Polar Geosci., **12**, 166–175, 1999

PRELIMINARY RESULT FOR THE Rb-Sr WHOLE-ROCK AGE AND INITIAL Nd ISOTOPE RATIOS FROM THE CLOSEPET GRANITE IN KARNATAKA, SOUTHERN INDIA

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Abstract: The Rb-Sr whole-rock isochron age was determined for granitic rocks from the Closepet granite, southern India. Porphyritic monzogranite, clinopyroxene quartz-monzonite, pink granite and grey granite, four main representative granitic rocks, gave an Rb-Sr age of 2669±125 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.70193±0.00088. This Rb-Sr whole-rock isochron age indicates a major period of equilibration of the isotopic system on a whole- rock scale at 2669 Ma. Initial εNd values normalized to 2669 Ma for individual granitic rocks range from –4.4 to –7.2. The large initial εNd values and low Sr initial ratios suggest that the Closepet granite has complicated history such as mixing.

key words: southern India, Closepet granite, Rb-Sr whole-rock age, initial εNd value

1. Introduction

The Closepet granite is the largest magmatic complex in the Archaean domain of southern India. This magmatic complex displays a vertical profile of the late Archaean crust and provides a unique opportunity to study a juvenile crustal accretion pattern (FRIEND, 1984).

The Closepet granite in southern India is clearly younger than the Peninsular gneisses (3.3 to 3.0 Ga) (FRIEND and NUTMAN, 1991; JAYANANDA *et al.*, 1995). Most isotopic ages of the Closepet granite show late Archaean age (around 2500 Ma, BUHL *et al.*, 1983; GREW and MANTON, 1984). However, the reliable Rb-Sr whole-rock isochron ages, which are expected to suggest the age of genesis of magma, have not been determined so far.

This paper presents the Rb-Sr whole-rock isochron age and initial Nd isotopic composition for granitic rocks from the Closepet granite in southern India. The equilibration age of the granitic rocks in the Rb-Sr whole-rock system will give the age of igneous histories of the plutonic rocks in southern India because the Closepet granite is the dominant igneous rock in Archaean age.

2. Samples

Granulite terrain in southern Peninsular India was affected by magamtism during different stages of crustal evolution. The plutonic activities are represented by calc-alkaline to K-rich granite (FRIEND, 1984). These plutons are generally restricted to the granulite terrain and to the transitional zone. The calc-alkaline to K-rich magmatic activity was subsequent to the regional metamorphism in supracrustal belts (Sargur belt), which is composed predominantly of charnockites, with minor amounts of calc-silicate metarmorphic rocks (BERNARD-GRIFFITHS *et al.*, 1988; DRURY and HOLT, 1980). These calc-alkaline to K-rich intrusives are essentially emplaced along faults and shear zones.

The Closepet granite is an N-S elongate composite intrusive body which cross-cuts the Dharwar craton, which is distributed in the granulite terrain in Kabbaldurga (PEUCAT *et al.*, 1993), southern India (Fig. 1). The Closepet granite is divided into four main rock-types as follows: clinopyroxene quartz-monzonite, porphyritic monzogranite, equigranular pink granite and equigranular grey granite (JAYANANDA *et al.*, 1995). The four rock-types show different field relationships with the surrounding basement.

The clinopyroxene quartz-monzonite and porphyritic monzogranite intrude into the

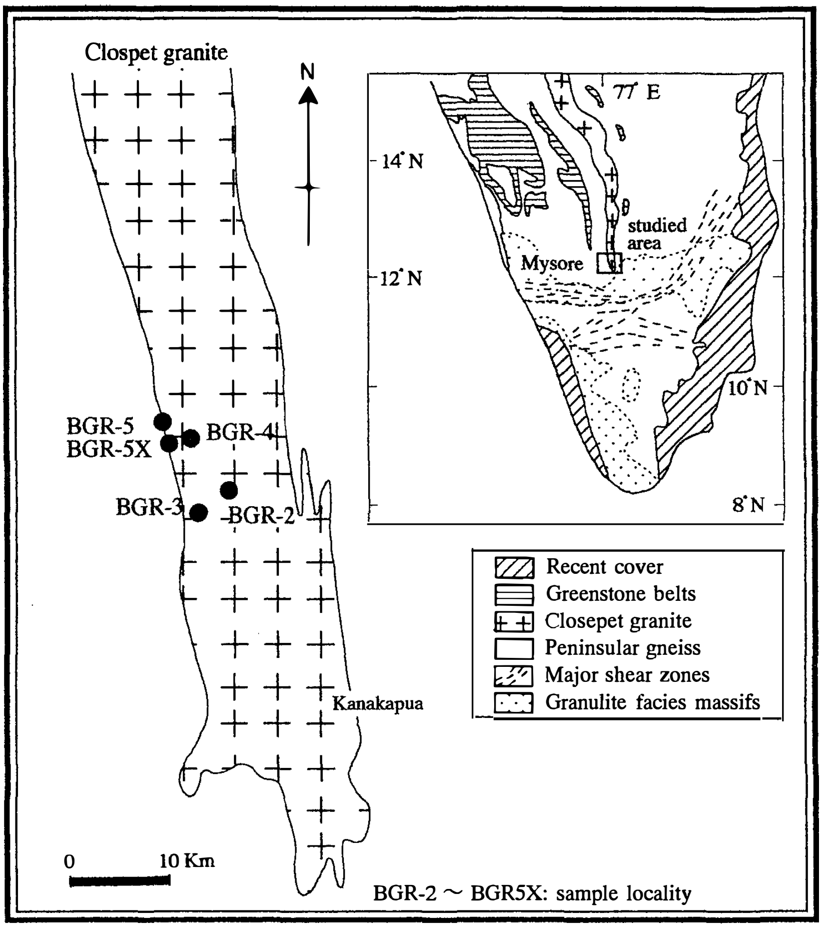

Fig. 1. Sketch map of southern India (FRIEND and NUTMAN, 1991) and the Closepet granite showing the location of the samples used for the whole-rock samples.

Peninsular gneiss and occupy the central part of the Closepet granite (JAYANANDA *et al.*, 1992). The porphyritic monzogranite is volumetrically the most important. The porphyritic monzogranite shows sharp intrusive contacts with the Peninsular gneiss. The contact between the clinopyroxene quartz-monzonite and porphyritic monzogranite is gradational (Fig. 2A). The clinopyroxene quartz-monzonite occurs as discontinuous sheets which contain an alignment of mafic minerals.

The equigranular pink and grey granites are emplaced in between the intrusive monzogranites and the Peninsular gneiss, and they grade progressively into the surrounding basement through a zone of migmatites located in the marginal part of the porphyritic monzogranite (FRIEND, 1984; JAYANANDA *et al.*, 1992). The progressive and continuous gradation from gneisses to grey and pink equigranular granites indicates that the latter rock-types were formed through anatexis of the Peninsular gneisses (JAYANANDA *et al.*, 1995). These equigranular grey and pink granites occur as pods in the gneiss (Fig. 2B). The equigranular pink granite is so closely associated with the schlieric migmatites that they can be confidently interpreted as anatectic granites marking the most advanced stage of melting and partial separation of melt from the restite, emplaced in between the intrusive monzogranites and the basement (JAYANANDA *et al.*, 1995). The two granite groups

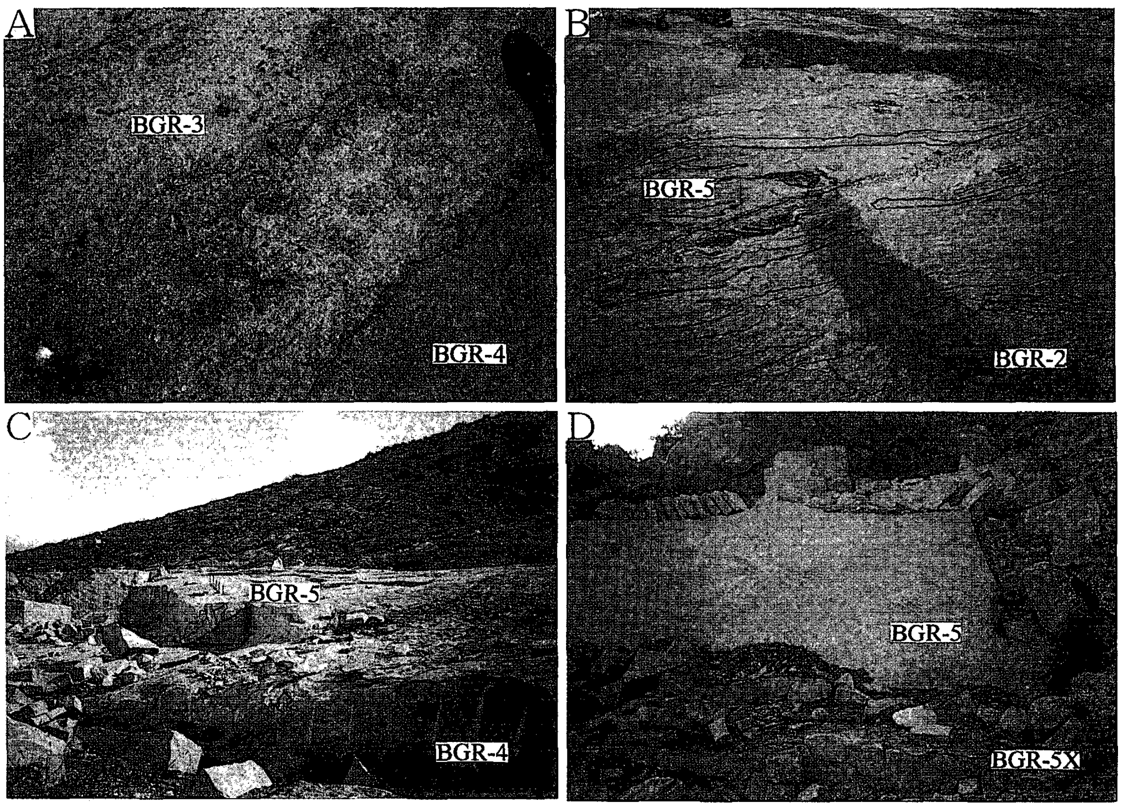

Fig. 2. Occurrence of the main granitic rocks.
A. Relation between porphyritic monzogranite (BGR-3) and clinopyroxene quartz-monzonite (BGR-4), B. Relation between equigranular pink granite (BGR-5) and equigranular grey granite (BGR-2), C. Relation between equigranular pink granite (BGR-5) and clinopyroxene quartz-monzonite (BGR-4), D. Dark inclusion (BGR-5X) in equigranular pink granite (BGR-5).

(monzogranites and equigranular granites) are broadly contemporaneous and mechanically mixed (JAYANANDA *et al.*, 1995). Mixing is here assumed to occur between anatectic and intrusive magamas. Mixing structures are widely observed in the field between intrusive and anatectic magmas (Fig. 2C). In many cases, the equigranular pink granite contains dark inclusions of clinopyroxene-quartz monzonites (Fig. 2D) (JAYANANDA *et al.*, 1992). Localities of the rock samples for Rb-Sr whole-rock dating are shown in Fig. 1.

The porphyritic monzogranite (BGR-3) is composed mainly of quartz (modal content, 18%), K-feldspar (30%), plagioclase (38%), hornblende (1%) and biotite (11%). Accessory minerals are zircon, allanite, sphene (1%) and opaque minerals (1%). Sample BGR-3 is slightly high in total FeO and K_2O (Table 1). Some of the K-feldspar occurs as large pink colored phenocryst. K-feldspar phenocrysts are commonly segregated along the sheets. K-feldspar is microcline and is found as large perthitic grains, and orthoclase content is high (Or_{97}) (Table 2). Plagioclase has weakly zonal structure (Fig. 3B) and its anorthite content is An_{15-31}. Myrmekite occurs at the contact surface between plagioclase and K-feldspar. The core part of hornblende is colorless actinolitic amphibole. Biotite is the major mafic mineral. The chemical composition of the biotite is slightly iron rich (Mg/Mg+Fe=0.5) (Table 2).

The clinopyroxene quartz-monzonite (BGR-4) is generally dark grey medium-grained that contains quartz (7%), K-feldspar (9%), plagioclase (67%), cinopyroxene (0.8%), hornblende (4%) and biotite (12%). The accessory minerals include zircon, apatite, sphene and magnetite. Sample BGR-4 has high total FeO and CaO (Table 1). Plagioclase has weakly zonal structure. Anorthite composition of plagioclase is An_{20-30}. Mafic minerals occur as aggregate. K-feldspar is anhedral perthitic mycrocline (Fig. 3C).

The equigranular grey granite (BGR-2) contains quartz (20%), plagioclase (37%), K-

Table 1. Chemical compositions of the dated samples.

Sample No.	BGR-2	BGR-3	BGR-4	BGR-5	BGR-5X
SiO_2	71.91	61.35	55.41	75.59	55.41
TiO_2	0.23	0.87	0.93	0.08	0.96
Al_2O_3	13.69	15.60	18.07	13.25	17.73
FeO*	2.01	6.31	7.48	1.08	7.93
MnO	0.03	0.13	0.11	0.02	0.08
MgO	0.37	1.69	2.28	0.07	2.23
CaO	1.25	3.28	4.51	0.71	3.96
Na_2O	3.51	4.41	5.07	3.21	4.76
K_2O	5.21	3.15	3.45	5.98	3.91
P_2O_5	0.01	0.59	0.65	0.02	0.01
H_2O-	0.47	0.75	0.53	0.23	0.82
H_2O+	0.66	1.04	0.77	0.25	1.29
Total	99.35	99.17	99.26	100.49	99.09

*Total FeO.

BGR-2; equigranular grey granite, BGR-3; porphyritic monzogranite, BGR-4; clinopyroxene quartz-monzonite, BGR-5; equigranular pink granite, BGR-5X; dark inclusion in equigranular pink granite.

Table 2. Chemical compositions of the minerals. Sample No. are same as Table 1.

Sample No. Mineral	BGR-2 Plagioclase	BGR-3 Plgioclase	BGR-5 Plagioclase	BGR-3 K-feldspar	BGR-5 K-feldsar	BGR-3 Biotite	BGR-5 Biotite
SiO_2	63.81	65.50	65.66	65.54	64.97	37.01	38.59
TiO_2	---	---	0.01	---	0.01	1.96	3.35
Al_2O_3	22.45	22.45	22.65	17.93	18.27	20.33	15.61
FeO	0.05	0.09	0.04	---	0.02	15.07	16.71
MnO	---	---	---	---	0.02	0.04	0.28
MgO	---	---	---	---	---	13.53	13.10
CaO	5.07	3.72	3.82	---	---	0.05	0.01
Na_2O	8.48	8.33	8.53	0.56	0.40	0.10	0.03
K_2O	0.27	0.05	0.21	17.67	17.36	10.42	10.21
P_2O_5	0.01	---	---	---	---	---	0.01
Total	100.15	100.14	100.95	101.72	101.05	98.54	97.93

feldspar (32%) and biotite (11%) with a very small amount of hornblende. Sample BGR-2 has high K_2O content and low MgO (Table 1). K-feldspar and plagioclase (An_{15-37}) are variably perthitic and antiperthitic with myrmekitic textures (Fig. 3A). Zircon, allanite, apatite and sphene are present.

The equigranular pink granite (BGR-5) is mainly composed of quartz (31%), K-feldspar (42%), plagioclase (27%) and biotite (0.8%). Accessory minerals are zircon, apatite, sphene and opaque minerals. Sample BGR-5 has high K_2O content and low MgO (Table 1). K-feldspar has microcline texture and is perthitic and antiperthitic with myrmekitic texture (Fig. 3D) and K-feldspar has high Or content (Or_{98}) (Table 2). The anorthite composition of plagioclase is 10–31. Chemical composition of biotite is high in TiO_2, and its Mg/Mg+Fe ratio is 0.56 (Table 2).

The dark inclusions (BGR-5X) are enclosed in the equigranular pink granite. Dark inclusions are very fine-grained with granoblastic texture (Fig. 3E). The dark inclusions contain quartz (9%), K-feldspar (6%), plagioclase (66%), biotite (16.5%) and hornblende (2.5%). The dark inclusions also have high K_2O (Table 1). The whole-rock chemistry of the dark inclusions is similar to that of the clinopyroxene quartz-monzonite (Table 1). The dark inclusions are derived from clinopyroxene quartz-monzonite judging from chemical and field data.

3. Analytical Procedures

Whole-rock samples weighing 0.5–1 kg were crushed. Rb, Sr, Sm and Nd concentrations were determined by the isotope dilution method. The $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios were determined by MAT260 type mass spectrometer at the Institute for study of the Earth's Interior, Okayama University (KAGAMI *et al.*, 1987, 1989, 1995). The $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ results are $^{86}Sr/^{88}Sr$=0.1194 and $^{146}Nd/^{144}Nd$=0.7219. $^{143}Nd/^{144}Nd$ results are reported relative to $^{143}Nd/^{144}Nd$=0.512640 for BCR-1. Sr isotope ratios for

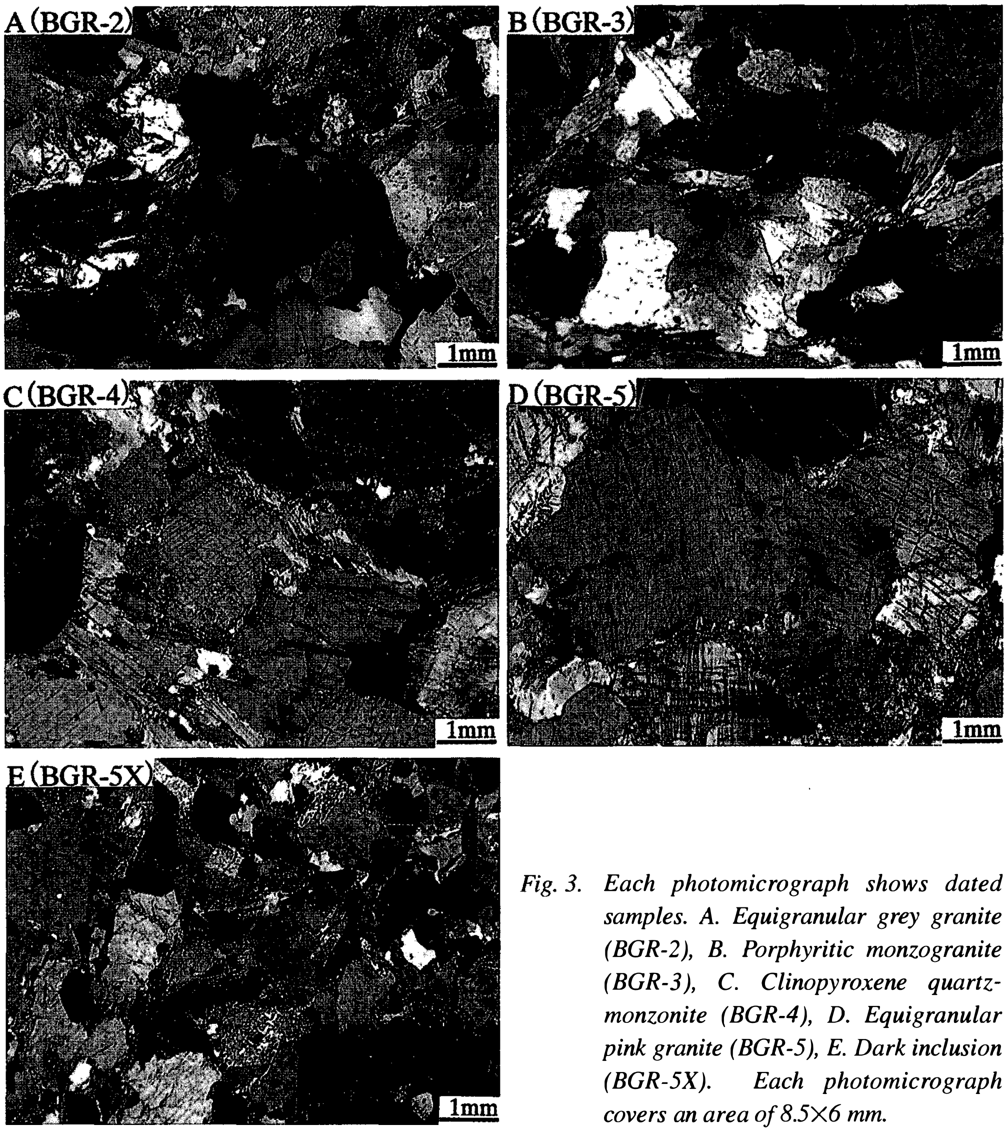

Fig. 3. Each photomicrograph shows dated samples. A. Equigranular grey granite (BGR-2), B. Porphyritic monzogranite (BGR-3), C. Clinopyroxene quartz-monzonite (BGR-4), D. Equigranular pink granite (BGR-5), E. Dark inclusion (BGR-5X). Each photomicrograph covers an area of 8.5×6 mm.

NBS987 were measured twice during this study, with a mean ratio of 0.710238±0.000009 (2σ). We estimate an error of 0.5% for the Rb/Sr and 0.1% for the Sm/Nd ratios of each sample based on reproducibility of the data. We used the following CHUR parameters for calculation of initial εNd values: $^{143}Nd/^{144}Nd$ (present)=0.512638, $^{147}Sm/^{144}Nd$ (present)= 0.1966, and $\lambda^{147}Sm=6.54\times10^{-12}y^{-1}$.

Whole-rock chemical compositions and mineral compositions were determined by XRF and EPMA at Kobe University.

4. Results and Discussion

4.1. Rb-Sr whole-rock analyses

Four samples of the granitic rocks and one sample of a dark inclusion were used for analyses. Rb/Sr analytical data for whole-rock samples of these granitic rocks are given in Table 3 and are plotted on an isochron diagram (Fig. 4). All five samples define an isochron of 2669±125 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.701931±0.00088. The

Table 3. Rb-Sr and Sm-Nd analytical data for the Closepet granite. Sample No. are same as Table 1.

Sample No.	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$
BGR-2	112	1139	0.2845	0.712759	17.5	97.0	0.1089	0.510872
BGR-3	19.3	125	0.4480	0.718993	22.7	144	0.0952	0.510609
BGR-4	16.7	127	0.3806	0.716562	23.0	124	0.1118	0.510879
BGR-5	19.3	26.8	2.0915	0.781804	5.9	33.6	0.1064	0.510675
BGR-5X	21.6	117	0.5339	0.723346	19.2	107	0.1081	0.510847

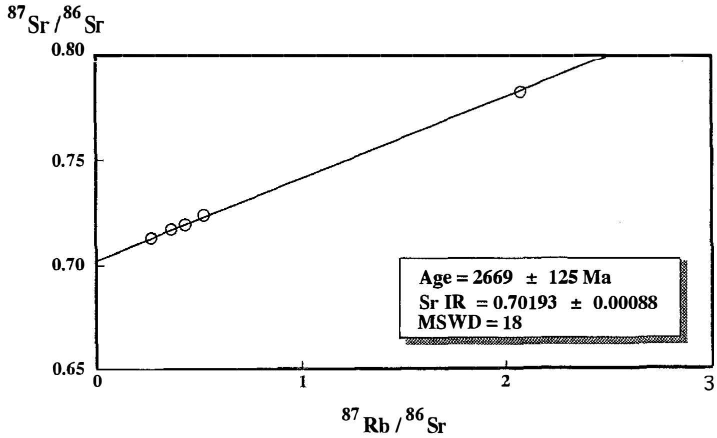

Fig. 4. Rb-Sr whole-rock isochron diagram for the Closepet granite from southern India.

MSWD value is 18, which is a bit high. Similar isochron ages (2500–2600 Ma) have been obtained from the Closepet granite (JAYANANDA *et al.*, 1995; GREW and MANTON, 1984; BUHL *et al.*, 1983). The intrusive porphyritic monzogranite and clinopyroxene quartz-monzonite of the Closepet granite accreted at 2518±5 Ma by the single-zircon $^{207}Pb/^{205}Pb$ process (JAYANANDA *et al.*, 1995). SHRIMP U-Pb dating from zircon by FRIEND and NUTMAN (1991) from equigranular pink granite in the Closepet granite provided an age of 2513±16 Ma. These ages indicate that both porphyritic monzogranite and the equigranular pink granite are contemporaneous. The Closepet granite is made up of two magam types (JAYANANDA and MAHABALESWAR, 1991): one is crust-derived (pink and grey granites) whereas the other has a deep-seated source (monzogranites). A large degree of mixing is observed on all scales between the two kind of magam, that is, the two magma types are broadly contemporaneous and mechanically mixed (JAYANANDA *et al.*, 1995). Rb-Sr whole-rock isochrons from two types of granite in this study gave an age of 2669±125 Ma, these Rb-Sr whole-rock isochrons show the major period of equilibration of the isotopic system on a whole-rock scale.

The eastern part of the Closepet granite also yields an Sm-Nd whole rock isochron age of 2732±155 Ma (BALAKRISHNAN *et al.*, 1990). Many ages are about 2500–2600 Ma elsewhere in the granitic pluton in southern India. These SHRIMP, U-Pb and Sm-Nd age data indicate that there was major intrusion (juvenile accretion) at about 2500–2600 Ma. We consider that the Rb-Sr whole-rock isochron age for the granitic rocks on the Closepet granite indicates a major period of equilibration of the isotopic system on a whole-rock at about 2500 Ma to 2600 Ma, that is, a significant igneous tectonic event occurred at that time elsewhere in southern India.

The $^{87}Sr/^{86}Sr$ initial ratio (0.70193±0.00088) at 2669 Ma of the Closepet granite is low. This low initial Sr isotope ratio precludes derivation from TTG (JANARDHAN and VIDAL, 1982). The Closepet granite suggests that they are derived from the mixing of a mantle component with older continental crust, judging from the Sr initial ratio. Consequently, some of the Closepet granites must have come from a deep source, probably lower crust or mantle.

4.2. Sm-Nd isotope analyses

Sm-Nd isotope analyses were done on five samples from the Closepet granite. These isotopic results are listed in Table 4. Whole-rock data are plotted on an isochron diagram but the data are scattered. Five samples gave an age of 2585 Ma±1649 Ma with an initial $^{143}Nd/^{144}Nd$ ratio of 0.5090±0.0011. However, they did not yield a well defined isochron age. Initial εNd values and Sr initial ratios normalized to 2669 Ma for individual granitic rocks ranged from -4.4 to −7.2 and 0.70101 to 0.70273 (Table 4). These εNd values are low compared with that of CHUR. The granitic rocks present a relatively wide range of initial εNd values and are plotted on the CHUR evolution curve. Figure 5 shows an εNd versus $^{87}Sr/^{86}Sr$ diagram. Initial Sr ratio and εNd values are normalized to 2669 Ma. The negative εNd values and low Sr initial ratios of the Closepet granite

Table 4. Sm-Nd and Rb-Sr analytical data for the Closepet granite. Sample No. are same as Table 1. Initial Nd and Sr ratios and εNd values are normalized to 2669 Ma.

Sample No.	BGR-2	BGR-3	BGR-4	BGR-5	BGR-5X
Nd I (2669 Ma)	0.50895	0.50893	0.50891	0.50881	0.50895
εNd (2669 Ma)	-4.4	-4.7	-5.2	-7.2	-4.5
Sr I (2669 Ma)	0.70177	0.70168	0.70186	0.70101	0.70273

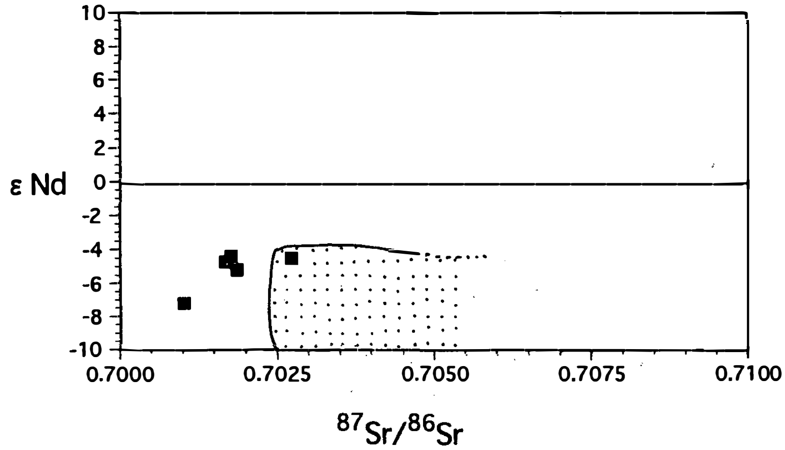

Fig. 5. εNd versus $^{87}Sr/^{86}Sr$ diagram. Initial Sr ratio and εNd values are normalized to 2669 Ma. Stippled field: Peninsular gneiss (JAYANANDA et al., 1995)

suggest that they are derived from the mixing of a mantle component and older continental crust which would have had a more negative εNd at 2669 Ma. No sample had a positive εNd at that time (Fig. 5). This result is in agreement with field data that show mixing between the magmatic bodies. The large negative initial εNd values suggest that the Closepet granite has a complicated history, such as mixing.

The initial Nd ratio normalized to 2669 Ma ranges from 0.508806 to 0.508952, average Nd initial ratio is 0.50891±0.00004. Furthermore, the samples plotted on the 2669 Ma isochron show model age T_{DM}=3200–3400 Ma, suggesting that the model age of *c.* 3200–3400 Ma indicates formation of the Closepet granite from the initial crust, because the oldest components of the Dharwar craton are the 3000–3300 Ma Peninsular gneisses associated with supracrustal belts (JAYANANDA *et al.*, 1995). JAYANANDA *et al.* (1995) had similar results, such as: the porphyritic monzogranite yields negative εNd values (–2.4 to –4.1) and clustered T_{DM} ages (3200 Ma).

Calc-alkaline to K-rich granites from the latest Archaean magmatic events in the Dharwar craton are clearly distinct from those of typical Archaean TTG (JAYANANDA *et al.*, 1995) judging from isotopical data. The strong N-S trending fabric of the Dharwar craton is partly the result of a late Archaean transcurrent shearing episode (DRURY and HOIT, 1980) and is contemporaneous with the emplacement of the Closepet granite (JAYANANDA and MAHABALESWAR, 1991).

5. Summary

The Closepet granite from southern India, gave an Rb-Sr age of 2669 Ma with low initial $^{87}Sr/^{86}Sr$ of 0.70193. This Rb-Sr whole-rock isochron age indicates a major period of equilibration of the isotopic system on a whole-rock scale. The large negative initial εNd values and low Sr initial ratio suggest that the Closepet granite has a complicated history, such as mixing.

Acknowledgments

We wish to express our sincere thanks to Prof. M. YOSHIDA (Osaka City University), for his kind support during the field work.

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(Received February 2, 1999; Revised manuscript accepted June 15, 1999)