Zeitschrift: Schweizerische mineralogische und petrographische Mitteilungen = Bulletin suisse de minéralogie et pétrographie

Band: 73 (1993)

Heft: 1

Artikel: Radiometric age determination of the Dadeldhura granite, Lesser Himalaya, Far Western Nepal

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DOI: https://doi.org/10.5169/seals-55564

SCHWEIZ. MINERAL. PETROGR. MITT. 73, 97–106, 1993

Radiometric age determination of the Dadeldhura granite, Lesser Himalaya, Far Western Nepal

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Abstract

On the Dadeldhura granite which occurs in Far Western Nepal within the Lesser Himalayan Range Rb–Sr whole-rock age determinations were performed. Eleven samples define an isochron yielding an Ordovician age of 470.0 ± 5.6 Ma (2 σ) and an initial $^{87}Sr/^{86}Sr$ ratio of 0.7266 ± 0.0012 (MSWD = 0.8). K–Ar analyses on biotites show discordant data typical for a later thermal overprint which may be ascribed to the deformation of the granite during the Himalayan orogeny.

Keywords: Granite, age determination, Rb–Sr whole-rock, K–Ar biotite, Ordovician, Lesser Himalaya, Nepal.

Introduction

A belt of granitoids in the Lesser Himalayan Range extends for more than 1600 km from Pakistan to Bhutan (Fig. 1). It is the southernmost of the Himalayan and Transhimalayan plutonic belts (Le Fort et al., 1980, 1983; Debon et al., 1986). This NW–SE trending belt is made up of more than fifteen independent plutons (Fig. 1) and has been termed the "Lesser Himalayan cordierite granite belt" by Le Fort et al. (1980) because of the characteristic occurrence of cordierite in many of these granites. In its Nepal section, six larger granites and a few minor occurrences in their vicinity occur in the Kathmandu nappe in Central Nepal and two granites in Far Western Nepal (Khaptad granite and Dadeldhura granite) (Fig. 1).

This paper presents whole-rock Rb–Sr data for the Dadeldhura granite obtained during a Technical Cooperation Project of the Department of Mines and Geology, HMG, Kathmandu, Nepal, and the Federal Institute for Geosciences and Natural Resources, Hannover, Federal Republic of Germany.

Regional geology

The Dadeldhura granite intruded into NW-SE-striking low- to medium-grade metamorphics regarded as of Precambrian age (Bashyal, 1986; Valdiya, 1986) called "Dadeldhura Crystalline Group" (Fig. 2). They are composed of phyllites, quartzites, slates, sericitic quartzites, chloritic mica schists, garnet-bearing mica schists, quartz-feldspathic mica schist and gneiss. Adjacent to the northeast and separated by an unconformity from the Dadeldhura Crystalline Group, unfossiliferous metasediments of the Damgad Metasedimentary Group occur consisting of dolomites, limestones and quartzitic sandstones. The whole sequence is named the "Dadeldhura Crystalline Complex". This complex is allochthonous and thrusts from the north onto the parautochthonous "Bunder Metasedimentary Complex" (not shown in the map), which consists of low-grade metamorphics (various coloured phyllites, chloritic mica schists, quartzites, some amphibolites and minor basic rocks). In the far south the Bunder metasedimentary complex contacts the Main Boundary Thrust (MBT).

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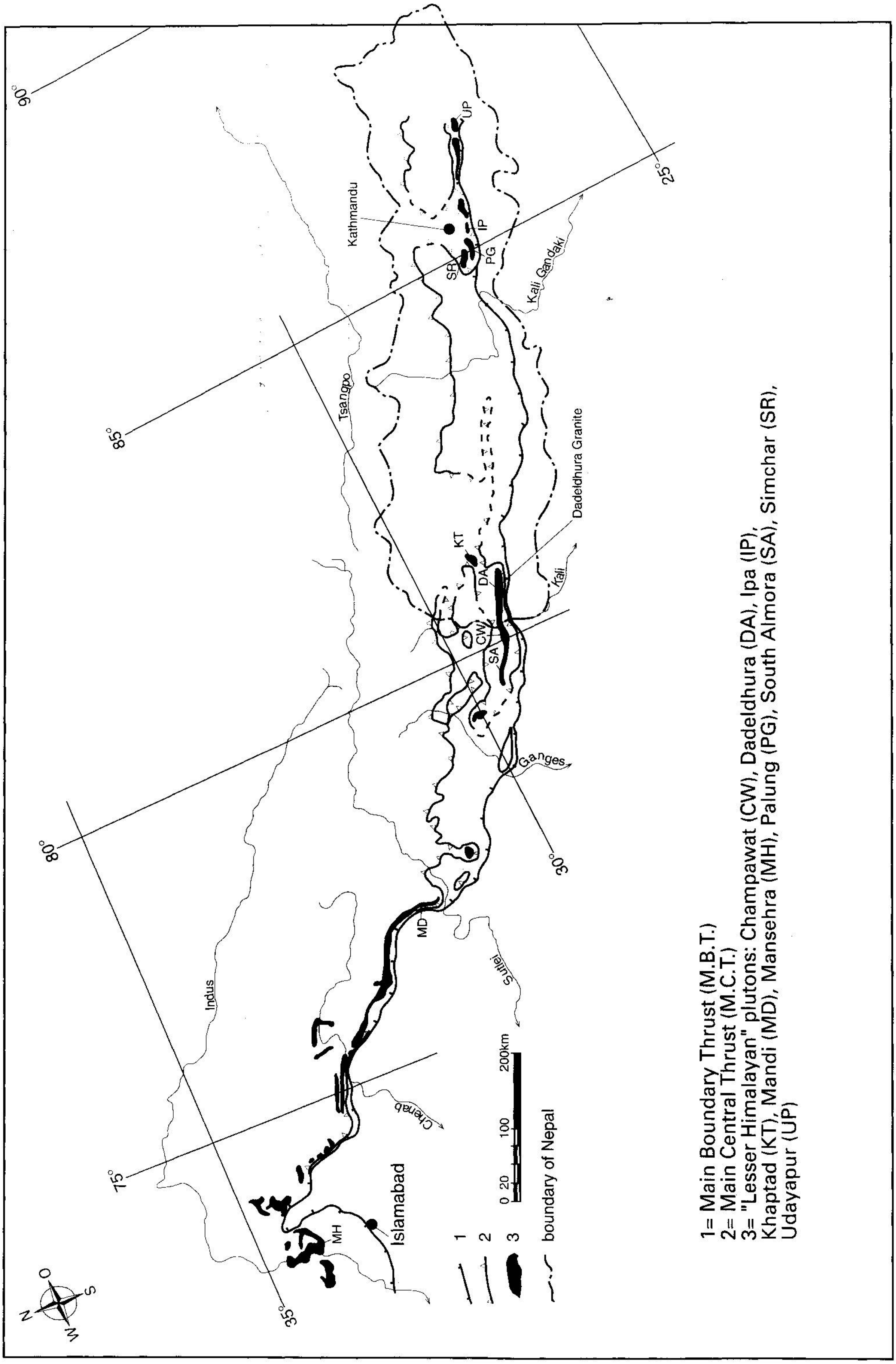
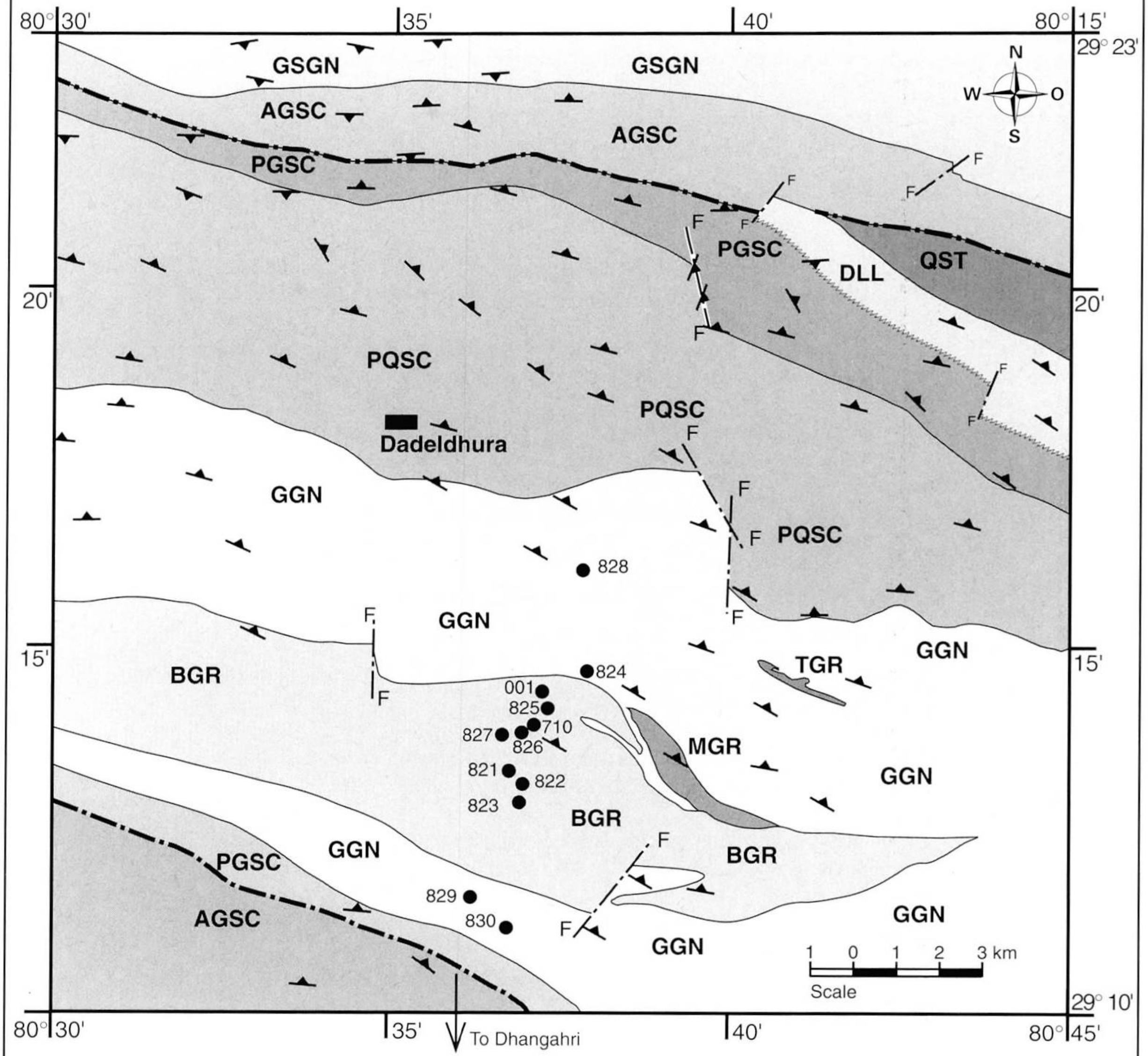


Fig. 1 Geological sketch map showing the locations of the "Lesser Himalayan" plutons from Pakistan to Nepal. Adopted from LE FORT et al., 1983, and supplemented for the Nepal area.



Index:

- Sample location point
- Contact
- Contact (thrusted)
- Unconformity (UC)
- Fault
- Strike/Dip of foliation

	Group	Formation (lithology)
Dadeldhura Crystalline Complex	Dadeldhura Granite Massif	Tourmaline Granite (TGR) Muscovite Granite (MGR) Biotite Granite (BGR) Granite Gneiss (GGN)
	Damgad Metasedimentary Group	Quartzite and Sandstone (QST) Dolomites and Limestone (DLL)
	Dadeldhura Cystalline Group	Phyllite, quartzite, slates, carbonaceous phyllite, chloritic mica schist and sericitic quartzite (PQSC). Phyllite, quartzite, very few fine grained garnet bearing chloritic mica schist and quartzite (PGSC).
		Garnetiferous mica schist, quartzite and sheared augen gneiss rarely with minor granite bodies (AGSC). Felspathic mica schist, gneiss, quartzite and few garnet bearing chloritic mica schist and amphibolites/minor basic rock bodies (GSGN).

Fig. 2 Geological sketch map of part of the Dadeldhura granite area showing the sample locations.

Tab. 1 Description of samples
General mineralogical characteristics: Coarse grained biotite granite with little muscovite (mentioned below if more frequent than usual for this granite), essentially no alteration, weakly zoned to unzoned plagioclase, K-feldspar as dominant feldspar (usually as microcline perthite or perthite), quartz, accessory minerals apatite and zircon. Biotite is not chloritized.

Sample No.	Grid coordinates	Sample description
		core granite
001	80°37'12" E 29°14'12" N	non porphyritic, unfoliated; greenish brown biotite, andalusite, sillimanite (fibrolite) in muscovite, muscovite rim around andalusite
710	80°36'56" E 29°13'48" N	porphyritic, slightly foliated; redbrown biotite, andalusite, sillimanite, abundant cordierite (altered); little sericite in plagioclase
821	80°36'58" E 29°13'03" N	slightly porphyritic, moderately foliated; redbrown biotite, cordierite (altered), little pumpellyite in biotite
822	80°37'12" E 29°12'55" N	porphyritic, moderately foliated; dark brown biotite, cordierite (altered), andalusite
823	80°36'56" E 29°12'45" N	porphyritic, strongly foliated with gneissic character; light brown biotite, muscovite
825	80°37'10" E 29°14'05" N	porphyritic, weakly foliated; dark brown biotite, muscovite, andalusite; pumpellyite in biotite
826	80°36'45" E 29°13'31" N	non porphyritic, unfoliated; redbrown biotite, cordierite (altered), dark blue tourmaline; weak sericitization of plagioclase
827	80°36'50" E 29°13'12" N	non porphyritic, weakly foliated; dark brown biotite, muscovite, tourmaline; little sericite in plagioclase
		gneissic peripheral part
824	80°37'28" E 29°14'25" N	porphyritic, gneissic structure; light brown biotite, muscovite; little sericite in plagioclase
828	80°38'02" E 29°15'55" N	porphyritic, augen gneiss; yellowish brown biotite; little sericite in plagioclase
829	80°36'10" E 29°11'20" N	porphyritic, gneissic structure; yellowish brown biotite, muscovite, tourmaline
830	80°36'45" E 29°11'10" N	porphyritic, gneissic structure; redbrown biotite, muscovite

The stratigraphy of this area (BASHYAL, 1981) and the lithotectonic units are comparable to the units of the Almora nappe in the adjoining part of India (HEIM and GANSSER, 1939; GANSSER, 1964; BASHYAL, 1986) and of the Kathmandu nappe in Central Nepal (STÖCKLIN, 1980).

Characterization of the Dadeldhura granite

The Dadeldhura granite is composed of four different types of granite with different mineralogical and geochemical characteristics and with different tectonic style (KAPHLE, 1988, 1991):

Tab. 2 Chemistry of Dadeldhura granite samples (main elements and selected trace elements). Samples were analysed by XRF, except for F (ion-sensitive electrode) and Li (AAS).

Sample	001	710	821	822	823	824	825	826	827	828	829	830
Main elements (%)												
SiO_2	74.30	71.82	73.22	70.90	74.61	73.64	74.13	73.45	72.67	70.64	73.37	71.18
TiO_2	0.12	0.39	0.27	0.35	0.27	0.12	0.11	0.36	0.28	0.30	0.28	0.51
Al_2O_3	13.43	13.84	13.66	14.68	12.75	13.56	13.50	12.86	13.62	14.79	13.39	13.84
Fe_2O_3	2.06	3.33	2.49	3.13	2.54	1.85	1.71	3.08	2.46	2.24	2.61	4.03
MnO	0.04	0.05	0.05	0.05	0.04	0.03	0.03	0.04	0.04	0.04	0.04	0.05
MgO	0.15	0.75	0.49	0.62	0.49	0.16	0.15	0.53	0.45	0.48	0.55	0.83
CaO	0.48	0.99	0.85	0.89	0.82	0.63	0.57	0.99	0.84	1.43	0.87	1.12
Na_2O	2.87	2.47	2.73	2.82	2.55	3.24	3.14	3.00	3.22	2.82	2.66	2.32
K_2O	4.91	4.45	4.48	4.85	4.22	4.93	4.96	4.11	4.53	5.59	4.33	4.01
P_2O_5	0.18	0.14	0.15	0.17	0.16	0.19	0.17	0.10	0.14	0.13	0.17	0.15
F^- (ppm)	1350	1020	910	1045	720	1015	1150	835	1000	990	940	715
LOI	0.98	1.20	1.13	1.05	1.06	1.20	1.04	0.96	1.24	1.00	1.23	1.44
Total	99.52	99.43	99.52	99.51	99.51	99.55	99.41	99.48	99.49	99.16	99.86	99.48
Trace elements (ppm)												
Ba	72	291	189	194	293	80	69	245	269	891	238	381
Ce	< 35	86	68	83	< 35	< 35	41	71	< 35	75	42	87
Co	11	12	12	15	7	13	13	12	18	10	13	17
Li	45	30	40	40	35	40	40	30	50	20	45	25
Nb	19	17	17	22	20	17	19	17	17	17	18	20
Ni	< 7	11	9	11	< 7	< 7	11	11	10	< 7	10	17
Pb	34	44	34	39	26	33	37	44	48	35	22	34
Rb	442	267	317	337	283	398	427	241	325	271	321	213
Y	16	22	17	21	20	15	11	27	16	29	15	14
Zn	52	64	53	63	52	45	41	52	75	36	62	71
Zr	45	168	113	139	127	75	64	164	135	161	120	212
Sn	< 30	31	33	30	< 30	35	57	39	42	32	47	< 30

– the *core granite* with little or no deformation, consisting of a mesocratic, coarse-grained biotite granite with minor amounts of muscovite and cordierite, at places with a porphyritic texture;

– a small outcrop of medium-grained to coarse-grained *muscovite granite* of leucocratic composition;

– dykes of fine- to medium-grained aplitic *tourmaline granite* and pegmatites of simple internal structure and mineralogical composition;

– the peripheral part, consisting of *gneissic granites* to weakly foliated granites developed from coarse-grained biotite granite, porphyroblastic biotite granite ("augen gneiss"), and leucocratic muscovite granite.

This granite exhibits many of the features listed by Le Fort et al. (1983) as characteristics of the "Lesser Himalayan" granites:

– a porphyritic texture in parts of the core granite and abundantly in the gneissic peripheral part;

– a post-magmatic deformation affecting a large part of the granite massif, leading to true orthogneisses accompanied by a partial recrystallization (blastoporphyritic "augen gneiss" and recrystallization of sericite in plagioclase);

– metasedimentary xenoliths of quartzite, micaceous quartzite and quartzitic mica schists, fairly abundant in the areas close to the contact to the metamorphics;

– a composition mainly of two granitic types (the mesocratic biotite granite and the leucocratic muscovite granite) similar to the Palung and Simchar granites of the Kathmandu Nappe;

– a strong peraluminous character and the occurrence of cordierite, andalusite and fibrolite.

Sample preparation and analytical procedure

The samples were collected along the road from Dhangari to Dadeldhura, which crosses the exposed granite from south to north (Fig. 2). Some small quarries and road cuts were used to collect fresh material in blocks of about 20 to 30 kg. Sample locations were chosen on the basis of XRF analyses of the Dadeldhura granite

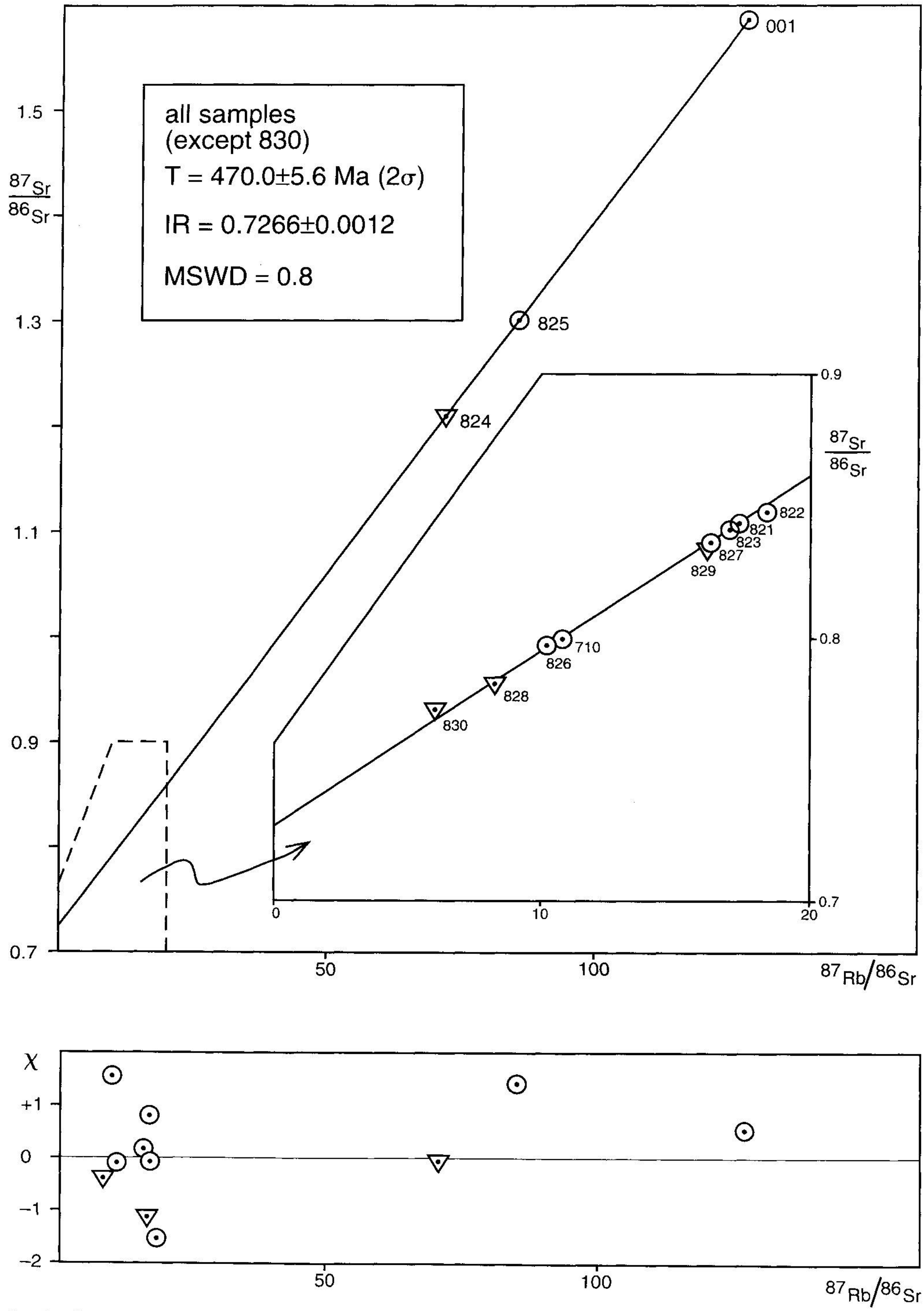


Fig. 3 Isochron diagram of samples from the Dadeldhura granite; ○ samples of biotite granite; ▽ samples of gneissic granite; upper part: isochron diagram; lower part: weighted deviations of the sample points from the isochron.

Tab. 3 Results of Rb–Sr WR analyses on samples of the Dadeldhura granite, Far Western Nepal.

Sample	Rock	^{87}Rb ppm	^{86}Sr ppm	$^{87}Rb/^{86}Sr$[a]	$^{87}Sr/^{86}Sr$[a]
001	biotite granite	125.1	0.970	127.5	1.58556
710	dto	75.5	6.977	10.70	0.79822
821	dto	89.7	5.111	17.35	0.84284
822	dto	95.8	5.178	18.28	0.84714
823	dto	78.7	4.618	16.85	0.84039
825	dto	120.4	1.388	85.74	1.30166
826	dto	66.5	6.474	10.15	0.79574
827	dto	90.0	5.480	16.23	0.83553
824	gneissic granite	113.6	1.558	72.09	1.20901
828	dto	75.9	9.140	8.206	0.78135
829	dto	89.4	5.535	15.96	0.83232
830	dto	59.9	9.772	6.055	0.77094

[a] Analytical precision derived from replicates on standard feldspar NBS 607 is at the level of 95% confidence: $d(^{87}Rb/^{86}Sr) = 2\%$, and $d(^{87}Sr/^{86}Sr) = 0.06\%$.

(KAPHLE, unpublished data) to obtain a suitable variation in the Rb/Sr ratios. Eight samples were taken from the biotite granite of the core and four samples from the peripheral part around the core granite.

The samples were crushed and pulverized at the Department of Mines and Geology, Kathmandu. Representative aliquots of the whole-rock samples were taken for Rb–Sr analysis. After addition of a ^{84}Sr and ^{87}Rb spike, 100–500 mg sample

Tab. 4 Age determinations on the "Lesser Himalayan granites"

Name of granite	Radiometric age (Ma)	Initial Sr ratio	Reference
Manserah granite, Pakistan	516 ± 16	0.7189 ± 0.0006	LE FORT et al., 1980
Mandi granite, India	507 ± 100	0.718 ± 0.025	JÄGER et al., 1971
	564 ± 12	0.7019 ± 0.0015	MEHTA, 1977 (recalculated for recommended decay constant)
Champawat granodiorite, Almora Nappe, India	560 ± 20	0.7109 ± 0.0013	TRIVEDI et al., 1984
Dadeldhura granite, (continuation of Almora Nappe into Nepal)	470.0 ± 5.6	0.7266 ± 0.0012	this paper
Simchar granite, Kathmandu Nappe, Nepal	466 ± 40	0.7205 ± 0.0046	LE FORT et al., 1983
Palung granite, Kathmandu Nappe, Nepal	486 ± 10	0.720	BECKINSALE in MITCHELL, 1981
	470 ± 4	(U/Pb on zircons, monazites)	SCHÄRER and ALLEGRE, 1983

Tab. 5 K–Ar data on biotites from the Dadeldhura granite.

Sample No.	Grain size (μm)	K–Ar date (Ma)	K (wt%)	Argon rad. (nl/g) STP	Argon atm. (nl/g) STP
biotite granite					
001	630–315	136.9 ± 1.2	7.66 ± 0.06	42.3 ± 0.2	0.9 ± 0.1
	315–160	135.5 ± 1.2	7.67 ± 0.06	42.0 ± 0.2	0.7 ± 0.1
822	630–315	189.2 ± 1.6	7.60 ± 0.06	58.9 ± 0.3	0.6 ± 0.1
	315–160	174.6 ± 1.5	7.58 ± 0.06	54.0 ± 0.3	0.8 ± 0.1
825	630–315	118.8 ± 1.0	7.61 ± 0.06	36.3 ± 0.2	0.3 ± 0.1
	315–160	115.3 ± 1.0	7.64 ± 0.06	35.3 ± 0.2	0.8 ± 0.1
gneissic granite					
824	630–315	824 ± 7	7.51 ± 0.06	304.9 ± 2.4	1.1 ± 0.5
	315–160	707 ± 6	7.60 ± 0.06	255.9 ± 2.0	1.0 ± 0.1
829	630–315	61.4 ± 0.5	7.50 ± 0.06	18.2 ± 0.1	1.6 ± 0.1
	315–160	55.1 ± 0.5	7.53 ± 0.06	16.4 ± 0.1	1.4 ± 0.1

Error estimates refer to the intralaboratory analytical precision at a 95% confidence level. Argon was determined by total fusion isotope dilution static mass-spectrometrical analysis, corrected for average blank analyses; K by flame photometry with Li as internal standard. The IUGS-recommended constants (Steiger and Jäger, 1977) are used.

material was dissolved in a mixture of con. $HF+HNO_3$. After evaporating to dryness, the residue was dissolved in 2.5 N HCl and loaded onto an ion exchange column packed with Dowex 50 W-X8 resin (200–400 mesh). Rubidium and strontium were separated by eluation with 2.5 N HCl. A Finnigan MAT 261 mass spectrometer equipped with five collectors was used for the isotopic analysis of Sr and a Micromass MM-30 was used for Rb. The blanks for the procedure as a whole, typically yielded values of 640 pg Sr and 440 pg Rb. Experimental errors of ± 2% for the $^{87}Rb/^{86}Sr$ ratio and ± 0.06% for the $^{87}Sr/^{86}Sr$ isotopic ratio at the 95% confidence level were estimated from the standard deviation of replicate analyses on samples and on the K-feldspar standard NBS 607, which was measured to 147.7 ± 1.5 ppm ^{87}Rb, 6.025 ± 0.015 ppm ^{86}Sr and $^{87}Sr/^{86}Sr$ = 1.2010 ± 0.0005. The IUGS-recommended constants (Steiger and Jäger, 1977) were used for calculations involving the measured isotope data.

Results

The petrographic description of the samples is given in table 1. The core granite and the peripheral part around the core granite are coarse grained biotite granites. They show essentially no alteration, except for cordierite which is often pinitized, and occasionally a rim of secondary muscovite around andalusite. The main element composition and the concentrations of selected trace elements for the samples are given in table 2.

The results of the Rb–Sr analyses are presented in table 3. The sample points define an isochron in the Nicolaysen diagram (Fig. 3). The regression line for the eight samples of the biotite granite yield 470 ±7 Ma (2 σ), initial $^{87}Sr/^{86}Sr$ ratio 0.7269 ± 0.0016 (MSWD = 0.9) and for three samples of the gneissic granite 468 ± 10 Ma (2 σ), initial ratio 0.7264 ± 0.0018 (MSWD = 0.5). Sample 830 of the gneissic granite was omitted from the regression calculation because it does not fit the isochron. This sample was taken at the southern margin of the outcrop of the gneissic envelope and therefore it may be contaminated to some extent by the neighbouring schist. The correspondence of the ages and the initial Sr ratios for the biotite granite and the gneissic granite prove that the two rock units are cogenetic. The combination of all samples in one isochron (except sample 830) yield an age of 470.0 ± 5.6 Ma (2 σ) with an initial Sr ratio 0.7266 ± 0.0012 (MSWD = 0.8). This age value is interpreted as the time of intrusion of the Dadeldhura granite. The high initial Sr ratio indicates a high proportion of assimilated older crustal material in the magma.

Discussion

In the past, many authors have considered the Lesser Himalayan granites to be of Tertiary age, like the granitic intrusions of the Higher Himalaya (cf. compilation of published ages in LE FORT et al., 1983), but BORDET (1961) inferred a Precambrian age. More recently, age data have been accumulated which establish a Lower Paleozoic age for these granites (LE FORT et al., 1986), as shown by the granites from Pakistan (Manserah granite), India (Mandi granite, Champawat granodiorite), and Nepal (Palung granite, Simchar granite) (Tab. 4).

The Middle Ordovician Rb/Sr isochron age of the Dadeldhura granite fits well in this age range. However, there is an unexplained difference of about 90 Ma from the age determined for the Champawat granodiorite, Almora nappe (560 ± 20 Ma, TRIVEDI et al., 1984), which is the continuation of the Dadeldhura granite into India. TRIVEDI et al. found age clusters around 1.8 Ga for the basal gneisses of the synformal Almora Nappe. The data presented here clearly show that the gneissic envelope of the Dadeldhura granite is a genuine part of the Paleozoic core granite and not an older crystalline component like the Proterozoic gneisses of the Almora nappe crystalline.

According to LE FORT et al. (1983), the gneissic envelope of the Lesser Himalaya granites was deformed during the main phase of the Himalayan orogeny. This is documented by apparent biotite ages of the Mandi granite in the range of 25–32 Ma (JÄGER et al., 1971) and a biotite date of 14 Ma from the Ipa granite (SONET, unpublished data cited in LE FORT et al., 1983).

From some samples of the Dadeldhura granite the biotite has been separated and analysed for K–Ar. The results given in table 5 show discordant dates for the two analysed grain size fractions and a large spread of the dates for the individual samples. Generally the fine fraction yields a younger date than the coarse fraction and most dates are younger than the age of the Dadeldhura granite. But the biotite of sample 824 yields much older dates which has to be explained by excess argon. Such a pattern of K–Ar dates of biotites is typical for a thermal overprint with elevated temperatures near to the closing temperature (about 200 °C) whereby the biotites may loose part of radiogenic argon or, on the contrary, pick up excess argon. Under these circumstances only the youngest biotite dates may give age informations. The time of the last thermal event must be younger than the youngest K–Ar date (about 50 Ma).

Acknowledgement

The authors are grateful to Mr. M.N. Rana, the former Director General of the Department of Mines and Geology, Kathmandu, and Mr. S.P. Singh, the present Director General, for their support to this study. We thank the staff of the Department of Mines and Geology for their help in sample preparation, F. Henjes-Kunst for final preparation of the biotite fractions and Mrs. B. Eichmann, L. Thiesswald and H. Schyroki for laboratory assistance.

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Manuscript received August 28, 1992; revised manuscript accepted January 15, 1993.