Proc. Indian Acad. Sci. (Earth Planet. Sci.), Vol. 91, No. 1, March 1982, pp. 65–73.

Rb-Sr age of Gaik granite, Ladakh batholith, northwest Himalaya

J R TRIVEDI, K GOPALAN, KEWAL K SHARMA*, K R GUPTA* and V M CHOUBEY*
Physical Research Laboratory, Ahmedabad 380 009, India
*Wadia Institute of Himalayan Geology, Dehra Dun 248 001, India

MS received 25 August 1981; revised 19 December 1981.

Abstract. The Gaik Granite is a part of the Ladakh batholith outcropping betweeen Gaik and Kiari in NW Himalaya. This is a pink porphyritic granite rich in biotite and poor in hornblende. Rb-Sr analyses have been made on six whole-rock samples of the Gaik Granite. Though the samples are poorly enriched in radiogenic Sr, they define a reliable isochron corresponding to an age of 235 ± 13 (2σ) m.y. and initial $^{87}Sr/^{86}Sr$ ratio of $0{\cdot}7081 \pm 0{\cdot}0004$ (2σ). Biotite, plagioclase and potash feldspar fractions separated from two of the samples have yielded a much younger mineral isochron at $30 \pm 1{\cdot}5$ m.y. indicating a nearly complete redistribution of Sr isotopes between mineral phases at a time much later than the primary emplacement of the granite. The present results show that at least some components of the Ladakh batholith are of Permo-Triassic age. These rocks were isotopically re-equilibrated on a mineral scale during Upper Oligocene in response to the Himalayan orogeny.

Keywords. Rb-Sr age; isochron; Ladakh batholith; Hercynian; Permo-Triassic; granite.

1. Introduction

The Ladakh batholith which occurs as a linear body measuring about 600 km long and 25-75 km wide and covers a major part of the Ladakh range in the Transhimalayan region has attracted the attention of geoscientists all over the world. In recent years, many attempts have been made to understand the nature, tectonic setting and the age of this batholith. The present paper deals with the Rb-Sr age of a distinct plutonic body of the pink porphyritic granite exposed between Gaik and Kiari (figure 1).

2. Geologic setting

The various aspects of the geology of the Ladakh region, including the Ladakh batholith, have been receiving attention of the geologists for more than a century now (Stoliczka 1866; Oldham 1888; McMahon 1901; De Terra 1932, 1935; Auden 1935; Berthelsen 1953; Tewari 1964; Gupta and Kumar 1975; Raiverman and Misra 1975; Shah *et al* 1976; Frank *et al* (1977; Fuchs 1977; Sharma and Gupta 1978; Pal *et al* 1978; Srikantia and Razdan 1980 and Thakur *et al* 1981). Recently, Sharma (1981) highlighted a few new features of the Ladakh-Deosai batholith (commonly

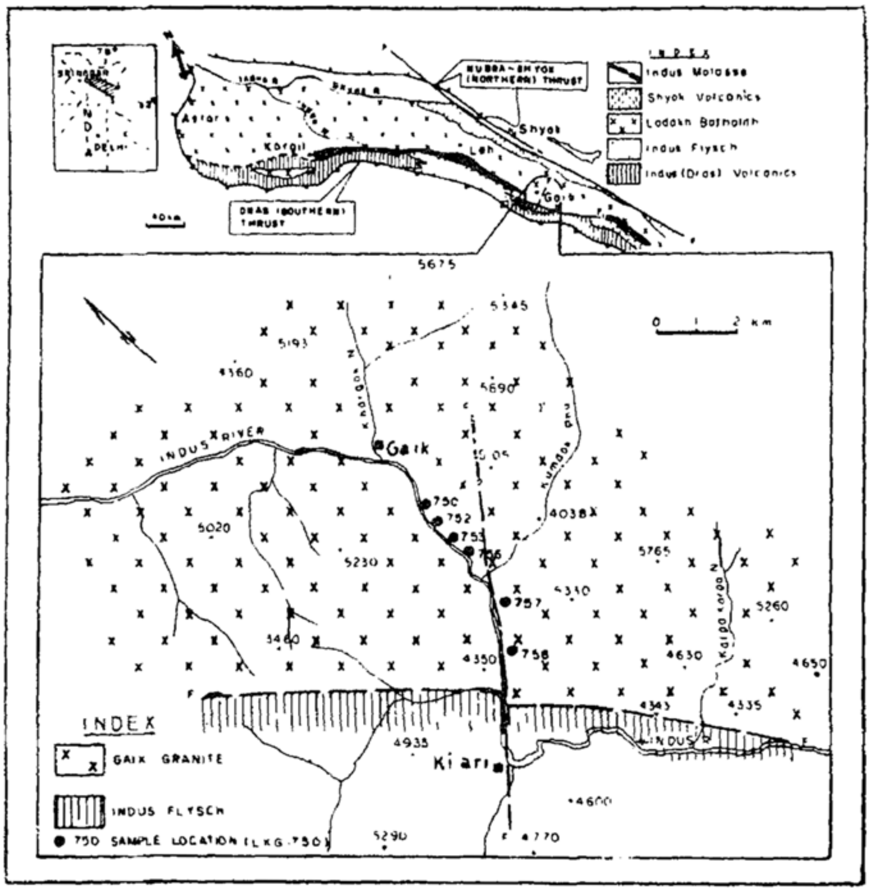

Figure 1. Simplified geological map of the Gaik Granite and vicinity with sample locations shown by black dots with accompanying label.

called Ladakh batholith) and its surrounding rocks along with a critical discussion of the existing beliefs on its age.. Only a brief geological account is given below.

The rocks of the Indus Suture Zone are separated from the Crystallines and the Tethyan rocks of the Himalayan region by a south dipping thrust commonly known as the Dras thrust. The Indus Suture zone rocks are largely shale and graywacke with turbidite structures, radiolarian chert, jasperoid shale, conglomerates and occasional limestone varying in age from Lower Cretaceous to Lower Palaeogene. A thick pile of basic to intermediate volcanics with associated ophiolitic melange is very well exposed around Dras in the northwest and Sumdo in the southeast of this zone whereas in between these two areas it is reduced to thin slices due to thrusting. The Ladakh batholith which lies to the north has an intrusive relationship with the Dras Volcanics near Burzil (Wadia 1937) and Kargil-Batalik area (Sharma 1981) and a tectonic relationship with the rocks of the Indus Flysch between Kiari and Chumathang. At other places the southern contact of the Ladakh batholith is covered

Table 1. Major litho-tectonic units of Ladakh region from south to north

North	Karakoram batholith (Tegar Granite) and associated Palaeozoic metamorphites	
	———Shyok (Northern) Thrust———	
	Ophiolitic melange and associated basic volcanics	*(Island arc ophiolites)*
	Upper Palaeozo metamorphites	
	———Nubra-Gartang Fault———	
	Shyok Volcanics and Upper Indus (Koyul) Molasse	
	———Unconformity———	
	Upper Jurassic Gondwana and Lower Cretaceous sediments	
	———Tectonic/intrusive contact———	
	Ladakh Batholith	
	———Unconformity———	
	Indus (Kargil) Molasse	
	———Thrust (interformational)———	
	Ophiolitic melange and basics	*(Subduction zone ophiolites)*
	Indus Volcanics and flyschoidal sediments	
	———Dras (Southern) Thrust———	
South	Crystallines and the Tethyan sediments of the Himalayan region.	

under a linear belt of the Indus Molasse of Miocene-Pliocene (?) age. The various litho-tectonic units exposed from south to north as reported by Sharma and Gupta (1981) are given in table 1.

As shown in figure 1 and table 1 the northern margin of the Ladakh batholith is covered by the Shyok volcanics of the early Cenozoic period, which are acid to intermediate (calc-alkaline) in composition (Sharma and Gupta 1981).

The Ladakh batholith is composed chiefly of quartz bearing rocks that vary widely in composition from quartz diorite, granodiorite, quartz- monzodiorite, quartz monzonite to granite with occasional masses of diorite, gabbro, pyroxenite and anorthosite. This batholith is a complex body composed of a large number of plutons of different composition and character which can be readily distinguished from one another in the field by differences in mineral composition and texture as is evident in the Gaik-Kiari and Hanuthang sections (Sharma 1981). An E-W trending fault in the Upshi-Kiari section has uplifted the rocks from the deeper levels of the Ladakh batholith and the deep gorge of the Indus river has exposed them for a direct observation. One can study the best development of a pink porphyritic granite body between Kiari and Gaik. Tongues and apophyses of leucogranite, a few tens of metres across, cut through the pink porphyritic granite towards its margin near Gaik. An extensive body of the leucogranite is exposed between Tirdo and Lickhe with occasional relicts of the pink porphyritic granite in it. It is interesting that the pink porphyritic granite and the leucogranite exposed in this section are either free from hornblende or very poor in it and thus differ from the hornblende granite, extensively developed in other parts of the Ladakh batholith.

3. Previous age data

The age of Ladakh Granite has been discussed by various workers mostly on the basis of the field relations. Stoliczka (1874) considered the Ladakh gneiss to be of Silurian age, whereas Lydekker (1880) compared it with 'Central Gneiss'. Auden (1935) and Wadia (1937) on the basis of their observations in the Skardu-Satpura and Astor-Burzil areas respectively consider the hornblende granite to be Tertiary, as it intrudes into the volcanics and limestones containing Upper Cretaceous-Eocene fossils. Auden (1935) also observed that the biotite granite into which the hornblende granite intrudes near Shyok-Indus confluence may be of an earlier age *i.e.* Hercynian, Caledonian, or even Precambrian. De Terra (1932) and Dainelli (1933–34) also assigned Hercynian age to this granite.

In recent years considerable interest has been shown by the geoscientists for a better understanding of the geology of the Ladakh region as it is believed to be the zone of plate-to-plate collision (Gansser 1964). The age of the Ladakh batholith which plays a crucial role in the palaeogeographic and palaeotectonic reconstruction of this region is still controversial. Shankar *et al* (1976 a, b), Shah *et al* (1976), Srikantia and Bhargava (1978), Pal *et al* (1978), Srikantia and Razdan (1980) consider the major part of the Ladakh batholith to be pre-Upper Cretaceous in age, and a few of them also believe that in the late Tertiary times widespread acid igneous activity resulted in the formation of the Kargil granite (Shah *et al* 1976; Varadarajan *et al* 1980); Chumathang-Kiari granite, pegmatite, aplites, quartz and quartz-fluorite veins (Shanker *et al* 1976 a, b; Srikantia and Bhargava, 1978). These authors based their views on the limited area of their study without a serious consideration of the radiometric age data on Ladakh granites. However, Desio *et al* (1964) reported a model Rb-Sr age of 48 m.y. for the granodiorite from Satpura, South of Skardu and Desio and Zanettin (1970) dated a granite boulder of the Hemis conglomerate as 38 m.y. Both these ages point to post-Upper Cretaceous age of the Ladakh batholith as believed by Wadia (1937), Frank *et al* (1977), Rai and Pande (1978) and Sharma and Kumar (1978). Sharma *et al* (1978) also reported K-Ar age of 28 $\pm$ 1 m.y. for the pink-porphyritic granite from Hemiya in the Upshi-Kiari Section. Recently, Sharma *et al* (1981) reported the fission track ages of sphene and apatite from different parts of the Ladakh batholith. The age of sphene varies from 25 to 34 m.y. and that of the apatite from 12 to 25 m.y. Although the K-Ar and fission track age data indicate only the cooling ages since the last thermal event, this data lend some support to the Rb-Sr ages reported by Desio *et al* (1964) and Desio and Zenettin (1970) from other parts of the Ladakh batholith. The field evidences and the limited radiometric age data so far available on the Ladakh batholith suggest that a major part of the Ladakh batholith is post-Upper Cretaceous.

4. Analytical procedure

The locations of the samples taken for analysis are shown in figure 1 and their petrographic descriptions given in appendix. Mass spectrometric analyses for Rb and Sr in the whole rocks were carried out on about 0·2 to 0·3 gm of finely powdered and well-homogenized samples prepared from whole-rock specimens weighing 12-15 kg. The crushing and grinding of the samples were carried out using a jaw crusher, disc grinder and Tema-Mill which were mechanically cleaned between the samples and preconditioned with a small portion of the sample under processing to minimise cross-contamination.

Various mineral fractions used for the analysis were separated with a magnetic separator and organic heavy liquids.

Total Rb and Sr contaminations from the reagents and chemical procedure were measured by periodically running blanks in parallel with the samples. The blank levels are usually 0·006 μg for Rb and 0·008 μg for Sr, which introduce negligible error ($<$ 0·15%) in the amount of Rb and Sr normally handled. The samples were run on a 23 cm, 60° sector, single focussing, mass spectrometer fitted with a Faraday cup collector. The peak heights were registered on a chart recorder. ^{87}Rb and ^{84}Sr spikes were used for isotope dilution analysis and the data were normalized to an assumed natural value of $Sr^{86}/Sr^{88} = 0{\cdot}1194$. The uncertainty in ^{87}Rb/^{86}Sr ratio is about 2% and in ^{87}Sr/^{86}Sr ratio is the standard deviation of a set of 10 peak height comparisons.

5. Results and discussion

The Rb-Sr data for the six whole-rock samples and mineral fractions separated from two of them are given in table 2. Individual sets of data are plotted on separate Rb-Sr isochron diagrams, with the straight line shown in each being the least squares fit of the data based on the two error weighed regression of York (1966). Figure 2 shows the isochron for six whole-rocks samples of the Gaik Granite. All the samples conform to a linear array within experimental error. The slope of this line gives the age of the Gaik Granite as 235 ± 13 m.y. (2σ) and its Y-intercept the initial ^{87}Sr/^{86}Sr ratio as 0·7081 ± 0·0004 (2σ) assuming the ^{87}Rb decay constant as $1{\cdot}39 \times 10^{-11}$ yr^{-1}. The low initial Sr ratio of the Gaik Granite is typical of Rb-poor sources implying a deep crustal origin with negligible contamination with crustal material.

Mineral isochrons for the two whole-rock samples LKG-752 and LKG-753 are shown in figures 3 and 4. The two mineral ages are concordant at 30 ± 1·5 m.y. and 29 ± 1·5 m.y., respectively. The minerals in sample LKG-753 have experienced a more complete reequilibration of their Sr-isotopes than the minerals in LKG-752.

Table 2. Analytical results

Sample	^{87}Rb (ppm)	^{86}Sr (ppm)	^{87}Rb/^{86}Sr (atomic)	^{87}Sr/^{86}Sr (atomic)
LKG 750 WR	60·24	89·38	0·67	0·7107 ± 0·0009
LKG 752 WR	70·76	50·98	1·37	0·7122 ± 0·0009
LKG 752 BIO-I	376·77	2·31	161·23	0·7791 ± 0·0010
LKG 752 BIO-II	331·32	7·12	46·00	0·7318 ± 0·0020
LKG 752 KF	113·09	59·46	1·88	0·7153 ± 0·0008
LKG 752 PlAG	8·6	49·28	0·17	0·7094 ± 0·0015
LKG 753 WR	108·28	15·70	6·82	0·7307 ± 0·0014
LKG 753 BIO-I	518·8	1·264	405·72	0·8774 ± 0·0011
LKG 753 BIO-II	513·71	0·638	795·9	1·0563 ± 0·0020
LKG 753 KF	173·77	19·79	8·7	0·7315 ± 0·0016
LKG 753 PLAG	8·54	9·22	0·92	0·7275 ± 0·0012
LKG 756 WR	58·67	96·41	0·60	0·7102 ± 0·0010
LKG 757 WR	57·98	87·12	0·66	0·7104 ± 0·0009
LKG 758 WR	72·80	46·33	1·55	0·7128 ± 0·0011

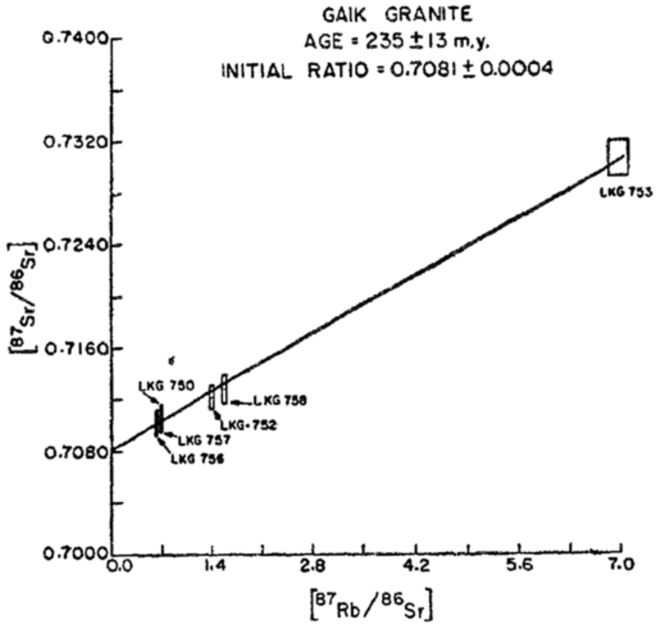

Figure 2. Rb-Sr isochron diagram for the whole rock samples of the Gaik Granite.

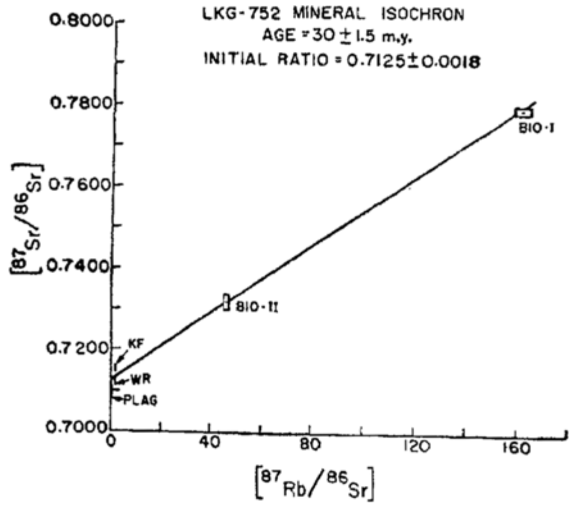

Figure 3. Rb-Sr isochron diagram for minerals separated from rock sample LKG-752.

This reequilibration between mineral phases is presumably due to a thermal event suffered by the Gaik Granite during the Upper Oligocene times.

The foregoing results clearly show that the pink porphyritic granite exposed between Gaik and Kiari is Permo-Triassic in age. This magmatic activity is possibly correlatable with the waning phase of the Hercynian Orogeny. This granitic body

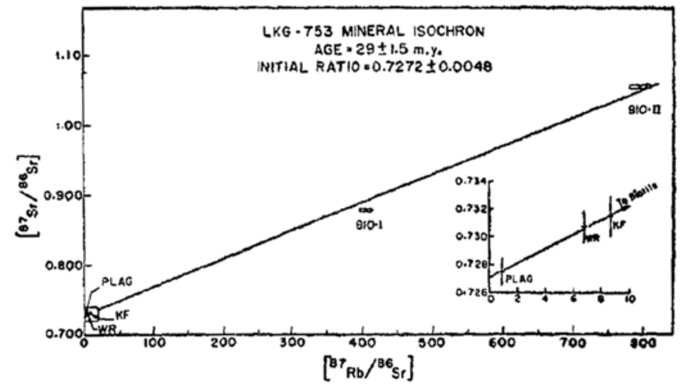

Figure 4. Rb-Sr isochron diagram for minerals separated from rock sample LKG-753.

was subsequently involved in a thermal episode presumably during the period of large scale magmatism in the Indus Suture Zone, which reequilibrated the strontium istopes between its mineral phases about 30 m.y. ago. Such a thermal event on rocks between Likche and Kiari during Upper Oligocene is also indicated by the K-Ar age of 28 + 1 m.y. for the pink porphyritic granite from Hemiya and fission track age of sphene from this area (Sharma *et al.*, 1978, 1981).

The present data is not adequate to resolve the controversy about the age of the Ladakh batholith as a whole. However, it does suggest that the Ladakh batholith is a complex granitoid body and some components of this may be as old as Permo-Triassic. The mineral isochron age of 30 m.y. for the Gaik Granite and the model Rb-Sr age of 48 m.y. for the granodiorite from Skardu (Desio *et al* 1964) bear evidence that a large scale plutonic activity in the early Tertiary time played a major role in the evolution of the Ladakh batholith. The detailed radiometric study of the Ladakh batholith, in progress, would lead to a better understanding the temporal evolution of this batholith.

Acknowledgements

The authors thank Professor D Lal, Dr S C D Sah for the encouragement and facilities to carry out this collaborative study, and Professor S N Sarkar for critical reading of the manuscript.

References

Auden J B 1935 *Rec. Geol. Surv. India* **69** (2) 125

Berthelsen A 1953 *Modd. Fra. Geologisk Forening* **12** (3) 351

Dainelli 1933-1934 *Relaz. Scient. Spediz. De Filippi* 11 (2)

Desio A, Tongiorgi E and Ferrara G 1964 *Proc. 22nd Int. Geol. Congr.* **2** 479

Desio A and Zanettin B 1970 Geology of Baltoro basin III—Geology and Petrology II Italian expedition.

De Terra H 1932 Wissensch. Ergebn, d. Dr. Zentralasien Expedition Berlin 2 1-114

De Terra H 1935 *Mem. Connecticut Aged. Arts Sci.* **8** (2) 18

Frank W, Ganssei A and Trommsdorff V 1977 *Schweiz. Mineral Petrgr. Mitt.* **57** 89
Fuchs G 1977 *Jb. Geol.* B.-A **120** (2) 219
Gansser A 1964 *Geology of the Himalayas* (London: Interscience) 1
Gupta V J and Kumar S 1975 Sonderdruckausder Geologischen Rundschau 64
Lydekker 1880 *Rec. Geol. Surv. India* **3** (1) 121
McMahon C A 1901 *Mem. Geol. Surv. India* **31** (3) 303
Oldham R D 1888 *Rec. Geol. Surv. India* **21** (4) 149
Pal D, Srivastava R A K and Mathur N S 1978 *Him. Geol.* **8** (1) 500
Rai H and Pande I C 1978 *Recent researches in geology* **5** (Delhi: Hindustan Publishing Co.)
Raiverman V and Misra V N 1975 *Geol. Min. Met. Soc. India Bull.* **48** 1
Shah S K, Sharma M L, Gergan J T and Tara C S 1976 *Him. Geol.* **6** 534
Shankar R, Padhi R N, Prakash G, Thussu J L and Das R N 1976a *Him. Geol. Seminar*, New Delhi
Shankar R, Padhi R N, Prakash G, Thussu J L and Wangdus C 1976b *Geol. Surv. India Misc. Pub.* **34** (1) 41
Sharma K K 1981 *Him. Geol.* **2** (In press)
Sharma K K and Gupta K R 1978 *Recent researches in geology* **7** (Delhi: Hindusthan-Publishing Corp.) p. 133
Sharma K K and Gupta K R 1981 *Him. Geol.* **2** (In press)
Sharma K K and Kumar S 1978 *Him. Geol.* **8** (1) 252
Sharma O P, Sharma K K and Nagpaul K K 1981 Fission Track Workshop Ahmedabad
Sharma K K, Sinha A K, Bagdassarian G P, Gaukasian R C H 1978 *Him. Geol.* **8** (1) 288
Srikantia S V and Bhargava O N 1978 *Tectonic geology of the Himalaya* (ed) P S Saklani (New Delhi: Today and Tomorrow's Printers and Publishers) p. 43
Srikantia S V and Razdan M L 1980 *J. Geol. Soc. India* **11** 523
Stoliczka A 1866 *Mem. Geol. Surv. India* **5** (1) 1
Stoliczka A 1874 *Rec. Geol. Surv. India* **7** (1) 12
Tewari A P 1964 *Proc. 22nd Int. Geol. Congr.* **11** 37
Thakur V C, Virdi N S, Rai H and Gupta K R 1981 *J. Geol. Soc. India* **22** (1) 46
Varadarajan S, Uppal U S and Vashist N 1980 *Proc. 3rd Indian Geol. Congr. Poona* 461
Wadia D N 1937 *Rec. Geol. Surv. India* **72** (2) 151
York D 1966 *Can. J. Phys.* **44** 1079

Appendix

Brief description of the samples analysed

Specimen No.	Description
LKG-750	Leucocratic, coarse grained, porphyritic granite with phenocrysts of pink to cream coloured feldspar, showing crude foliation and enrichment in biotite. It shows hypidiomorphic granular texture and is composed of 22·5% quartz, 34% K-feldspar (orthoclase and perthite), 33% plagioclase, 8·5% biotite and 2% accessories (sphene, titano-magnetite, apatite, zircon).
LKG-752	Coarse grained, porphyritic granite with cream to pink coloured feldspar, enriched in biotite and show crude foliation. It is composed of 27% quartz, 46% K-feldspar (perthite, orthoclase), 22% plagioclase, 4% biotite and 1% accessories (apatite, zircon and titano-magnetite).

Appendix (*Contd.*)

Specimen No.	Description
LKG-753	It is medium to fine grained massive pepper and salt coloured granite. It is composed of 27% quartz, 41% K-feldspar, 25% plagio-clase, 5% biotite and 2% accessories.
LKG-756	Coarse grained, porphyritic granite containing 25% quartz, 35% K-feldspar, 30% plagio-clase, 8% biotite and 2% accessories (apatite, zircon and titano-magnetite).
LKG-757	Coarse grained foliated, gneissose granite rich in biotite. It is composed of 22% quartz, 27% K-feldspar, 40% plagioclase, 8% biotite and 3% accessories (sphene, magnetite, zircon, apatite and rutile). The minerals in general, show strain effects.
LKG-758	Coarse grained granite with crude foliation. It is composed of 25% quartz, 40% K-feldspar (orthoclase, microcline, perthite), 25% plagio-clase, 8% biotite and 2% accessories (apatite, sphene and titano-magnetite). The minerals show strain effects.