun migmatite).

$^{87}Sr/^{86}Sr$ ratios of the Himalayan gneisses and the Makalu granite are plotted on a time versus $^{87}Sr/^{86}Sr$ diagram in Fig. 6. The $^{87}Sr/^{86}Sr$ ratio and age of the Himalayan gneiss are quoted from Part I.

The present-day $^{87}Sr/^{86}Sr$ ratio of the lower part of the Himalayan gneiss (the Barun gneiss and the Irkhua gneiss) is 0.7499. The point of the Makalu granite falls on the Sr evolution line defined by the initial $^{87}Sr/^{86}Sr$ ratio and age of the isochron of the Himalayan gneiss. The high initial $^{87}Sr/^{86}Sr$ ratio is explicable of the Sr evolution of the gneiss if the gneiss is a source of the granite. The consideration for the Sr isotopes and age is consistent that the Makalu granite is originated from the remelting of the Himalayan gneiss, as suggested by Le FORT (1975).

IV. Conclusions

The conclusions obtained by the present study are summerized as follows:

1) The whole rock isochron of the Makalu granite gives 92.7 ± 9.4 m.y.

2) The analytical results of the small slabs of the Makalu granite suggest that Sr isotopic redistribution occurred after the time of its intrusion. The Sr isotopic redistribution may reflect the Tertiary metamorphism.

3) The initial $^{87}Sr/^{86}Sr$ ratio of the Makalu granite is 0.7433 ± 0.0019. The conspicuously high ratio indicates that the granite was formed by the remelting or partial melting of old crustal materials such as the Himalayan gneiss.

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