STUDIES IN Rb-Sr GEOCHRONOLOGY AND TRACE ELEMENT GEOCHEMISTRY IN GRANITOIDS OF MYSORE CRATON, INDIA

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ABSTRACT

Rb-Sr isochron age measurements in zones of differing metamorphic grade in the cratonic region of Mysore State are described. The isochron plots dilineate granitic events at 3000 M.Y., 2500 M.Y., and 2000 M.Y. in these zones. The geochemical distribution of K, Rb, Li, U and Th in the different generations of granites in the different metamorphic grade zones has been investigated. The results reveal palingenetic effects with progressive enrichment of granitophile elements in younger granites, as well as depletion of Rb, U and Th under granulite facies conditions.

Key words: Geochronology, Rb–Sr isochron, K/Rb ratios, Precambrian granitoids.

INTRODUCTION

Remnants of the Archaen crust that have survived undisturbed since Precambrian times are of three broad types [1],

(*a*) Greenstone belts—volcanics with associated clastic sediments of low-to-medium metamorphic grade,

(*b*) Granitic rocks that surround and partially incorporate the greenstones—these tend to be Na-rich tonalitic and granodioritic gneisses,

(*c*) High-grade gneisses, often of the pyroxene-granulite type. The age relationships between the greenstone belts and the migmatites and gneisses is a matter of controversy; further, the rock sequences with their contrasting metamorphic grades are usually separated by narrow zones of younger, porphyritic granites that appear as diapiric masses or high level stocks injected along the synformal axes of the greenstone belts.

All these characteristics of the Archaen crust are manifested in the craton of Mysore (now known as Karnataka) State (Fig. 1). The greenstone belts are represented by the "Dharwar schists" that occur in well-defined

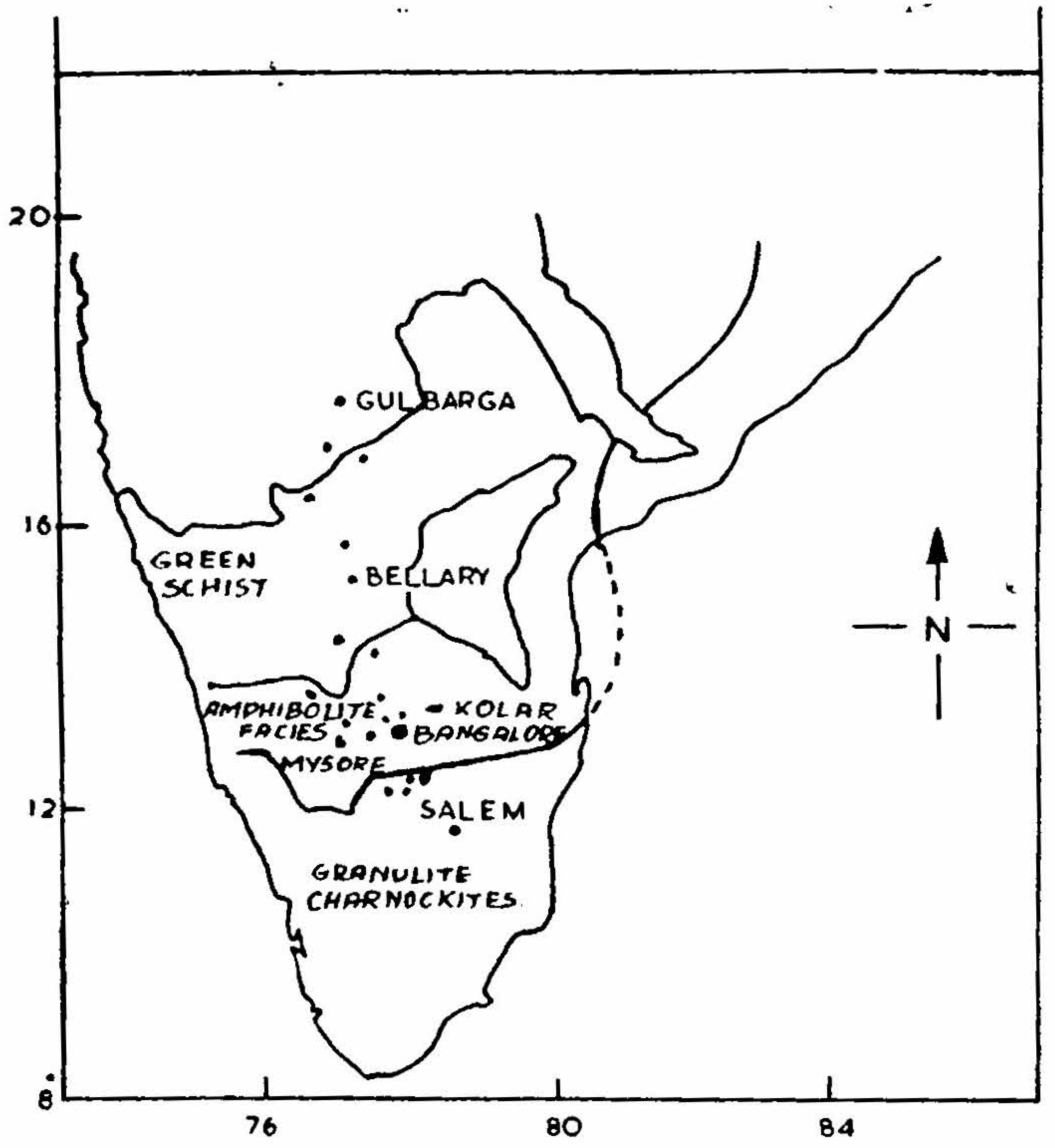

FIG. 1. General pattern of metamorphic facies in South India (sample locations in dots).

belts and isolated stringers, consisting of chlorite schists associated with metavolcanics and clastic sediments in the north, and hornblende schists associated with ultra-basics further south. The granitic gneisses and migmatites form a huge complex classified into different lithological types and considered as reflecting different granitization episodes. Ubiquitous are the "Peninsular Gneisses" covering nearly 80% of the region. Rama Rao [2] distinguishes different rock types—banded gneisses, augen gneisses, gneissic granites, and granites in this broad group, which also contains enclaves and xenoliths of the schist belt. The "Champion gneiss"—a fine-grained micaceous rock with blebs of opalescent quartz—probably belongs to this older suite of granitics. A well-demarcated belt of a range of hills running north-south in the middle, consisting of porphyritic granites is the Closepet suite, regarded as a younger series on the basis of field relations and petrographic data. The Archaen granulite complexes are represented in the south of Mysore by the Charnockites and associated high grade gneisses, and these probably incorporate both intrusive igneous bodies and metamorphosed supra-crustal sequences.

Further, the rocks of this region show evidence of progressive regional metamorphism. Pichamuthu [3] cites field evidence indicating a major structure in the form of a northward-plunging anticlinorium whose effect is to expose deeper sections of the fold southwards, with progressively higher metamorphic grade. The schist belt in the north belongs to the green-schist facies, with the presence of characteristic minerals—chlorite, tremolite and actinolite. Further south, the rocks acquire the impress of the almandine-amphibolite facies with the development of almandine, hornblende, biotite and staurolite. The charnockitic region in the south shows the granulite facies of metamorphism characterised by the minerals hypersthene, diopside and garnet, and this belt extends to Tamil Nadu and Kerala States.

Considerable work has been done in recent years on the trace element geochemistry of regionally associated granites. The main problems pertain to (*a*) the variation of trace element distribution with grade of metamorphism and (*b*) the palingenetic (selective fusion) effects of older upon younger generations of granites.

This laboratory has been engaged for the past few years, on studies in the geochronology and trace element geochemistry of granitic rocks of this cratonic region. In this paper, we give a comprehensive survey of

(*a*) the Rb–Sr isochron age measurements in the zones of differing metamorphic grade mentioned above,

(*b*) the geochemical distribution of K, Rb, Li, U and Th in the different generations of granites in these zones.

Some of these results have been published [4, 6, 7].

GEOCHRONOLOGY

The data reported below have been obtained by the Rb-Sr method. Concentrations of Rb and Sr by the stable isotope dilution technique, and Sr^{87}/Sr^{86} isotope ratio measurements have been carried out with the aid of a 10 inch radius, 90° deflexion Nier type mass spectrometer equipped with a thermal ionisation source, constructed in the laboratory. The chemical separation and ion exchange techniques follow those described by Aldrich *et al.* [8]. Isochron plots have been made in most cases, as computerised best fit curves following the statistical procedure of Brooks *et al.* [9]. The major results are discussed below.

Greenschist Facies Zone

(*a*) Granites from an extended area in the districts of Gulbarga, Raichur, Bellary and Shimoga Districts have been examined in a reconnaissance isochron survey, and the analytical data have been given in Table I, while

TABLE I

Analytical data on N. Mysore granites

Specimen	Rb^{87} (ppm)	Sr^{86} (ppm)	(Rb^{87}/Sr^{86}) at	(Sr^{87}/Sr^{86}) at normalized
Ngl	45·4±0·8	18·0±0·1	2·49±0·05	0·808±·003
Ng2	44·7±0·7	36·C±0·2	1·23±0·02	0·761±·004
Ng3	18·2±0·4	44·1±0·4	0·406±0·01	0·727±·005
Ng4	39·3±0·6	22·9±0·2	1·70±0·03	0·779±·003
Ng5	76·0±0·9	19·6±0·1	3·84±0·05	0·864±·004
Ng6	4·68±·08	3·02±·03	1·53±1·03	0·769±·003

the rock types and locale have been given in the Appendix. The prevalent formations here are the chlorite schists and associated gneisses and granites. The schistose bands of Lingsugur show unmistakable Dharwarian trends, while the area N.E. of Shikaripur (near Horeguppa) contains grey-wackes with rounded grains of quartz and feldspar in a base of sericite and chlorite —these being regarded as products of the basement. The Horeguppa granites are regarded as an acidic member of the Champion gneiss suite.

Figure 2 shows that the rock points fall on an isochron of 2990 ± 120 M.Y., with an initial ratio $Sr^{87}/Sr^{86} = 0{\cdot}707 \pm {\cdot}004$. The biotite from a

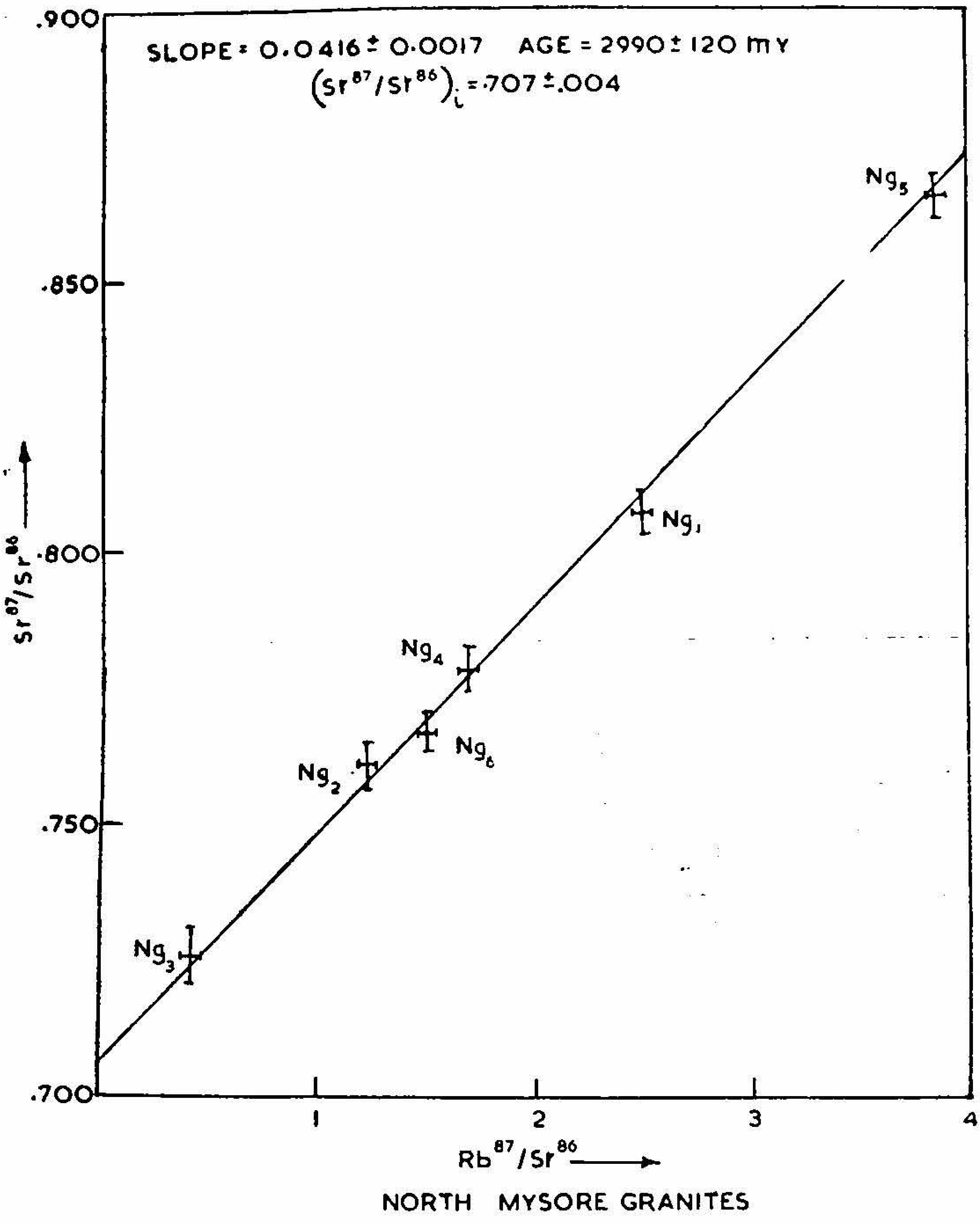

FIG. 2. Rb–Sr isochron, North Mysore Granites.

granite of Siriguppa yields a mineral age of 2890 M.Y. The existence of such an age value comparable with the highest ages obtained for the craton [10] is striking and confirm the widespread nature of this event. The inclusion of the granites of Shikharipur suggests the relationship of the Champion gneiss with this early granitic event.

(*b*) A younger suite of granites in this metamorphic zone is constituted by the Chitradurga granites, which are intrusive into the chlorite schists, The geology of this area has been summarised by Radhakrishna [11] and the analytical data and specimen details are given in Table II and the Appendix.

TABLE II

Analytical data on Chitradurga granites

Specimen	Rb^{87} (ppm)	Sr^{86} (ppm)	(Rb^{87}/Sr^{86}) at	(Sr^{87}/Sr^{86}) at normalized
Cg1	$134 \cdot 6 \pm 1 \cdot 2$	$34 \cdot 9 \pm 0 \cdot 3$	$3 \cdot 82 \pm 0 \cdot 05$	$0 \cdot 837 \pm \cdot 003$
Cg2	$86 \cdot 0 \pm 0 \cdot 9$	$15 \cdot 9 \pm 0 \cdot 1$	$5 \cdot 35 \pm 0 \cdot 06$	$0 \cdot 889 \pm \cdot 003$
Cg3	$56 \cdot 2 \pm 0 \cdot 8$	$21 \cdot 0 \pm 0 \cdot 2$	$2 \cdot 65 \pm 0 \cdot 05$	$0 \cdot 798 \pm \cdot 004$
Cg4	$35 \cdot 8 \pm 0 \cdot 5$	$33 \cdot 6 \pm 0 \cdot 3$	$1 \cdot 06 \pm 0 \cdot 02$	$0 \cdot 745 \pm \cdot 004$

The isochron plot is given in Fig. 3, and this shows that the 4 granites define an isochron of age 2475 ± 85 M.Y., with initial Sr-isotope ratio (87/86) $= 0 \cdot 706 \pm \cdot 004$. Similar ages (2450 M.Y. and 2575 M.Y.) were obtained by Crawford [10] for individual biotite enriched granites in this region, and in the neighbouring Jampalnainakote granites. There is considerable field evidence of the granites being intrusive into the schists, as for instance, the deformation of the schist belts and the grey trap of the adjacent Jogimardi hills and the abrupt cutting off of the quartz reefs. In addition, measurements [10] on the Rb-poor Dharwar volcanics (pillow lavas and bore-hole samples) yield ages in the range 2350–2450 M.Y., and as these do not differ significantly from the isochron age reported here, the later granitic intrusion is part of the igneous-plutonic episode represented by the lava flows.

The Amphibolite Facies Region

The rock formations of Bangalore and its vicinity constitute one of the well-defined exposures of the Peninsular gneiss suite, in *sensu stricto*. Analytical data on specimens from the quarries at the Indian Institute of Science, Lal Bagh, Mount Joy, and Tippugondanahalli are given in Table III, while descriptions of the rock types—augen and banded gneisses, hornblende-biotite gneisses, caught-up amphibolite enclaves (agmatites) and gneissic and light coloured granites—are given in the Appendix.

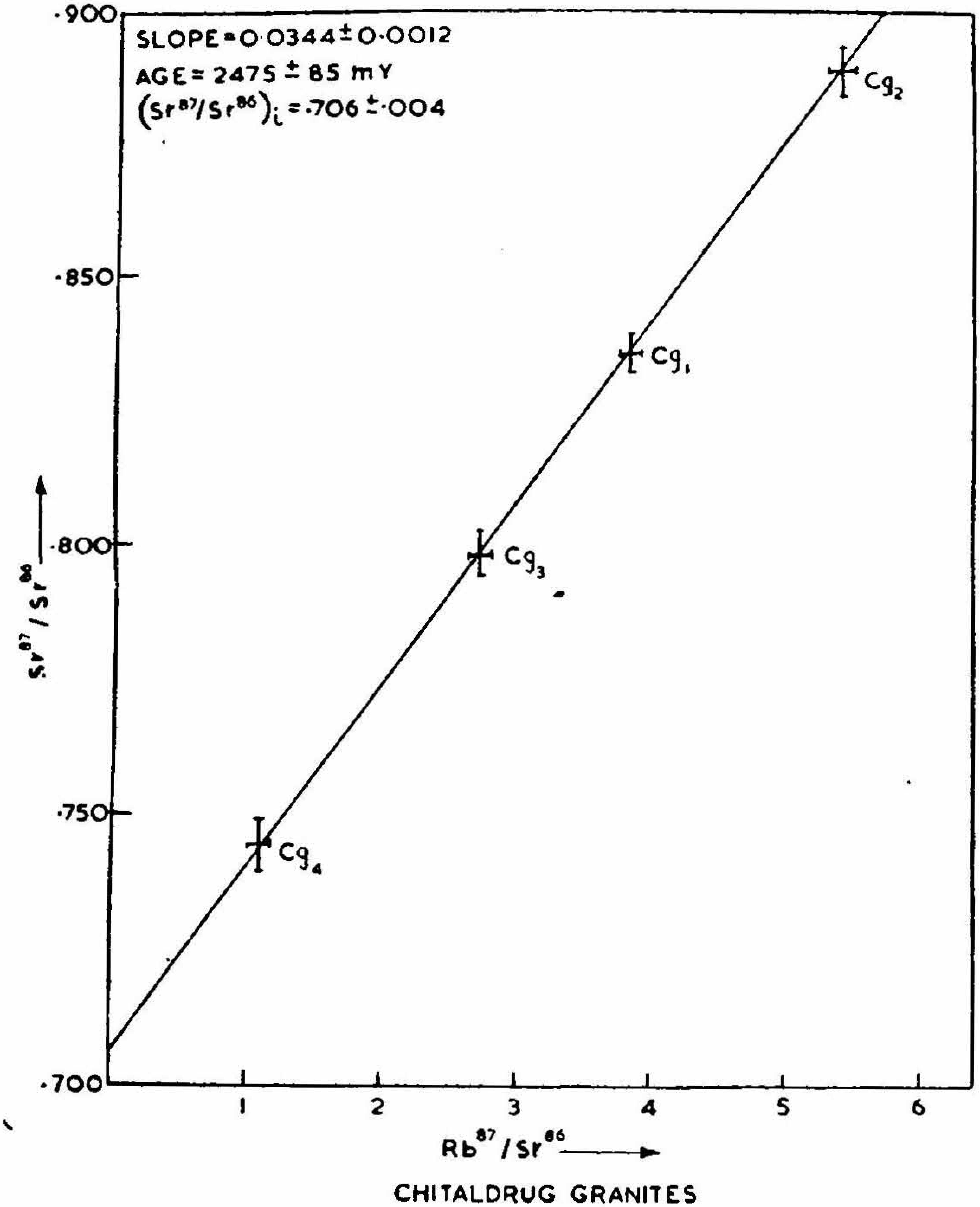

FIG. 3. Rb-Sr isochron, Chitaldrug Granites.

The isochron plots (Figs. 4 and 5) distinguish two granitic events in the region of ages 2950 ± 120 M.Y. and 2540 ± 100 M.Y. This idea gains further support from the observations—

(*a*) The mineral isochron for the augen-gneiss of the older event yields an age of 2520 M.Y., with an initial Sr isotope ratio $Sr^{87}/Sr^{86} = 0 \cdot 73$, indicating isotopic rehomogenisation after the later event,

TABLE III

Analytical data on Peninsular gneiss and granites, Bangalore

Specimen	Rb^{87} (ppm)	Sr^{86} (ppm)	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86}
IR1	59·2	14·93	3·92	0·880
IA1	50·1	9·39	5·27	0·932
LR1	46·8	41·1	1·13	0·746
LR2	65·6	24·2	2·67	0·822
JR1	56·3	17·3	3·21	0·839
TR1	16·2	4·16	3·85	0·841
KuR1	84·8	19·2	4·35	0·851
IR2	75·2	10·67	6·98	0·936

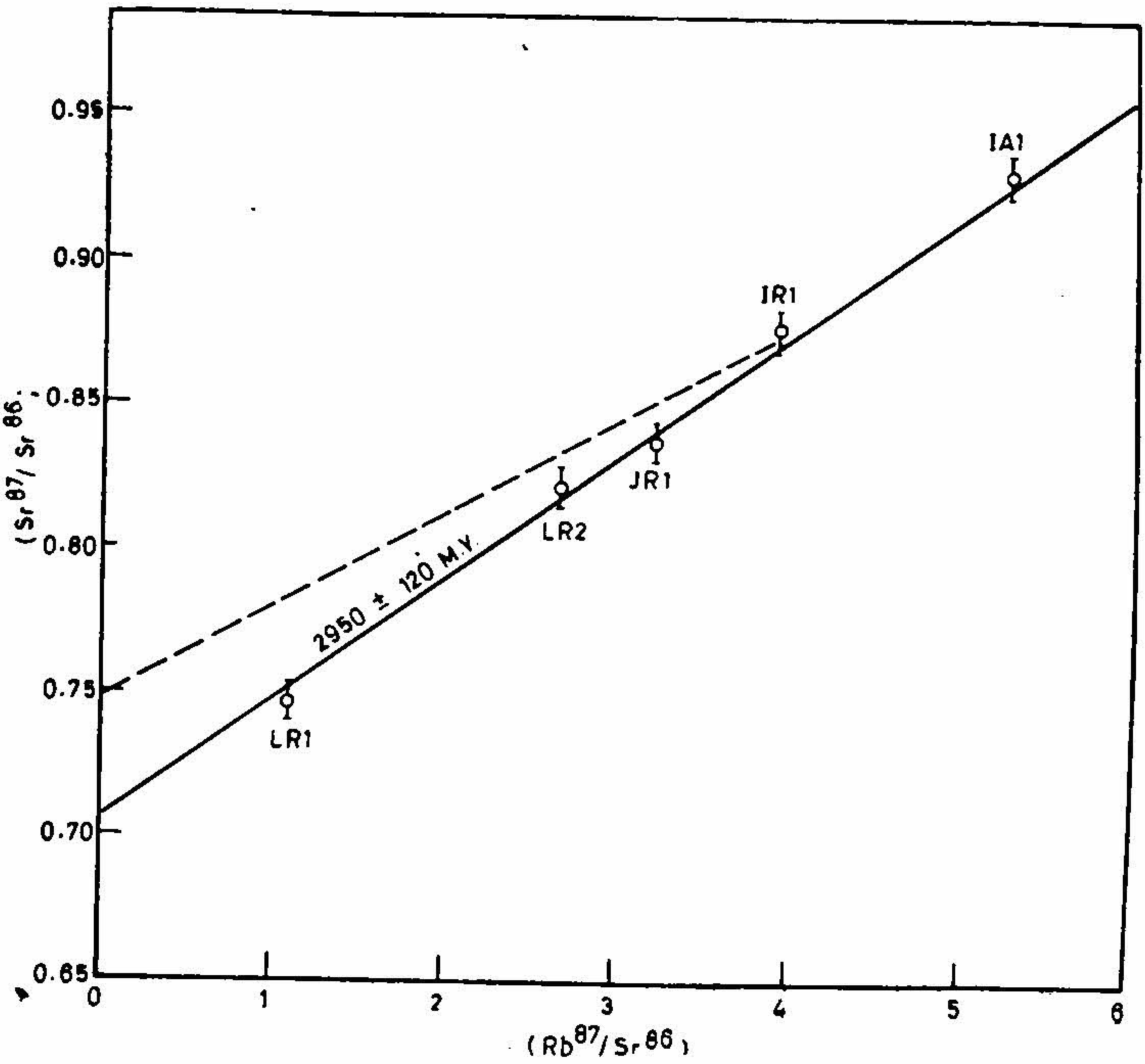

FIG. 4. Rb–Sr isochron, Peninsular Gneisses, Bangalore.

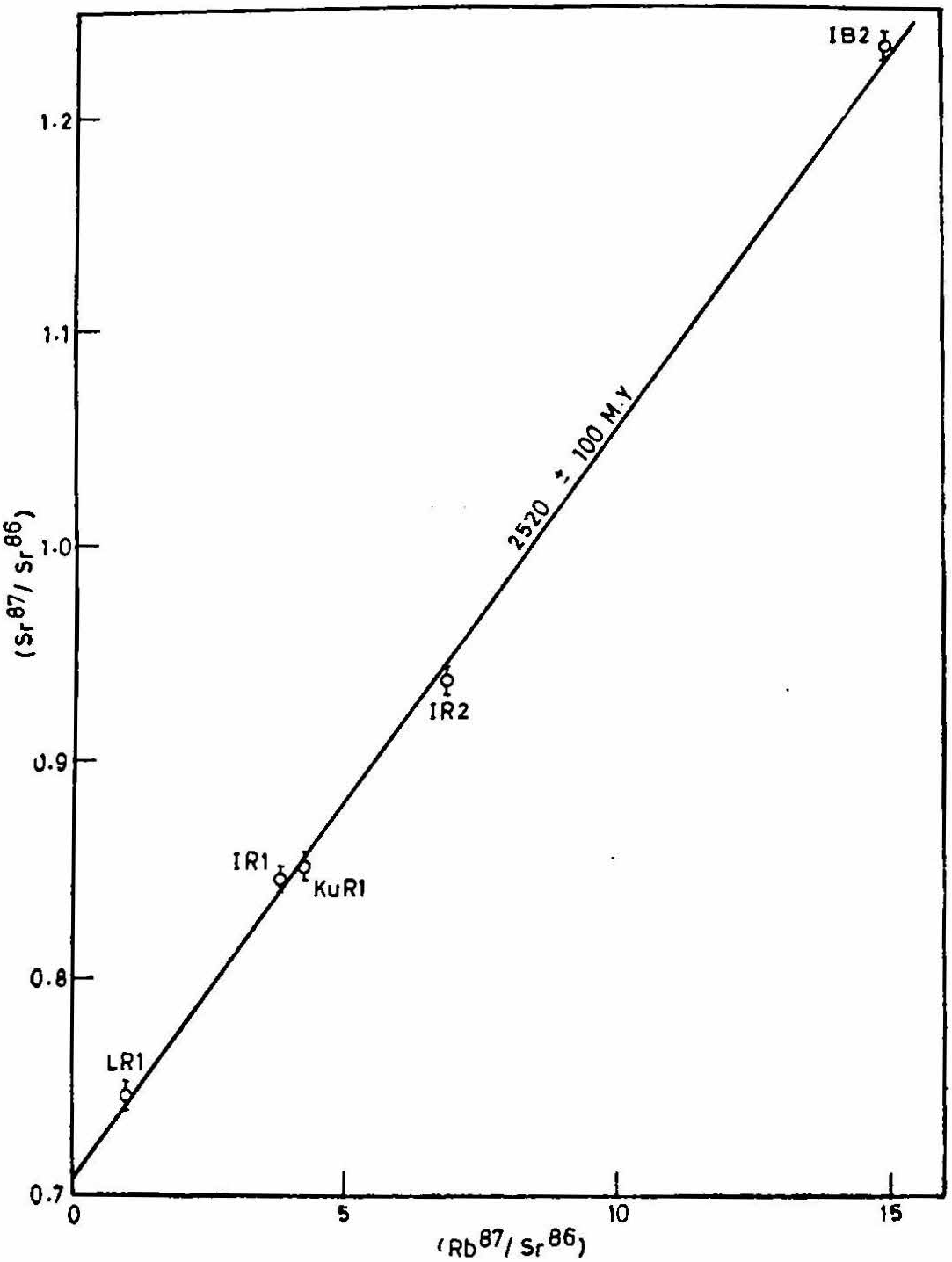

FIG. 5. Rb–Sr isochron. Granites. Bangalore and vicinity.

(*b*) The older isochron includes the amphibolite enclave so that isotopic ratios in the xenolith have not been remodelled.

(*c*) Biotite ages from a number of locations in the vicinity span an age interval 2000–2900 M.Y., with a prominent peak in the histogram in the range 2100–2300 M.Y.

Typical of the migmatites of this region is the Kathriguppe quarry, where field and petrological relations indicate hornblende schists in different degrees of alteration and assimilation among quartz diorites, banded gneisses and granites with aplite veins. Table IV gives the analytical data for the samples selected from the region, with details as in the Appendix.

TABLE IV

Analytical data on Kathriguppe samples

Specimen	Rb^{67} (ppm)	Sr^{86} (ppm)	(Rb^{87}/Sr^{86}) at	(Sr^{87}/Sr^{86}) at normalized	Age M.Y.
Kg1	$19\cdot6\pm0\cdot2$	$11\cdot06\pm0\cdot1$	$1\cdot76\pm\cdot02$	$0\cdot782\pm\cdot003$	..
Kg2	$22\cdot5\pm0\cdot3$	$22\cdot1\pm0\cdot2$	$1\cdot01\pm\cdot02$	$0\cdot748\pm\cdot003$	..
Kg3	$50\cdot6\pm0\cdot4$	$12\cdot1\pm0\cdot1$	$4\cdot13\pm\cdot06$	$0\cdot872\pm\cdot003$	..
Kg4	$43\cdot8\pm0\cdot5$	$12\cdot8\pm0\cdot1$	$3\cdot38\pm\cdot05$	$0\cdot845\pm\cdot003$	..
Kg5	$44\cdot3\pm0\cdot4$	$5\cdot52\pm0\cdot06$	$7\cdot93\pm0\cdot1$	$0\cdot966\pm\cdot003$	..
B Kg P	$148\cdot8\pm1\cdot7$	$1\cdot23\pm0\cdot03$	$119\cdot6\pm3\cdot3$	$4\cdot57\pm\cdot02$	2270 ± 40
B Kg2	$103\cdot9\pm1\cdot4$	$3\cdot25\pm0\cdot06$	$31\cdot6\pm0\cdot7$	$1\cdot73\pm\cdot01$	2260 ± 50

It is seen that the isochron plot shown in Fig. 6, again delineates the older granitic event at 2950 ± 110 M.Y. Also, biotites from the granites and aplitic veins yield mineral ages of 2300 M.Y., suggesting the latter as a metamorphic episode subsequent to the primary event involving the emplacement of the gneisses.

Granitic masses forming bold hills exist in the vicinity of Arsikere and Banavar, and specimens from these apparently diapiric bodies have been dated, with a view to delineating their relationships with the surrounding Peninsular gneisses and the adjacent Closepet suite of granites. The data are given in Table V. It is seen that these granites define an isochron (Fig. 7) of 2625 ± 90 M.Y., with an initial Sr isotope ratio of $0\cdot703\pm0\cdot004$ so that this coincides with the later granitic event observed in the Peninsular gneissic suite. The biotites from the granites yield mineral ages of 2000 M.Y.,

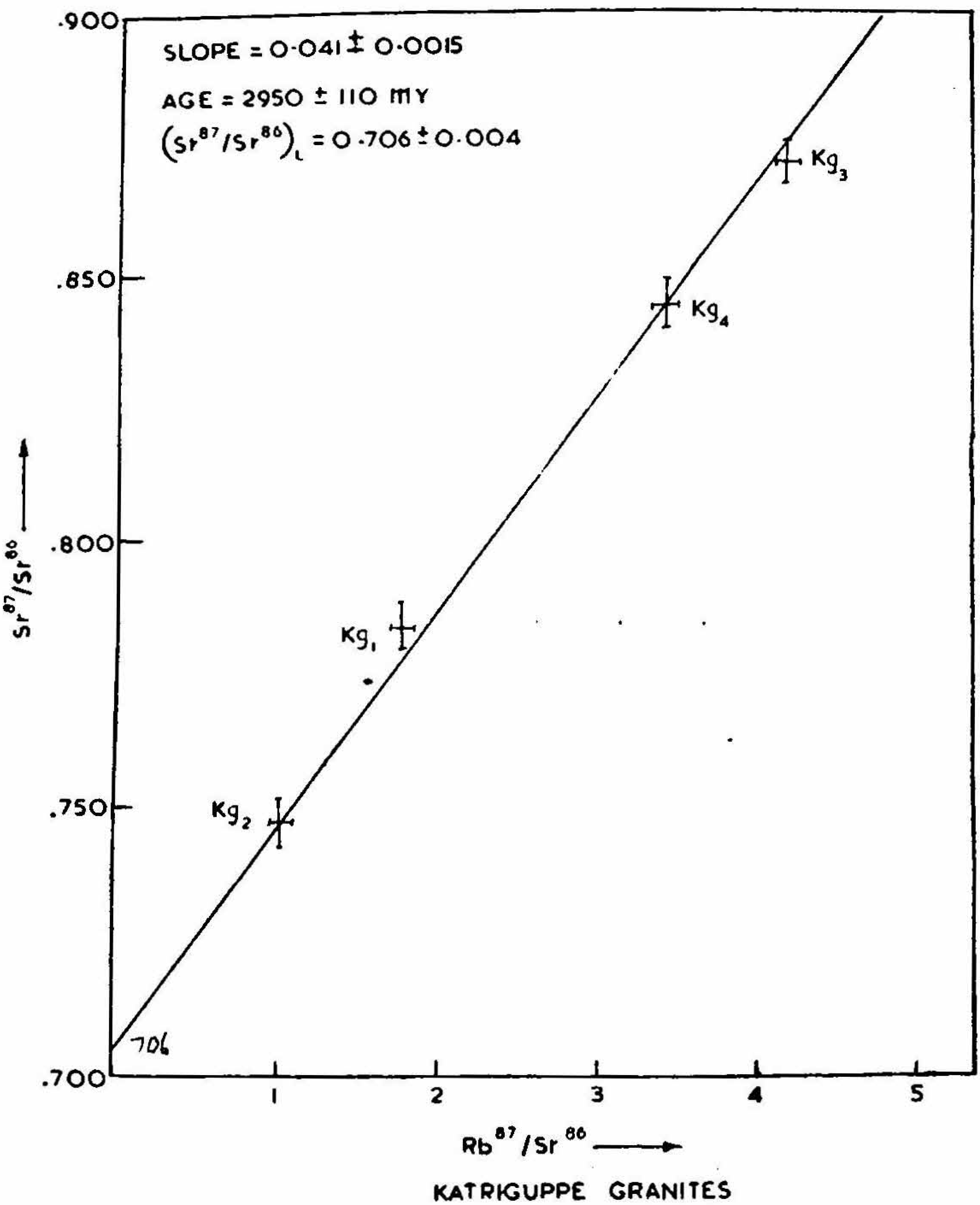

FIG. 6. Rb–Sr isochron, Kathriguppe Granites and Migmatites.

indicating a resetting of the ages apparently in response to the Closepet event referred to below.

The youngest granitic ages obtained in the present studies in this region pertain to the Closepet suite, which is typified by the porphyritic granites that occur as lenticular masses in the locations studied (Closepet, Savan-

TABLE V

Analytical data on Arsikere–Banavar samples

Specimen	Rb^{87} (ppm)	Sr^{86} (ppm)	(Rb^{87}/Sr^{86}) at	(Sr^{87}/Sr^{86}) at (normalized)	Age M.Y.
Ag1	42·7±0·4	15·6 ±0·1	2·71±0·03	0·802±·003	..
Ag2	27·9±0·3	16·1 ±0·2	1·71±0·03	0·768±·003	..
Ag3	19·0±0·3	36·5 ±0·3	0·52±0·01	0·732±·005	..
Bg1	29·0±0·4	7·80±0·4	3·68± ·06	0·837±·002	..
Bg2	30·9±0·4	15·9 ±0·1	1·92± ·03	0·773±·004	..
Bg3	24·7±0·3	22·3 ±0·2	1·10± ·02	0·742±·004	..
B Ag2	215·2±2·1	2·64± ·04	80·5 ±1·5	4·66 ±·04	1940±40
B Bg3	165·0±1·9	2·71± ·03	60·2 ±1·0	3·12 ±·02	2020±50

durga and Magadi). The analytical data are given in Table VI, and sample descriptions in the Appendix.

TABLE VI

Analytical data on Closepet granites

Specimen	Rb^{87} (ppm)	Sr^{86} (ppm)	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86}	$(Sr^{87})^*$	Age (M.Y.)
CR1	113·8	22·17	4·95	0·842	..	..
CF1	113·2	17·25	6·49	0·881	..	..
MgR1	126·8	47·7	2·63	0·783	..	..
SR1	14·9	7·33	2·01	0·761	..	..
CB1	107·0	2·91	..	..	1·21	810±60
MgB1	417·0	6·40	..	..	4·64	810±40

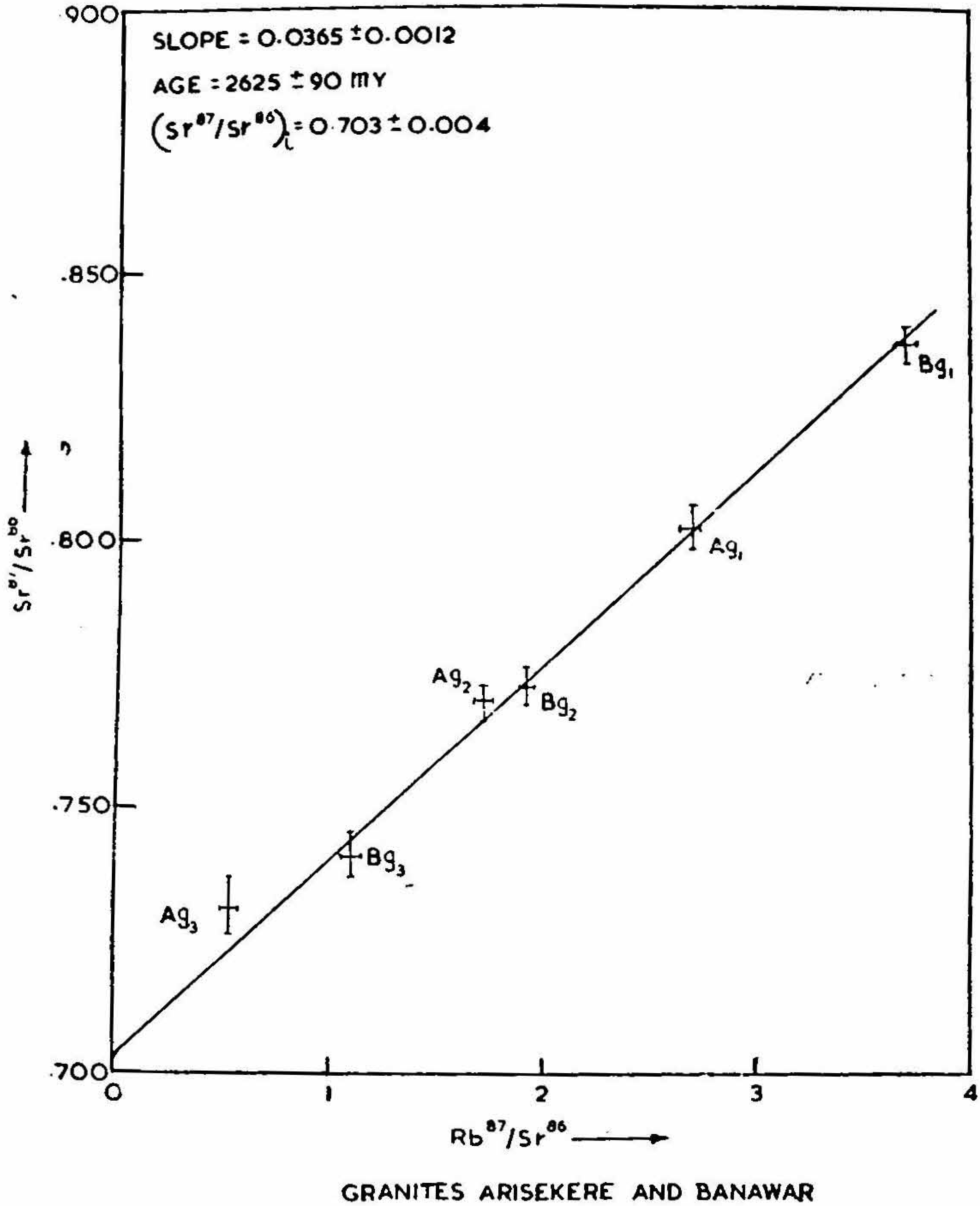

FIG. 7. Rb–Sr isochron, Granites. Arsikere and Banavar.

The whole rock samples and a feldspar define an isochron of 2000 ± 80 M.Y. (Fig. 8). Also mica samples from Magadi and Closepet yield the low age value of 800 M.Y. which corresponds to the last metamorphic episode that has affected the region. This idea gains support from the data of Crawford [10] on granites of similar age (795 ± 35 M.Y.) in Chamundi Hills, Mysore.

Granulite Facies Region

Measurements of charnockite ages are of significance as deep-seated granulites are observed in all Precambrian regions; the suggestion has been made that granulites and their associates underlie the Archaen crust, extending in places up to the surface. In this study, charnockites from Kabbaldurga and Halagur, and the associated gneiss have been examined. These exposures at the southern end of the Closepet suite are coarse-grained granitic in texture, and contain inclusions of basic granulites prominently showing hypersthene. Table VII shows the analytical data on charnockite.

TABLE VII

Analytical data on Charnockite samples

Specimen	Rb^{87} (ppm)	Sr^{86} (ppm)	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86}	$(Sr^{87})^*$	Age (M.Y.)
KdG1	59·5	49·8	1·19	0·7476	..	..
KdG2	102·3	41·8	2·42	0·7926	..	..
KdCh	26·0	97·4	0·264	0·7145	..	..
HCh1	26·2	49·4	0·522	0·7239	..	..
HCh2	15·3	23·4	0·640	0·7283	..	..
BKdG1	390·5	0·68	..	..	7·63	1320
BKdG2	250·4	2·71	..	..	6·65	1880

These measurements have been made using the AEI MS702 mass spectrometer, with thermal ionisation source, and peak switching techniques. It is seen that the data for whole rocks plot on an isochron of 2670 $\pm$ 60 M.Y., (Fig. 8) with initial Sr isotope ratio of 0·704 $\pm$ 0·001. This agrees with a few measurements available on charnockites in Coorg and Nilgiris [12]. Distinctly lower mineral ages have been observed in this region; biotites from the gneiss in Kabbaldurga yield an age of 1320 M.Y., while those from nearby porphyries yield 1880 M.Y. This region is interesting in that Pichamuthu [13] found evidence of rheomorphism causing a transformation of the gneiss

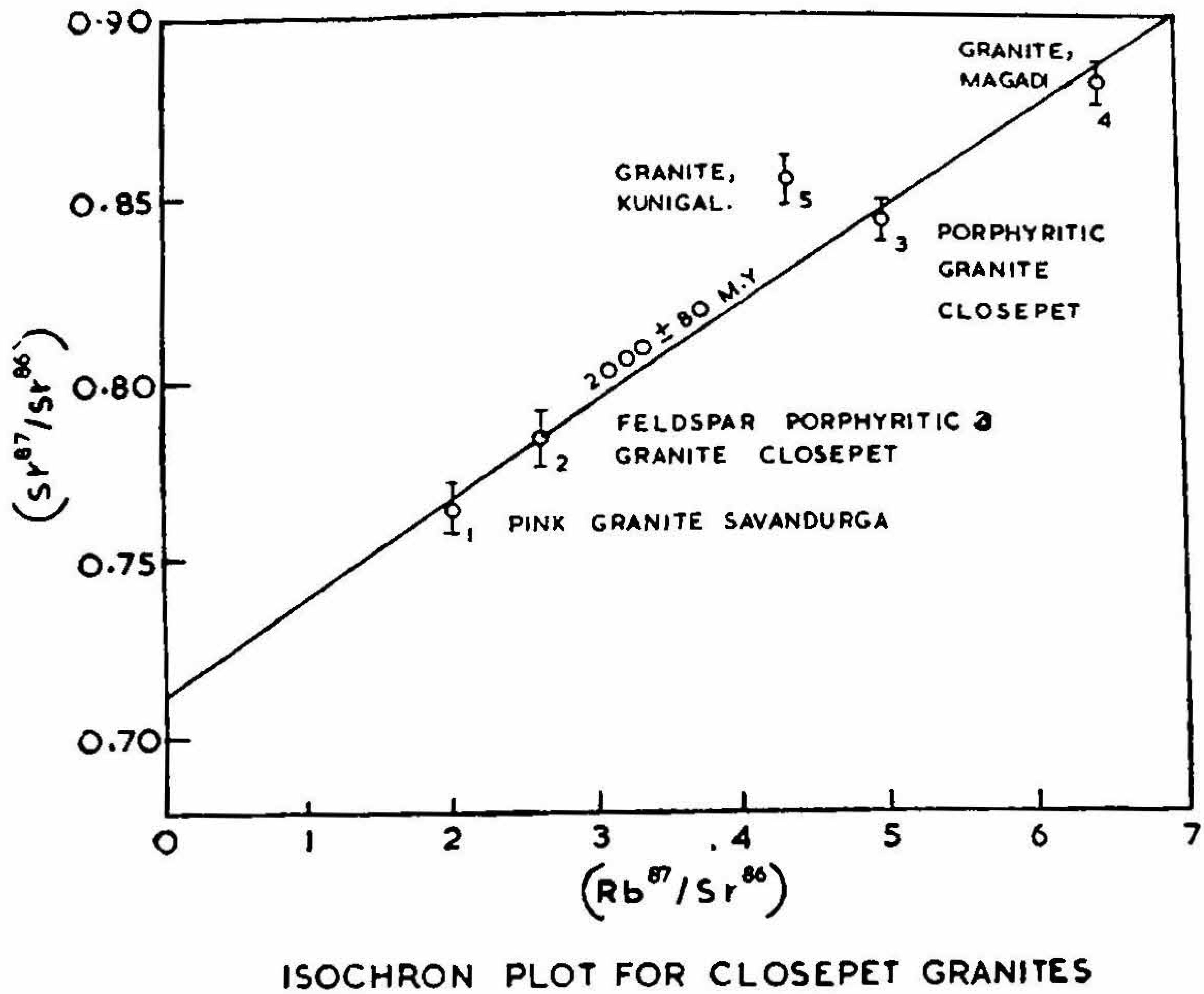

FIG. 8. Rb–Sr isochron, Closepet Granites.

into charnockite, and also field and mineralogical evidence of two generations of charnockites one exhibiting intrusive relations with the other. The mineral age also corresponds to ages of charnockitisation in some regions associated with the Eastern Ghats orogeny, and probably has not caused rehomogenisation of the Sr isotopes in whole rock samples of this area.

TRACE ELEMENT STUDIES

Studies in metamorphic zones indicate that the factors that control the diadochy, capture and admission of trace elements in crystallising magmas apply *mutatis mutandis* to palingenetic rocks as well. At the same time, the selective fusion of the older granites to form the younger generation of palingenetic products is expected to lead to a concentration of granitophile elements. In view of the progressive increase in metamorphic grade from the north to the south in this cratonic region, and in view of the observation of granitic rocks of differing ages in the different metamorphic facies zones, it is of interest to study the influence of the above factors in trace element distribution in these rocks.

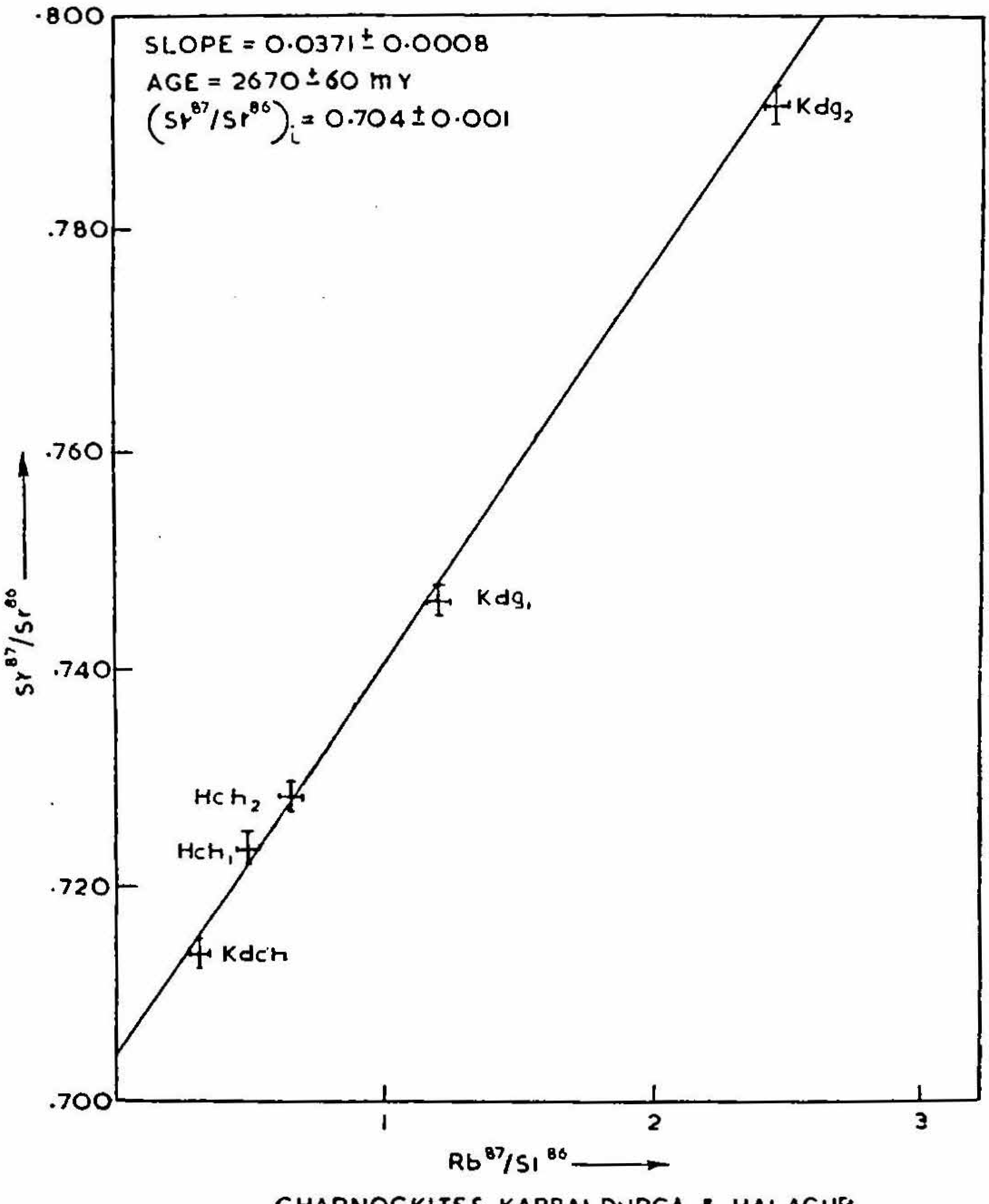

FIG. 9. Rb–Sr isochron, Charnockites, Kabbaldurga and Halagur.

In the present work, the distribution of K, Rb, Li, U and Th has been studied in granitic rocks (and in some cases, mica and feldspar separates) of different age groups and from regions of different grades of metamorphism. K contents have been measured by flame photometry, Rb and Li concentrations by the mass spectrometric isotope dilution technique, and U and Th by scintillation γ-spectrometry with suitable calibrated standards.

Table VIII gives the K and Rb concentrations and the (K/Rb) ratios for granitic rocks belonging to the 3000 M.Y. and 2500 M.Y. groups of the greenschist facies region, the mean values and the standard deviation for (K/Rb) being also indicated. Sample descriptions are given in the Appendix. Table IX gives similar results for the 3000 M.Y., 2600 M.Y., and

TABLE VIII

K, Rb and K/Rb ratios for different age groups of granites

Rock group (No. of samples)	K % and $\sigma/\sqrt{n}$	Rb ppm and $\sigma/\sqrt{n}$	K/Rb ratio and $\sigma/\sqrt{n}$	Student's t-test t_{12} and t_{23} values
Greenschist				
(1) 3000 M.Y. (20)	3·7±0·5	107±22	344±26	..
(2) 2500 M.Y. (16)	5·4±0·5	233±52	277±35	$(t_{12})_{Rb}$ = 2·6; $(t_{12})_{K/Rb}$ = 3·0; $(t_{0\cdot95})$ = 1·70
Amphibolite				
(1) 3000 M.Y. (16)	4·1±0·6	143±20	301±21	
(2) 2600 M.Y. (20)	3·8±0·5	167±20	236±12	$(t_{12})_{Rb}$ = 0·8; $(t_{12})_{K/Rb}$ = 2·6; $(t_{0\cdot95})$ = 1·70
(3) 2000 M.Y. (12)	3·6±0·6	308±40	113±15	$(t_{23})_{Rb}$ = 3·5; $(t_{23})_{K/Rb}$ = 2·8; $(t_{0\cdot95})$ = 1·72
Granulite				
2600 M.Y.	4·0±0·5	81±20	499±27	

TABLE IX

U, Th and Th/U ratios for granites of different facies

Metamorphic zone	No. of samples	Average values and $\sigma/\sqrt{n}$		
		Th (ppm)	U (ppm)	Th/U
Greenschist	16	$27 \cdot 9 \pm 3 \cdot 3$	$4 \cdot 2 \pm 0 \cdot 7$	$6 \cdot 7 \pm 0 \cdot 6$
Amphibolite	32	$29 \cdot 6 \pm 2 \cdot 5$	$4 \cdot 8 \pm 0 \cdot 6$	$5 \cdot 6 \pm 0 \cdot 3$
Granulite	20	$5 \cdot 5 \pm 0 \cdot 4$	$1 \cdot 8 \pm 0 \cdot 2$	$3 \cdot 1 \pm 0 \cdot 3$

2000 M.Y. age groups of granitic rocks of the amphibolite facies, with mean values and deviation for K/Rb.

The results show a definite trend for granitic rocks in the same facies region; the (K/Rb) ratios decrease progressively for the younger age groups. For the amphibolite facies rocks, there is a decrease in K/Rb ratios from 301 ± 20 to 236 ± 12 to 113 ± 15 for the 3000 M.Y., 2600 M.Y. and 2000 M.Y. age groups; and similarly from 344 ± 29 to 277 ± 36 for the 3000 M.Y. and 2500 M.Y. groups in the greenschist facies region.

A decrease in K/Rb ratios of differentiated sequences of granites has been observed by several workers, *e.g.*, Gerasimovsky and Lebedev [14] for successive intrusives of the Lovazero complex, and Butler [15] for the granitic sequences of Nigeria. More pertinent to the present results is the work of Siedener [16] who observed a similar decrease in K/Rb ratios in three generations of granites (Precambrian to mid-Jurassic) in S.W. Africa.

Similar results have been obtained from Lithium measurements in granitic rocks of the amphibolite facies zone. These yield progressively increasing Li contents in decreasing age groups—

$17 \cdot 1 \pm 2 \cdot 4$ ppm for the 3000 M.Y. group,

$33 \cdot 2 \pm 3 \cdot 6$ ppm for the 2600 M.Y. group,

$97 \cdot 6 \pm 10$ ppm for the 2000 M.Y. group.

The enrichment in the later differentiates is in consonance with the expected geochemical behaviour, involving the admission of Li^+ in place of Mg^{++} and Fe^{++}.

A more spectacular variation is observed in the Rb-distribution in the granitic rocks of the granulite facies zone. Results for granites and acid charnockites are given in Table VIII and show the average K/Rb ratio as 499 ± 27, *i.e.*, higher by a factor of about 2 as compared with those for granites from the greenschist and amphibolite facies zones. As the measurements show only a minor decrease in K-contents in the present case, the increase in K/Rb ratios is related to depletion of Rb in the granulites. Similar results have been reported for high grade granulites in other regions of the world, *e.g.*, by Heier and Thoresen [17] for the banded granulites of Lofoten Norway; and Lambert and Heier [18] for the granulite facies rocks of W. Australia. A number of measurements on feldspar separates in some of the present samples also show the high values of the K/Rb ratios, while a limited number of measurements of distribution coefficients

$$K_D = \frac{(K/Rb)\ \text{feldspar}}{(K/Rb)\ \text{biotite}}$$

yield values in the range 3–4, with no significant change with metamorphic grade. These facts lend support to the hypothesis that anatectic melting under granulite facies conditions results in a concentration of Rb in the melt, and its removal by upward migration of the anatectic liquid to lower pressure regions, raises the K/Rb ratios of the granulite facies rocks. In general, this process leads to a depletion of granitophile elements in the granulites now exposed to the surface.

U and Th measurements.—A number of measurements of U, Th and K have been carried out in granitic rocks in all the metamorphic facies zones by the total γ-spectrometry method. These data are summarised in Table IX.

An examination of these results shows that while there is no major variation in the trends of U and Th distribution in the rocks of the greenschist and amphibolite facies, there is a definite decrease in Th and U concentrations in the granulite facies. A second feature is that the amphibolite and greenschist facies rocks have Th/U ratios higher than the crustal average of $\sim 3 \cdot 5$ (the present results being $6 \cdot 7 \pm 0 \cdot 6$ and $5 \cdot 6 \pm 0 \cdot 3$ respectively), while the granulites have an average $Th/U = 3 \cdot 1 \pm 0 \cdot 3$. The observed Th and U depletion in granites is in conformity with results for the felsic rocks of the Australian shield [19], and the higher than crustal Th/U ratios with similar values for the amphibolite facies rocks of the Canadian shield [20].

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