The "Lesser Himalayan" Cordierite Granite Belt Typology and Age of the Pluton of Manserah (Pakistan)

PATRICK LE FORT, FRANCOIS DEBON and JACQUES SONET

Abstract: The Manserah pluton is a very typical example of the discontinuous belt of two mica-cordierite granites of the "Lesser Himalaya". It is aluminous, quartz rich but feldspar and sodium deficient, and igneous "microgranular" inclusions are frequent. Severely deformed to the North, the Manserah pluton has been metamorphosed and gneissified during the Himalayan orogeny. Rb-Sr whole rock isotopic data give a well defined seven point isochron with a Cambrian age of 516 + 16 m.y. The high initial ratio of 0.7189 ± 6 implies derivation from a source containing a major and very old crustal contribution. The geodynamic framework for the genesis of this huge belt of similar plutons could be that of a simple thinning of a Precambrian shield or that of a late Pan African orogeny.

INTRODUCTION

1. The "Lesser Himalayan" cordierite granite belt

Along some 1600 km of the Himalaya (between longitudes 73 and 87° East) and in general at a short distance North of the Main Boundary Fault (fig. 1), the authors have described and studied a belt of cordierite granites. This belt is made up of more than fifteen independant plutons with very typical and similar characteristics (Le Fort *et al.*, 1978).

2. The Manserah pluton

The western most pluton recognized in this belt outcrops as a large body, North of Islamabad and West of the western syntaxis of the Himalaya. This pluton is readily accessible and clearly marked on every geological map of the region although with very variable limits and characters (for the most recent references: Bakr and Jackson, 1964; Calkins *et al.*, 1975; Desio, 1976, 1977; Stocklin, 1977; Tahirkheli, 1979; Tahirkheli *et al.*, 1979).

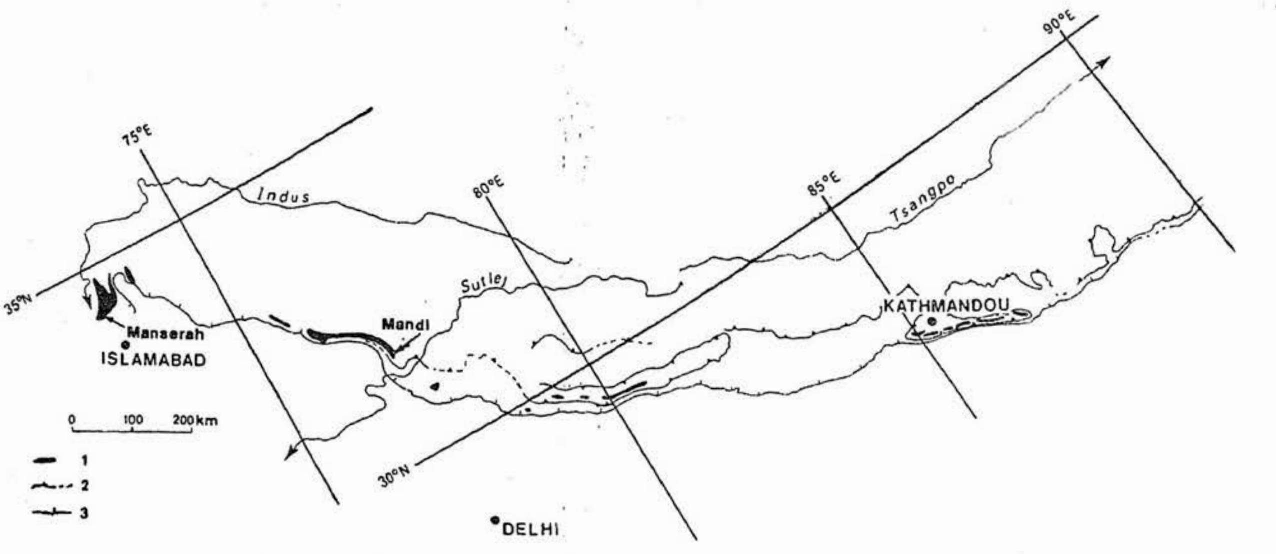

Fig. 1 Location map of the "Lesser Himalayan" granites (Le Fort et al., 1978). 1 — "Lesser Himalayan" granites. 2 — Main Central Thrust (M.C.T.) 3 — Main Boundary Thrust (M.B.T.).

The name of Manserah granite was first given to a portion of this pluton by Shams (1961) and extended to the totality by Calkins *et al.*, (1975) who have published a detailed map covering most of it at a 125.000 scale. It covers some 1800 km² between the Muzzaffarabad re-entrant and the left bank of the Indus. But similar granites appear to the East of the re-entrant (Calkins *et al.*, 1975; fig. 2) as well as on the right bank of the Indus (Bakr and Jackson, 1964), and therefore the total surface area may be substantially larger.

Proc. Intern. Commit. Geodynamics, Grp. 6, Mtg. Peshawar, Nov. 23-29, 1979: Spec. Issue, Geol. Bull. Univ. Peshawar, Vol. 13, 1980.

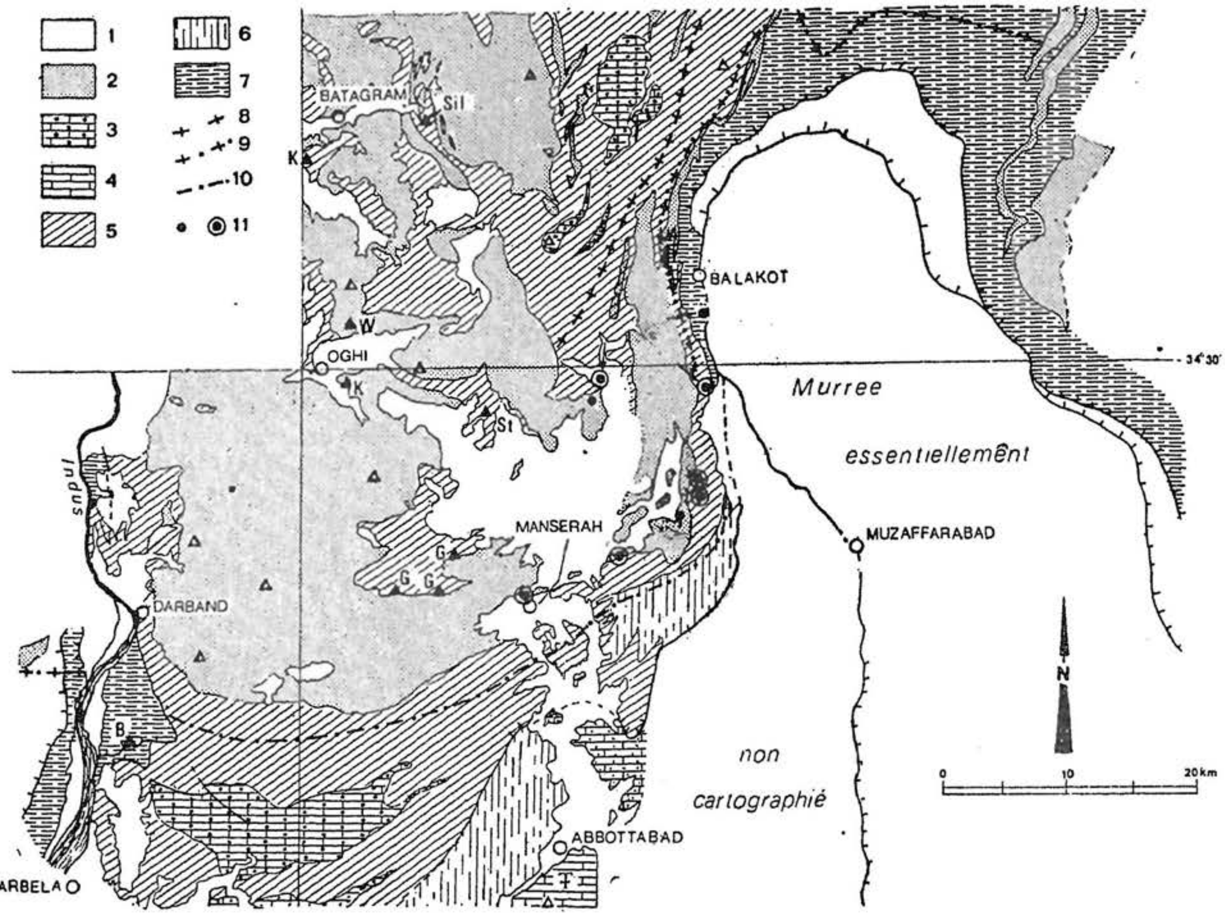

Fig. 2. Geological map of the Manserah pluton (after Calkins et al., 1975).
1 — Mostly Cenozoic and recent. 2 — Manserah granite. 3 — Kingriali formation (Carboniferous to Triassic ?). 4 — Fossiliferous Abbottabad formation (Cambrian). 5 — Tanawal formation. 6 — Hazara formation. 7 — Salkhala formation. 8 — Garnet-staurolite isograd. 9 — Biotite-garnet isograd. 10 — Chlorite-biotite isograd. 11 — Locations of the geochemical samples, the double circle for the Rb/Sr samples analysed. B, G, St, K, Sil, W for isolated occurrences of biotite, garnet, staurolite, kyanite, sillimanite, tungsten respectively.

All the authors that we know of have given an alpine (or Himalayan) age to this pluton. After two short geological trips that we made in this region in 1977 (F.D., P.L.F. and J. Stebbins) and 1979 (F.D. and P.L.F.) we have revised the description of this pluton and questioned its age.

THE SURROUNDING FORMATIONS OF THE MANSERAH PLUTON

According to the map of Calkins *et al.* (1975) the granite of Manserah intrudes three different formations:

— first and principally the Tanawal formation (Ordovician ? to Devonian ?) that consists mainly of quartzose schist, quartzite and at places, layers and lenses of quartzose conglomerate;

— second, East of the syntaxial zone, a detached equivalent of the same granite intrudes the Precambrian Salkhala formation according to Calkins *et al.* (1975). This formation consists largely of quartz schist, marble, graphitic schist and quartzo-feldspathic gneiss;

— third, South-East of Tarbela village a small outcrop of granite now covered by water intruded the Hazara Formation (Cambrian ??) that consists mainly of slate and phyllite with a few layers of limestone, carbonaceous shale and graywacke sandstone.

The surrounding rocks where we visited them were always observed to be alternating schists and quartzites; the relative abundance of both lithologic types varying greatly from one outcrop to another. We also saw a thick mass of polygenic conglomerate North of the town of Oghi and a talc bearing zone in the East, on the road to Balakot. The surrounding formations very often appear to be folded isoclinaly.

The grade of metamorphism increases regularly toward the North from the chlorite to the sillimanite zone (fig. 2). There is a discrepancy between the text and the map in Calkins *et al.* (1975): only andalusite is mentioned in the text whereas only kyanite is shown on the map (?). As kyanite schists have been reported to occur at several places around Oghi as small lenses in the pluton (Ahmad, 1969, p. 97) we accordingly feel that the regional metamorphism is of Barrovian type.

MACROSCOPIC FEATURES AND GEOLOGICAL SETTING OF THE MANSERAH PLUTON

Exposures of the granite are relatively large and good, particularly along the roads and valleys. However it has been strongly weathered.

1. Macroscopic features

a – Dominant type

It is a porphyritic granite with euhedral tabular megacrysts of potassium feldspar. The matrix has a medium grain size. The megacrysts which generally have anhomogeneous size in one exposure (Manserah region) may measure from one to over fifteen centimeters from one outcrop to another. The grain size of the matrix also varies according to the size of the megacrysts. The cordierite often occurs as rectangular crystals up to three centimeters.

The granite has quite abundant metasedimentary (metaquartzite, micaschist, biotite *and* igneous "microgranular" inclusions. In some regions, in particular close to the contacts, the metasedimentary inclusions predominate. In other regions, "microgranular" inclusions become dominant and together with them the amount of cordierite seems to increase.

The planar disposition of the megacrysts and the elongation of the inclusions define the foliation (flow structure) of the granite.

b – Gneissic type

In the southern regions, the foliation of the granite is merely reflecting its flow structure. But towards the North or North-East first a fracture cleavage appears and farther away a flow cleavage that affects essentially the matrix, the megacrysts keeping their tabular shape. The flow cleavage almost always parallels the foliation; it is accompanied by a stretching lineation (around N 10° E) and the recrystallization of big flakes of biotite and muscovite in the schistosity plane. The inclusions are very elongated; they sometimes show small isoclinal folding. Exceptionally and in very limited zones the megacrysts of K feldspar have an eye-shape. On the contrary in the gneissic regions a crenulation cleavage with a steep axial plane often gets superimposed; this crenulation affects the megacrysts as well as the matrix and the inclusions as well as the dykes.

2. Contacts of the pluton with the surrounding formations

The pluton shows subconcordant to discordant contacts with the bedding of the surrounding formations. Actually the discordant contacts are principally visible in the southern area and one can suggest that intense gneissification is responsible for the apparent concordant contacts in the northern area.

Close to the contact the surrounding rocks are penetrated by numerous dykes of aplites/pegmatites and masses of granite. No contact metamorphism has been observed. The granite itself has xenoliths of the surrounding metasedimentary rocks, the density and size of which diminish away from the contact.

One can sometimes observe on the outcrops in the northern area that the contact has been folded. This fact is also quite clear at the scale of the map where the sheets of granite show crosier shapes (fig. 2). In fact both the granite and the country rocks seem to have undergone isoclinal folding; this folding would be responsible for the repetition of sheets of granitic material within the micaschists and quartzites.

Later differential movements have sometimes taken place along the contact zone; they are responsible for intense but narrow schistification on both sides of the contact.

3. Mafic dykes

Numerous mafic dykes occur in the pluton as well as in the country rocks. They have a gabbroic (table 3) to dioritic composition; sometimes they show a typical ophitic texture. Orthogneissification of the granite parallel to the dykes often takes place for a short distance. However they have suffered the Himalayan tangential tectonics and we suggest that they could well correspond to the Permo-Carboniferous volcanic activity of the Panjals.

4. Mineralization in the pluton

A prospect of wolfram is shown by Calkins *et al.* (1975) in the northern area of the granite (fig. 2). In the Rajdhawari area, pegmatites have been mined for beryl, feldspar, mica and quartz (Khan, 1964; Ahmad, 1969, p. 126).

MICROSCOPIC FEATURES OF THE MANSERAH GRANITOID

1. Dominant type

The dominant type has the composition of a granite (table 1) or more strictly speaking of a monzogranite (Streickeisen, 1974).

Table 1. Mean mineralogical composition of the Man serah granitoid. Because of the porphyritic texture this composition has been calculated starting from the chemical analyses (table 3) and using the microscopic observations, and the chemical analyses of biotite (table 2) and K feldspar.

Nature	quartz	K spar	plagio.	biotite	muscovite	cordierite andalusite tourmaline	apatite opaques
granite type	33	26	22	9.5	7	2	0.5
granodiorite type	29	17	42	5.5	6	—	0.5

In thin section :

— the *quartz* (33%) has a globular tendency. However it has a euhedral shape at the contact with K feldspar;

— the *K feldspar* (26%) megacrysts are more or less poikilitic, generally with microcline twinning and show numerous irregular perthitic veinlets. A chemical analysis of the K feldspar from sample M H 9 gave 33% albite content. The triclinic index, measured by X Ray on the same sample, gave a Δ = 84 value;

— the subhedral *plagioclase* (22%) is concentrically zoned with sometimes patchy zoning. Locally it forms aggregates with a synneusis texture. Its mean composition is oligoclase. Sericitization — or saussuritization in the core of the crystals — is more or less developed;

— the *biotite* (9.5%) is iron, titanium and aluminum rich (table 2). The $Fe^{2+}/Fe^{2}+Fe^{3+}$ ratio is high (0,936), close to 1. Chloritization is not frequent. It sometimes seems to have partially recrystallized;

— the *muscovite* has a variable abundance (average 7%). The habit also is variable: sometimes subhedral, sometimes dentilliform, sometimes made of an aggregate of crystals;

— the anhedral to subhedral *cordierite* is in general totally altered to felty pinite. It occurs mainly in the darkest varieties of granite. In the light coloured varieties *andalusite* appears instead. This andalusite has a euhedral acicular habit (sizes: 0.37 x 3.12 mm, for example). It is often zoned with a pinkish pleochroic core and a colourless margin. It is more or less altered to muscovite as well as to fibrolite sometimes;

— the *tourmaline* is xenomorphic to subhedral with yellowish brown to blue-green colour;

— apatite is frequent, *zircon* quite common and *opaques* infrequent.

Table 2. Chemical analyses of two biotites of the Manserah granite ("quantometric" analysis, C R.P.G., K. Govindaraju).

	MH9	MH28		MH9	MH28
SiO_2	35.12	34.98	Ba	637	259
Al_2O_3	17.94	18.96	Co	<10	16
TiO_2	3.16	3.07	Cr	245	161
$(Fe_2O_3)^*$	1.72	1.68	Cu	59	44
$Fe_2O_3t^{**}$	26.84	25.70	Ni	67	55
$(FeO)^*$	22.63	21.59	Rb	1237	1256
MgO	6.56	6.09	Sr	31	28
MnO	0.42	0.52	V	307	253
CaO	0.00	0.00	Zn	432	449
Na_2O	0.11	0.09			
K_2O	8.27	8.13			
P_2O_5	0.08	0.03			
l.i.	1.12	1.52			
TOTAL	99.62	99.09			
Si	5.404	5.391	Z	8.00	8.00
Al^{IV}	2.596	2.609			
Al^{VI}	0.651	0.828	Y	5.69	5.62
Ti	0.365	0.354			
Fe^{3+}	0.200	0.194			
Fe^{2+}	2,904	2.774			
Mg	1.514	1.405			
Mn	0.056	0.070			
Ca	0	0	X	1.65	1.63
Na	0.028	0.026			
K	1 625	1.600			
Mg/Fe t + Mg	0.329	0.321			
Fe^{2+}/Fe t	0.937	0.935			

* FeO titrated by wet chemical analysis (C.R.P.G., M. Vernet), Fe_2O_3 recalculated.

** total iron as Fe_2O_3

2. Gneissic type

The metamorphism does not only affect the surrounding rocks but also the granite itself. In thin section, the texture of the gneissic type is typically blastoporphyritic. These orthogneisses although they mostly keep the granitic composition characteristically have no cordierite, andalusite or fibrolite, but muscovite is more abundant. However, to the North, kyanite and sillimanite have been reported in the granite itself (Calkins *et al.*, 1975; fig. 2).

3. Granodioritic type (M H 38)

It is a single block of gneissified granodiorite whose mineralogical composition differs from the other types (table 1).

GEOCHEMISTRY

1. Chemical-mineralogical characteristics of the Manserah pluton

Sixteen geochemical samples have been analysed on the C.R.P.G. "quantometer" (table 3).

a – Granite type

Considering the mineralogy and the chemistry, the Mansehra pluton is quite homogeneous. Most of the porphyritic as well as the gneissic types have the chemical composition of a granite (table 3).

Yet this granite is not common; it has a number of remarkable peculiarities:

— the quartz content is high and quite constant (fig. 3);

Table 3. Chemical analyses of 16 samples of granitoid, 2 inclusions and 2 mafic dykes (Quantometer, C.R.P.G., K. Govindaraju).

Nature	Granite type	Granodiorite type	Igneous inclusions	Mafic dykes
n	15	1	2	2
SiO_2	71.79	72.56	72.20	48.19
σ	0.83	-	4.26	1.94
Al_2O_3	14.49	15.23	13.44	15.45
σ	0.46	-	1.47	0.80
Fe_2O_3t	2.91	1.47	3.61	12.38
σ	0.44	-	1.84	0.22
MnO	0.05	0.03	0.07	0.20
σ	0.01	-	0.02	0.01
MgO	0.73	0.33	1.03	7.22
σ	0.14	-	0.52	0.88
CaO	1.01	1.53	1.25	10.68
σ	0.20	-	1.17	0.66
Na_2O	2.87	4.30	3.13	2.27
σ	0.14	-	0.95	0.18
K_2O	4.55	3.56	3.67	0.63
σ	0.38	-	1.51	0.05
TiO_2	0.39	0.17	0.47	1.63
σ	0.07	-	0.26	0.15
P_2O_5	0.19	0.25	0.11	0.21
σ	0.03	-	0.07	0.00
P.F.	0.87	0.49	0.68	1.31
σ	0.13	-	0.07	1.14
TOTAL	99.85	99.92	99.66	100.17
Ba	289	475	147	123
σ	52	-	75	2
Co	52	46	55	88
σ	12	-	13	6
Cr	22	<10	<25	201
σ	4	-	>15	21
Cu	<10	<10	<10	120
σ	-	-	-	43
Ni	<18	<10	14	154
σ	>5	-	3	21
Rb	287	188	226	24
σ	20	-	31	7
Sr	64	461	42	716
σ	6	-	6	6
V	42	14	<41	281
σ	9	-	>31	23

Total iron titrated as Fe_2O_3. σ : standard deviation. Trace elements in p.p.m.

— the feldspar content is more or less deficient (fig. 3);

— it has a deficit in alkalis with a high and steady K/Na + K ratio. Therefore it is sodium deficient (table 3).

— it belongs to the domain of aluminous granitoids with a conspicuous excess in alumina (not balanced in feldspar) (fig. 4);

— the Mg/Fe ratio is rather high;

— the Rb content is rather high, Sr rather low;

Because of all these characteristics it falls entirely out of the domain of common igneous rocks (fig. 3, 4).

A few variations mainly concern the contents in dark minerals and feldspars (fig. 3) as well as the percentage of alumina in excess than the muscovite/biotite ratio (fig. 4).

b — Granodioritic type (M H 38)

The granodioritic sample is clearly different (fig. 3, 4 and table 3). It is a leucocratic granodiorite rich in both alkalis and feldspar. It has also a high Sr content.

2. Comparison with other "Lesser Himalayan" plutons

From a chemico-mineralogical point of view, the Manserah samples are similar to those collected from other massifs of the Lesser Himalayan granitoids (fig. 1). Here we consider only four plutons from cetral Nepal: Simchar, Palung, Ipa and Narayan Tan (Debon and Le Fort, work in progress) (fig.3, 4). The Manerah granite is in an intermediate position but with a slight shift toward a less quartzitic, less magnesian and more aluminous domain for the same content in dark minerals.

Other granites from the Lesser Himalayan belt present the same remarkable chemical and mineralogical peculiarities as those listed for the Manserah granite. It forms a broad group quite distinct from the domain of common igneous rocks but close to the domains of sedimentary and metamorphic rocks such as arkoses, shales, greywackes and gneisses (fig. 3, 4).

Furthermore the entire group shows a remarkable evolutionary trend. From the dark to the light coloured members, this evolution is characterized by an increase of the feldspar/dark minerals and muscovite/biotite ratios (fig. 3, 4) as well as an increase of the Na + K content. This evolution is original as the quartz content and the K/Na + K ratio are nearly constant (or slightly decreasing (fig. 3), whilst the percentage of alumina in excess increases very slightly (fig. 4). In figure 4, this evolution extends from the zone III to I. The absence of any significant drift toward the zones IV and V,

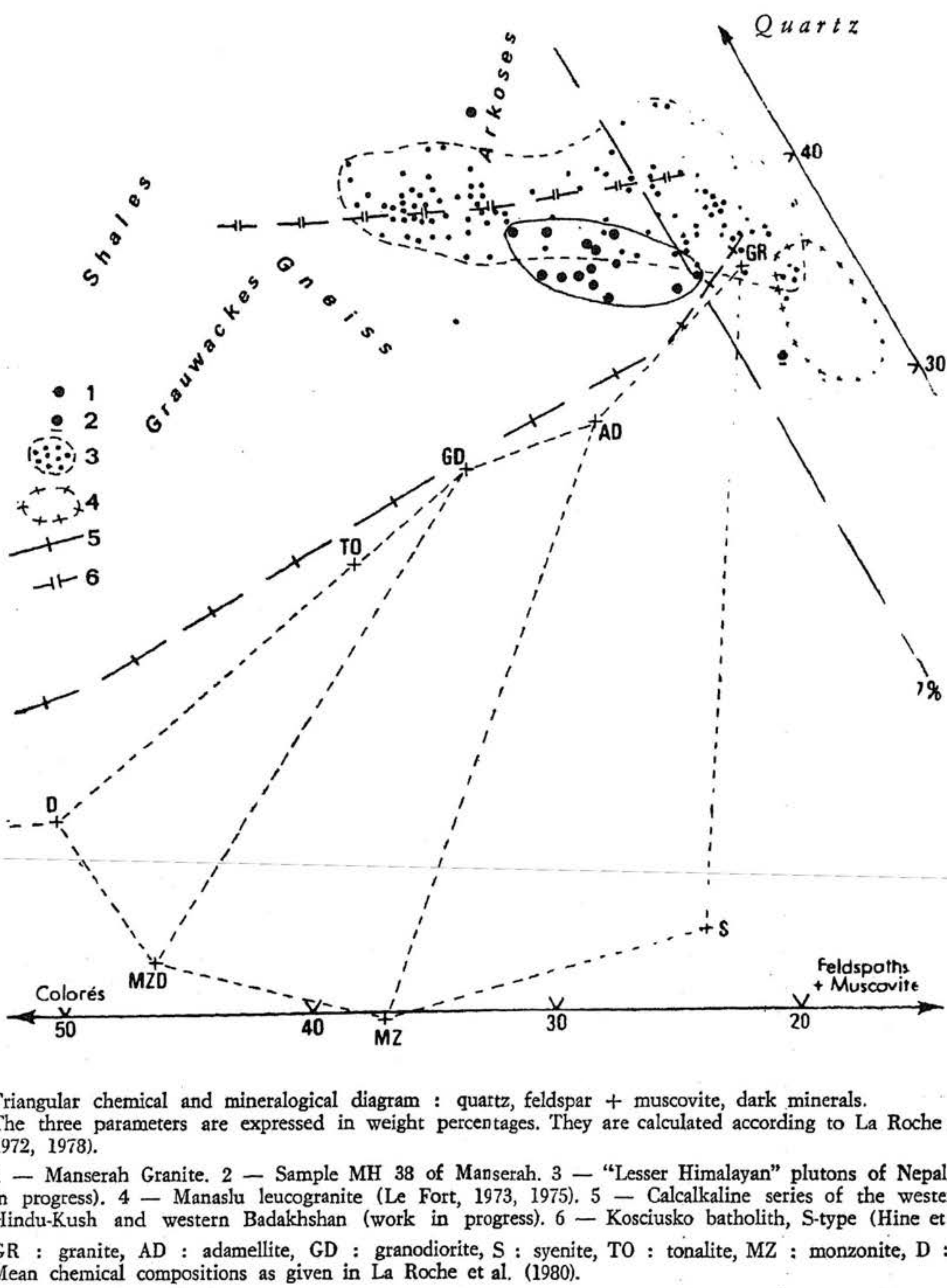

Fig. 3. Triangular chemical and mineralogical diagram : quartz, feldspar + muscovite, dark minerals. The three parameters are expressed in weight percentages. They are calculated according to La Roche (1964, 1972, 1978).

1 — Manserah Granite. 2 — Sample MH 38 of Manserah. 3 — "Lesser Himalayan" plutons of Nepal (work in progress). 4 — Manaslu leucogranite (Le Fort, 1973, 1975). 5 — Calcalkaline series of the western Hindu-Kush and western Badakhshan (work in progress). 6 — Kosciusko batholith, S-type (Hine et al., 1978).

GR : granite, AD : adamellite, GD : granodiorite, S : syenite, TO : tonalite, MZ : monzonite, D : diorite. Mean chemical compositions as given in La Roche et al. (1980).

The locations of the sedimentary and metamorphic rock types correspond to average ranges of usual composition (from C.R.P.G. data files).

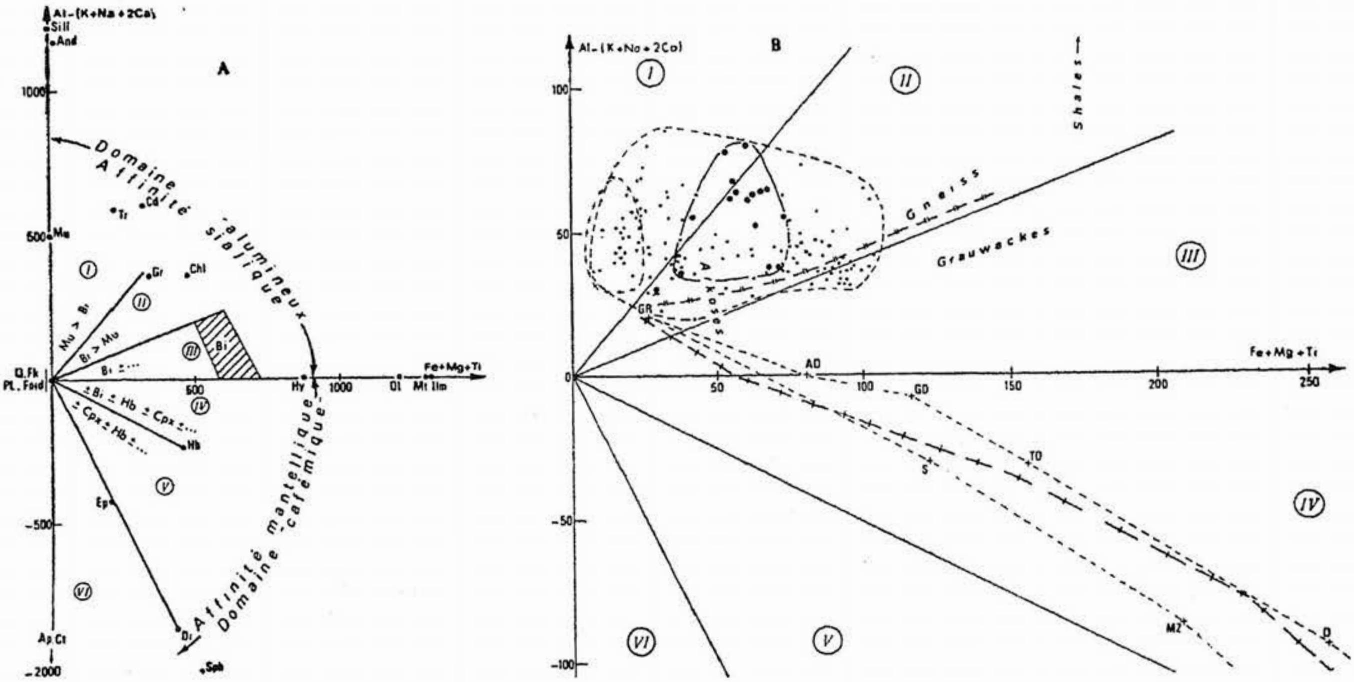

Fig. 4 Characteristic minerals diagram. This diagram follows the same principles as adopted by Barriere (1972, 1980). Four lines and the two axes divide the plane into six areas numbered I to VI. The aluminous granitoids are located in the areas I, II and III; the cafemic granitoids are located in the areas IV and V. This distinction has been established by La Roche (1979) although in a different diagram and with a different limit. This diagram is very efficient in recognizing the nature of mineral phases other than quartz and feldspars (these two phases being located at the origin). In particular, it gives a good idea of the muscovite/biotite ratio in micaceous granitoids.

In this diagram, the location of the analyses and the trend of the series give good clues to the origin and affinities of the parental magma.

Real and theoretical mineral compositions have been plotted on the diagram 4 A : And = andalusite, Ap = apatite, Bi = biotite (hatched domain), Cd = cordierite, Chl = chlorite, Ct = calcite, Di = diopside, Ep = epidote, Fk = K feldspar, Foid = leucite or/and nepheline, Gr = pyralspite, Hb = hornblende, Hy = hypersthene, Ilm = ilmenite, Mt = magnetite, Mu = muscovite, Ol = olivine, Pl = plagioclase, Q = quartz, Sill = sillimanite, Sph = sphene, Tr = tourmaline. Other symbols as in figure 3.
All parameters are expressed as millications-g in 100 g of rock or mineral.

characteristic of igneous rocks with total or mantellic affinity, is very noteworthy for the Lesser Himalayan granitoids. These observations favour a majority crustal contribution in their genesis.

3. Relationship of the Lesser Himalayan plutons with the "S" type Series

The composition as well as the evolutionary trend of the Lesser Himalayan granitoids differ very obviously from the Higher Himalayan leucogranites (Le Fort, 1973, 1975) (fig. 3) and from the calc-alkaline series, the Hindu-Kush type for example (Debon *et al.,* 1978, 1980) (fig. 3, 4). On the contrary they resemble very closely the "S" type series (Chappell and White, 1974; White and Chappell, 1977) of which the Kosciusko batholith (Hine *et al.,* 1978) gives a good example (fig.3, 4). The only significant difference appears in figure 4 wehere the Kosciusko trend has a positive slope that expresses the more or less constant value of the biotite/muscovite ratio; however we know that other "S" type series (mainly unpublished data) may show an horizontal or even a slight negative slope. (We suggest that this slope depends partly on the nature of the source material).

The genuine that may exist actually concerns the nature of the inclusions : numerous typical igneous "microgranular"(*) inclusions for the Lesser Himalayan granites, but apparently essentially of metasedimentary type for the "S" series.

(*) Despite their name, their composition is in general very different from the composition of common igneous rocks. Following the results of recent studies (Leterrier, 1972; Debon and Laterrier, 1974; Debon, 1975; Leterrier and Debon, 1978; Orsini, 1979) we consider that their chemical composition is a secondary feature acquired during metasomatic exchange at the magmatic stage between them and the granitoid matrix.

Rb-Sr ISOTOPIC GEOCHEMISTRY AND ABSOLUTE AGE OF THE MANSERAH GRANITE

Prior to this study, knowledge of the age of the Manserah granite was extremely tentative : (1) there are major uncertainties concerning the lithostratigraphic ages of the formations it intrudes (up to Ordovician(?) or Devonian(?), (2) it is supposed to be a precursor of the Himalayan tectonic and metamorphic events, and (3) an unpublished age determination by R.G. Davies (in Calkins *et al.,* 1975) has suggested a late Cretaceous (80 m.y.) age.

The Abbottabad fossiliferous limestones with a well defined Cambrian age (Rushton, 1973) (fig. 2) are never in direct contact with the granite although they outcrop nearby. Three samples from the Hazara slate formation collected along the road some 10 km South of Manserah have been analysed as total-rock samples by the Rb–Sr method by Crawford and Davies (1975). The results suggest to these authors that the part of the formation sampled is Precambrian.

1. Samples analysed

Seven samples of the Manserah granite were selected, using the geochemical data and according to their representativeness, their small degree of alteration and to their dispersion of $^{87}Rb/^{86}Sr$ values. Five samples have been collected from the porphyritic granite (MH 1, 9, 17, 19, 28), one from the gneissified granodiorite (MH 38) and one from an igneous "microgranular" inclusion (MH 2). Five samples have been collected in the biotite zone of metamorphism and two in the garnet zone (fig. 2).

2. Analytical techniques and methods

Rb and Sr concentrations were obtained by isotope dilution on two spiked fractions of the same solution and measured mass spectrometrically. $^{87}Sr/^{86}Sr$ ratios were determined directly on two non-spiked fractions. The errors (2σ) given in the Table 4 for the $^{87}Rb/^{86}Sr$ ratio have been calculated from the errors on each analysis.

The mean value of $^{87}Sr/^{86}Sr$ obtained on NBS 987 was 0.71024 ± 25 (2σ) compared to the recommended value of 0.71014 ± 20. The isochrons were calculated following the methods of York (1969).

3. Results and interpretations

The analytical results are reported in Table 4. The seven analysed samples give a well defined isochron (MSW ≪ 1) with an age of 516 ± 16 m.y. and an initial ratio of 0.7189 ± 6 (fig. 5). The calculated age is considered to correspond to the age of the isotopic homogenization on the scale of the massif and not a result of a mixing phenomenon (fig. 6).

Table 4. Analytical results for Rb—Sr.

N°	Rb ppm	Sr ppm	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86} *
MH 1	262.5	68.8	11.0450 ± 0.26	0.80173 ± 0.0025
MH 2	251	40.8	17.8212 ± 0.57	0.84672 ± 0.00045
MH 9	297.2	67.9	12.6584 ± 0.41	0.81543 ± 0.0006
MH17	312.7	57.7	15.6762 ± 0.35	0.83648 ± 0.0016
MH19	271.6	68.6	11.4563 ± 0.27	0.79891 ± 0.0005
MH28	315.2	67.3	13.5624 ± 0.37	0.82054 ± 0.0007
MH38	195.2	492.4	1.1476 ± 0.018	0.72733 ± 0.0002
PHS1	431	42.1	29.802	0.9322
PHS2	424	42.6	28.967	0.9314
PHS3	395.7	64.2	17.928	0.8502
PHS4	402.8	58.6	19.986	0.8608

Samples MH - Manserah granite - Analyses C.R.P.G. - 1979
" PHS - Mandi granite - Analyses E. Jäger - 1971
* Ratios normalised : $^{86}Sr/^{88}Sr = 0.1194$

Could this isotopic homogenization be related to the observed metamorphism and orthogneissification of the granite ? We do not believe so for the following reasons.

First the metamorphism is regional, corresponds to the Himalayan structures and affects the Paleozoic and Mesozoic series. It thus seems to be essentially Himalayan. Second, the minerals should also have been rehomogenized by such a regional process; however the two isotopic determinations made on biotites of samples MH 9 and MH 28 gave a biotite — whole rock age of 135 and 114 m.y. respectively. Therefore we consider the Cambrian age of 516 m.y. represents the formation age of the Manserah granite.

A similar age has already been reported for the Mandi granite (Jager *et al.,* 1971) that we consider to be part of the Lesser Himalayan belt. This granite gives a poorly defined isochron of 518 ± 100 m.y. with an initial ratio of 0.718. Also, Frank *et al.* (1977) give another similar age for intrusive granites in the Lahul crystalline nappes (512 ± 16 m.y. with an initial ratio of 0.720 ± 2).

The data of Jagar *et al.* (1971) have been combined with ours for comparison in fig. 7. Because errors are not quoted for the $^{87}Rb/^{86}Sr$ and $^{87}Sr/^{86}Sr$ ratios in Jager et al. (1971) for the Mandi granite these have been estimated to be 2% for the $^{87}Rb/^{86}Sr$ ratio and ± 0.0001 (absolute error) for $^{87}Sr/^{86}Sr$. The four points for the Mandi granite plot, within analytical uncertainty, on the Mansehra granite isochron. The combined date for both granites define an isochron with age 511 ± 9 m.y. and initial ratio 0.7190 ± 3, indistinguish-

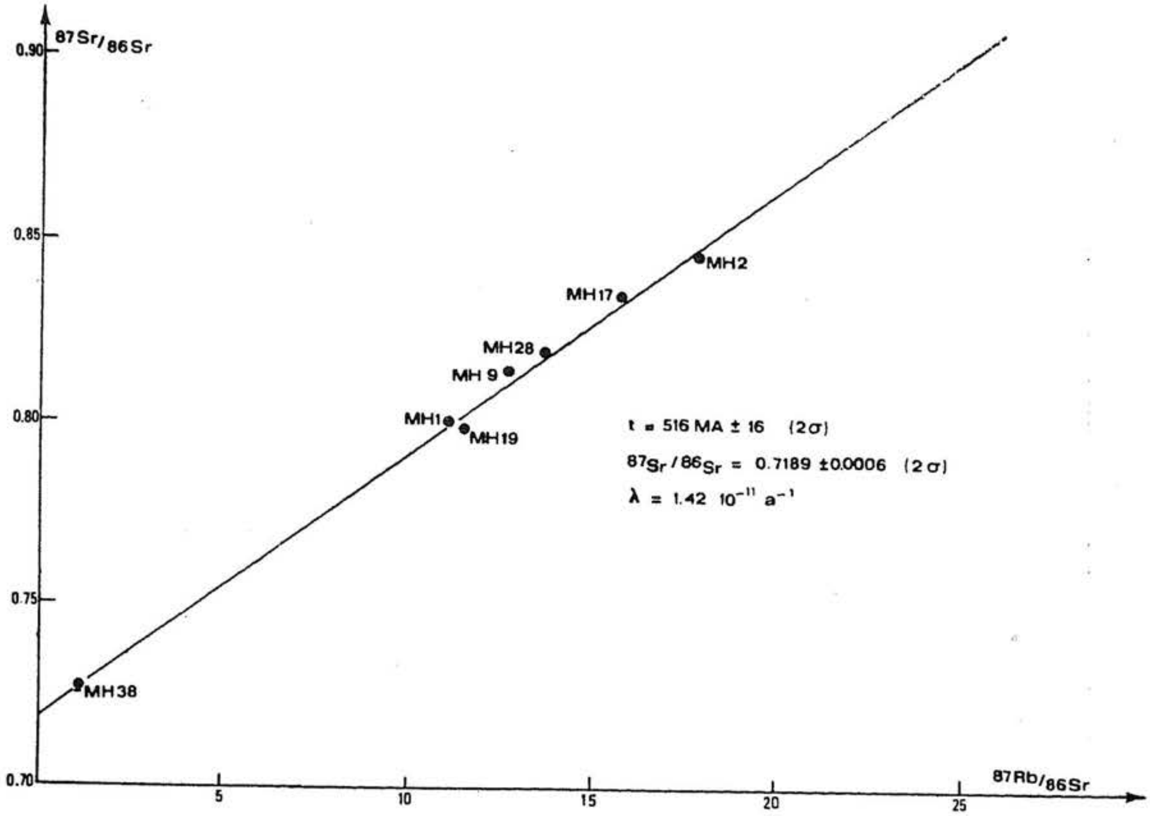

Fig. 5 Rb—Sr whole rock isochron for the Manserah pluton.

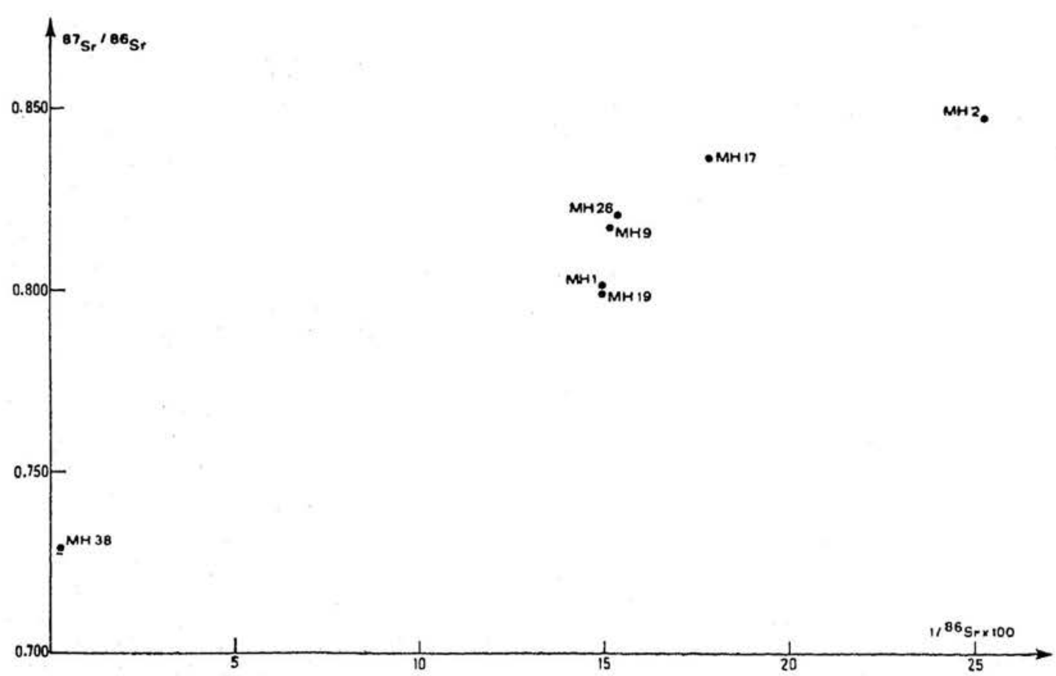

Fig. 6 Plot of $^{87}Sr/^{86}Sr$ v.s. $10^2/^{86}Sr$. The absence of an alignment implies that the data are not interrelated by a mixing process.

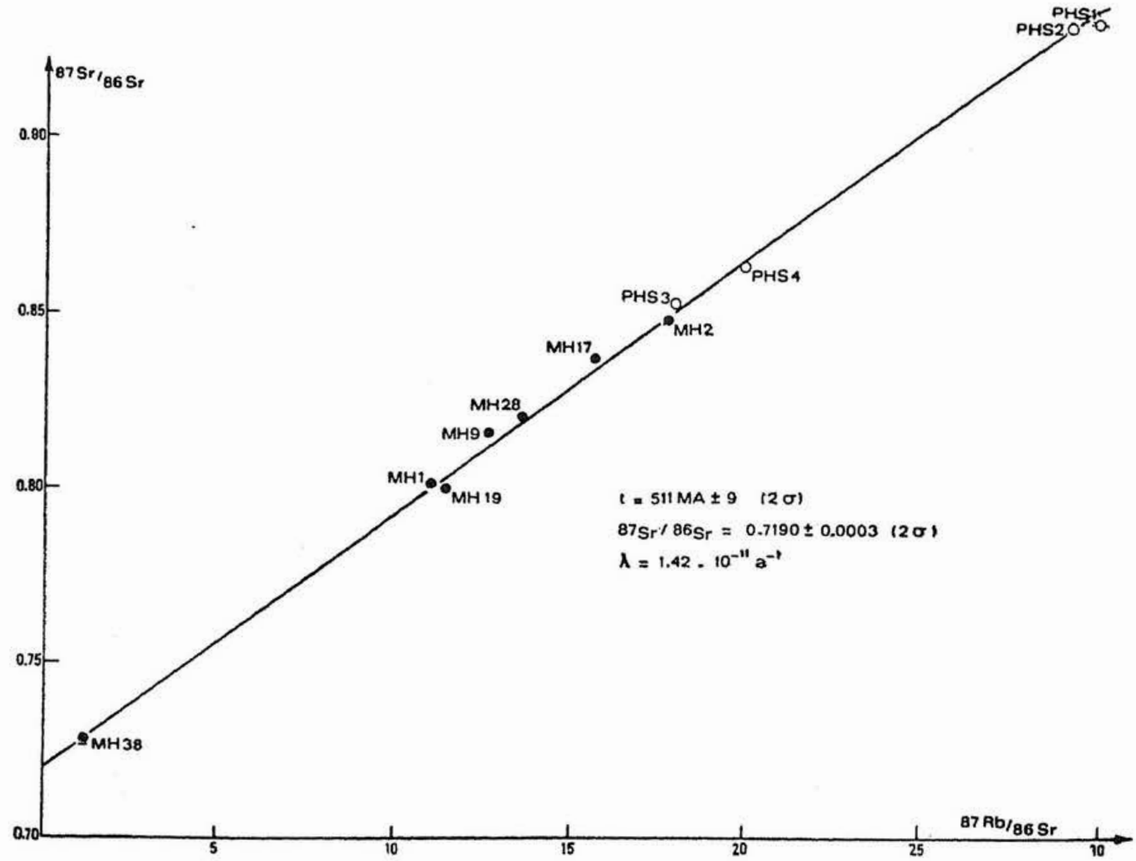

Fig. 7. Rb—Sr whole rock isochron for the combined data from the Manserah and Mandi plutons.

able from those values for the Mansehra granite alone, within the limits of experimental and estimated errors. The identical and high initial ratio for these two granites implies derivation from a common source containing a major and very old crustal contribution.

CONCLUSIONS

The Mansehra pluton clearly is very much older and therefore has no direct connection with the Himalayan orogeny. It has been incorporated as a whole in the Himalayan edifice and strongly deformed. As a consequence of the Cambrian age of the pluton, the formations it intrudes, namely the Tanawal, Salkhala and Hazara formations, are Pre-Cambrian.

The Mansehra pluton is part of a belt of similar granites that outcrop for at least 1600 km along the Himalaya. In Nepal as most likely in India and maybe in Pakistan, these plutons have intruded the formations in the Cambrian and then during the Himalayan orogeny, the whole block was overthrusted along the Main Central Thrust (see fig. 1). The tight folding superimposed upon the massifs implies that most of them were emplaced as sheets of magma.

Is the emplacement of the plutons related to an orogenic episode ? Some deformation is still recognizable but to a limited extent. No indication of a previous metamorphism has yet been observed. The presence of igneous "microgranular" inclusions suggests to us some involvement of the mantle although the principal contribution should derive from an old crustal basement. Thus, for the moment, it is difficult to relate the generation of these granites either to a definite orogeny — say a late Pan African one for example — or to another phenomenon — like an extended thinning of the crust.

Finally let us emphasize the fundamental geochemical and age differences that exist between the Higher Himalayan belt of leucogranites of Manaslu type and the Lesser Himalayan belt of cordierite granites. Only the leucogranites are genetically linked with the Himalayan orogeny.

Acknowledgements: This research was supported by the GRECO n°12 "Himalaya-Karakorum" of the Centre National de la Recherche Scientifique. Work in the field was carried out with J. Stebbins.

The writers are grateful to R. Grawford, A. Gansser, J. Stocklin and R.A.K. Tahirkheli for stimulating discussions. Paper was reviewed and greatly improved by S.M.F. Sheppard.

REFERENCES

Ahmad, Z., 1969, Directory of mineral deposits of Pakistan: Records Geol. Survey Pakistan, V. 15, pt. 3, 220 p.

Bakr, M.A., and Jackson, R.O., 1964, Geological map of Pakistan (1:2.2000.000): Geol. Survey Pakistan, Quetta.

Barriers, M., 1972, Sur la distinction des granites hypoalumineux, alumineux, hyperalumineux: Comptes Rendus Academie des Sciences, Paris, serie D, V. 274, p. 2416-2418.

Barriere, M., 1980, Les granitoides paleozoiques armoricaine: Congres geologique international, Paris, in press.

Calkins, J.A., Offield, TW., Abdullah, S.K.M., and Tayyab Ali, S., 1975, Geology of the Southern Himalaya in Hazara, Pakistan, and adjacent areas: U.S. Geol. Survey Prof. Paper 716 C. 29 p.

Chappell, B.W., and White, A.J R., 1974, Two contrasting granite types: Pacific Geology, 8, p. 173-174.

Crawford. A.R., and Davies, R G., 1975, Ages of Pre-Mesozoic formations of the Lesser Himalaya, Hazara District, Northern Pakistan: Geol. Mag., V. 112, n°5, p. 509-514.

Debon, F., 1975, Les massifs granitoides a structure concentrique de Cauterets-Panticosa (Pyrenees occidentales) et leurs enclaves. Une etude petrographique et geochimique: Sciences de la Terre, memoire n°33, 420 p.

Debon, F., Le Fort, P., and Sonet, J., 1978, Des caracteres geochimique de deux provinces plutoniques d'Afghanistan: Hindou Kouch et "Montagnes Centrales": 6e Reunion ann. Sciences de la Terre, Orsay, p. 135.

Debon, F.. Le Fort, P., and Sonet, J., 1980, Typologie chimique et chronologie des roches plutoniques d'Afghanistan: 8e Reunion ann. Sciences de la Terre, Marseille.

Debon, F, et Letterier, J., 1974, Liaisons chimico-mineralogiques entre les granites at leurs enclaves microgrenues dans six unites granitiques de la Zone axiale pyreneenne (masifs de Cauterets, Panticosa at Querigut): Comptes Rendus Academie des Sciences, Paris, serie D, V. 279, p. 1825-1828.

Desio, A., 1976, Some geotectonic problems of the Kashmir Himalaya — Karakorum — Hindu Kush and Pamir area: in "Geotettonica delle zone orogeniche del Kashmir Himalaya — Karakorum — Hindu Kush — Pamir", Academia nazionale dei Lincei, Roma, p. 115-129.

Desio, A., 1977, Correlations entre les structures des chaines du Nord Est de l'Afghanistan et du Nord-Ouest du Pakistan: in Livre a la memoire de A F. de Lapparent, Mem. hors-serie n°8, Soc. geol. France, p. 179-188.

Frank, W., Thoni, M., and Purtscheller, F., 1977, Geology and petrography of Kulu — South Lahul area: in Colloque intern. CNRS n°268 "Ecologie et geologie de l'Hamalaya", Paris, Vol Sc. de la Terre, p. 147-172.

Hine, R., Williams, I.S., Chappell, B.W., and White, A.J.R., 1978, Contrasts between I- and S-type granitoids of the Kosciusko Batholith: Journal of the Geological Society of Australia, V 25, pt. 4, p. 219-234.

Jaeger, E., Bhandari, A.K., and Bhanot, V.B., 1971, Rb-Sr age determinations on biotites and whole rock samples from the Mandi and Chor granites, Himachal Pradesh, India: Eclogae geol. Helv., V. 64. n°3, p. 521-527.

Khan, S.N., 1964, Geology of Rajdhawari pegmatites, Oghi subdivision, Hazara district, West Pakistan: Inf. release, Geol Survey Pakistan, n°19, 18 p.

La Roche, H. de, 1964, Sur l' expression graphique des relations entire la composition chimique et la composition mineralogique quantitative des roches plutoniques. Presentation d'un diagramme destine a l'etude chimico-mineralogique des massifs granitiques ou granodioritiques. Application aux Vosges cristallines: Sciences de la Terre, t., 9, p. 293-337.

La Roche, H. de. 1972. Revue sommaire de quelques diagrammes chimico-mineralogiques poor l'etude des associations ignees ou sedimentaires et de leurs derives metamorphiques: Sciences de la Terre, t. 17, p. 31-46.

La Roche, H. de, 1978, La chimie des roches presentee et interpretee d'apres la structure de leur facies mineral dans l'espace des variables chimiques. chimiques. Fonctions specifiques et diagrammes qui s'en deduisent. Application aux roches ignees: Chemical Geology, V. 21, p. 63-87.

La Roche, H. de, 1979, Muscovitisation deuterique, caractere alumineux des leucogranites at classification des granites subvolvus: Bulletin Soc. Geol. France, t.21, n°1, p. 87-93.

La roche, H. de, Leterrier, J., Grandclaude, P., and Manchal, M., 1980, A classification of volcanic and plutonic rocks using $R_1 R_2$ diagram and major element analyses. Its relarelationships with current nomenclature: Chemical Geology in press.

Le Fort, P., 1973, Les leucogranites a tourmaline de l'Himalaya sur l'exemple du granite du Manaslu (Nepal central): Bulletin Soc. Geol. France, V. 15, n°5-6, p. 555-561.

Le Fort, P., 1975, Le granite du Manaslu: in "Recherches geologiques dans l'Himalaya du Nepal, region du Nyi-Shang", Ed. CNRS, Paris, p. 49-65.

Le Fort, P., Debon, F., and Stebbins, J., 1978, Mise en evidence d'une ceinture de granites a cordierite et enclaves "microgrenues" en Bas-Himalaya (Nepal-Indes-Pakistan): 6e Reunion ann. Sciences de la Terre, Orsay, p. 243.

Leterrier, J., 1972, Etude petrographique et geochemique du massif granitique de Querigut (Ariege): Sciences de la Terre, memoire n°23, 320 p.

Leterrier, J., et Debon, F., 1978, Caracteres geochemiques compares des roches granitoides et de leurs enclaves microgrenues. Implications genetiques: Bulletin Societe Geologique de France, V. 20, p. 3-10.

Orsini, J., 1979, Contribution a la connaissance des granitoides tardi-orogeniques du batholite corso sarde Les enclaves sombres de l'association plutonique calco-alcaline: Travaux Laboratories Sciences de la Terre, St Jerome, Marseille, n°3, 104 p.

Rushton, A W.A., 1973, Cambrian fossilis from the Hazira shale, Pakistan: Nature, Phys. Sci., London, V. 243, p. 142.

Shams, F.A., 1961, A preliminary account of the Mansehra area, Hazara district. West Pakistan: Punjab Univ. Geol. Bulletin, I, p. 57-62.

Stocklin, J., 1977, Structural correlation of the Alpine ranges between Iran and Central Asia: Memoire hors-serie Societe geologique France, n°8. p. 333-353.

Streckeisen, A., 1974, Classification and nomenclature of plutonic rocks: Geological Rundschau, Bd. 63, Ht 2, p. 773-786.

Tahirkheli, R.A.K, 1979, Geology of Kohistan and adjoining Eurasian and Indo-Pakistan continents, Pakistan: in "Geology of Kohistan" (R.A. Khan Tahirkheli and M. Qasim Jan, editors), Geol. Bulletin Univ. Peshawar (Special issue), V. 11, n°1, p. 1-30.

Tahirkheli, R.A.K., Mattauer, M, Proust, F. and Tapponnier, P., 1979, The India-Eurasia suture zone in Northern Pakistan: synthesis and interpretation of recent data at plate scale: in "Geodynamics of Pakistan" (Abul Farah and K. de Jong, editors), Geol. Survey of Pakistan, Quetta, p. 125-130.

White, A.J.R., and Chappell, B.W., 1977, Ultrametamorphism and granitoid genesis: Tectonophysics, 43, p 7-22.

York, D., 1969, Least squares fitting of a straight line with correlated errors: Earth Planet, Sci. Lett., 5. p. 320-324