CHAPTER VIII

B A S I C R O C K S

GENERAL

The basic rocks of the study area are confined to the Kusma Unit, to the north of Phalebas Thrust. They have been variously described as diabase, gabbro and amphibolites by different authors (Nadgir & Nanda, 1966 ; Fuchs, 1967 ; Fuchs & Frank, 1970 ; Talalov, 1972 ; Sharma, 1975 ; Remy, 1975a, b, 1978 ; Lasserre, 1976). These basic rocks occur in the lensoid form invariably interbedded with quartzitic rocks (Fig. III.2). They are also seen intercalated in gritty quartzose phyllites and quartz-sericite-phyllites of Balewa Formation. The lensoid bodies vary in size from a few

meters to a few hundreds of meters in thickness, and a few tens of meters to a kilometer or more in length. The smaller bodies of these basic rocks are affected by the metamorphism and now they more or less resemble chloritic phyllites. The larger bodies, on the other hand, are gradational, the green foliated variety occurring along the margins with foliations parallel to the country rock, passes gradually towards the core into an unfoliated, hard and compact mass. Invariably, the smaller lenses of basic rocks have been intensly weathered, and fresh samples are difficult to collect.

On the basis of the petrographic study and petrochemistry, these basic rocks have been found to be spilitic in nature.

Depending upon the mineralogical and textural characters, the basic volcanics of the study area have been classified into the following main varieties:

(i) Spilitic diabase

(ii) Spilitic basalt

(iii) Tuffs and tuffites.

SPILITIC DIABASE

Megascopically, these rocks are medium to coarse grained and of dark greenish-gray in colour. The larger

bodies of these lensoid basic rocks show massive nature with coarse grained texture in the median portion, whereas the marginal part exhibits well developed foliation. As these rocks have undergone some metamorphism, they do not always retain their original texture and structure. However, in many cases, the relict texture and structure are still preserved.

No pillow-lava structures have been recognised from any of these basic rock bodies.

Textures

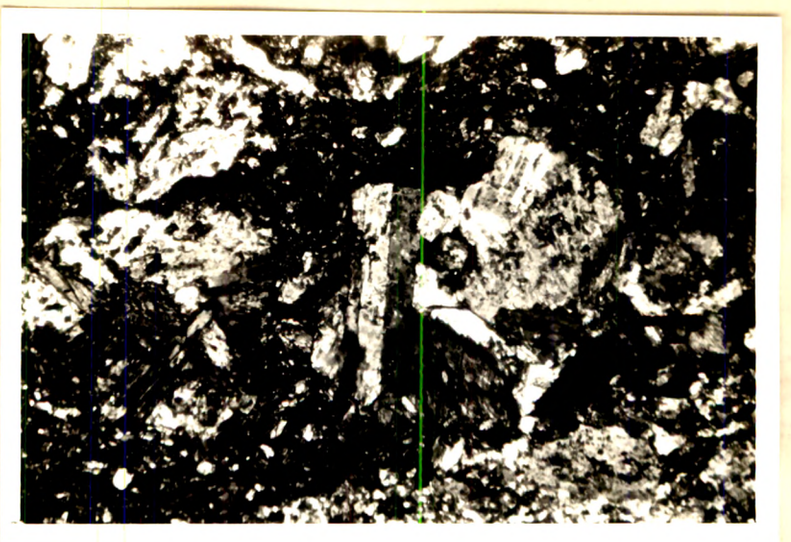
Thin section studies of the nearly undeformed massive diabasic rocks show the following two varieties of textures:

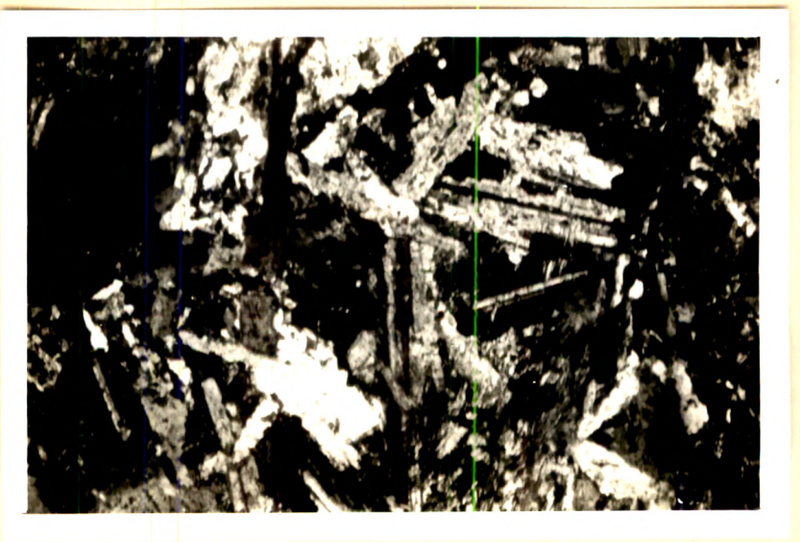
(i) Ophitic texture Relict ophitic texture of these rocks are occasionally observed, and the laths of sodic plagioclase are enclosed partly or wholly within uralite or hornblende. (Plate VIII.1A).

(ii) Intersertal texture Fresh to slightly altered plagioclase laths show unoriented meshwork in which the interstitial space is filled by very fine chloritic and uralitic mass exhibiting typical intersertal texture(Plate VIII.1B).

Plate VIII.1A Photomicrograph of spilitic diabase with sub-ophitic texture. The lath of plagioclase is partially enclosed within hornblende (crossed nicols, x 50).

Plate VIII.1B Photomicrograph of spilitic diabase showing intersertal texture (crossed nicols, x 50).





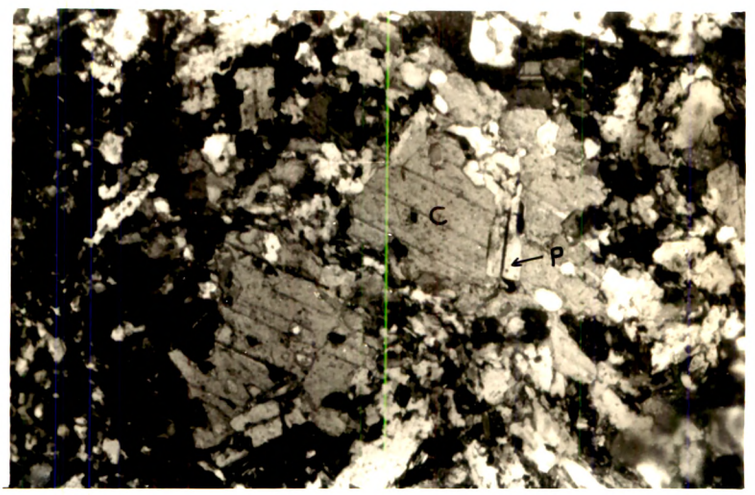
Mineralogy

These basic rocks are primarily composed of plagioclase (albite-oligoclase), chlorite, uralite and minor amount of hornblende, calcite, epidote, sphene, ilmenite, leucoxene, magnetite, pyrite and stilpnomelane.

Plagioclase The plagioclase felspar is one of the major constituents. It forms laths that are fresh to partially saussuritized. Many grains are well suited for the determination of anorthite content under universal stage (Federov's stage) following Reinhard's method (Naidu,1958). In all the spilitic varieties, the anorthite content of plagioclase was determined and a sufficient number of grains were taken to have the representative value. It was found that the anorthite content varies from 6 % to 10 % in most of the cases, confirming that they are albitic in composition. $2V_z$ of these plagioclase ranges between 78^o to 84^o. In some cases, the twin lamellae of the plagioclase show bending due to deformation. Plagioclase laths show random orientation and form interseertal and relict ophitic textures. A few tiny plagioclase laths are also noticed to occur within calcite grains (Plate VIII.2).

Chlorite Chlorite is the second abundant and important constituent. Under microscope, it shows various modes of

Plate VIII.2 Photomicrograph of spilitic diabase showing a small lath of plagioclase (P) completely entrapped in a calcite (C) grain (crossed nicols, x 85).


C
P

occurrences. The chlorite mostly fills the inter-spaces between the plagioclase felspars or it occurs as matrix constituent in variable proportion. Also, it is not uncommon to find tiny inclusions of chlorite in albite-oligoclase. This mode of occurrence is of much significance as it indicates the primary nature of chlorite. (Amstutz & Patwardhan, 1974, P.74). Sometimes minute flakes of chlorite form spherulitic structures. It is, however, difficult to estimate the proportion of primary chlorite and secondary chlorite. The isotropic and the radial aggregate dominate over the other varieties of chlorite. The radial aggregate variety occurs in clusters and patches with diverse orientation. The pleochroism varies from bluish-green to pale greenish-yellow, with almost straight extinction.

Uralite Uralite is a common mineral. It forms tiny needles with fibrous nature (sheaf-like). Its pleochroic scheme is somewhat similar to hornblende (bluish-green to pale greenish-yellow). One set of cleavage is well developed. Extinction angle varies from 18^{o} - 20^{o} . These uralites appear to have been derived from pyroxenes.

Hornblende It is not a very common mineral and is recorded in a few thin sections only. Plagioclase laths are found to be enclosed partially within the hornblende. It is prismatic

in habit with well developed cleavages. Basal section shows development of two sets of cleavages at 56^{o} and 124^{o}. Extinction angle ranges from 20^{o} - 22^{o}. Pleochroic scheme is as under:

Z = bluish green

Y = green

X = pale greenish yellow

Alteration of hornblende to chlorite and uralite is commonly noticed.

Calcite Though calcite is not very common, it occurs in small quantity in some thin sections. It forms discrete small crystals. Some larger grains show bent twin laminae. Calcite is mostly found in the groundmass and whenever it is found near plagioclase grains, it shows sharp contact. Sometimes small laths of plagioclase are found enclosed within calcite grains (Plate VIII.2).

Epidote It is also not a very common mineral but sometimes occurs in abundance in some varieties. Epidote occurs as stray equidimensional grains and is recognised by its typical interference colour and high relief. Some of them are euhedral with very well developed short face boundary. Occasionally, they occur as tiny grains scattered throughout

the thin section. Also, it forms small inclusions in plagioclase.

Sphene Sphene is a generally scarce accessory mineral but sometimes it is found in appreciable quantity in some thin sections. It shows dark yellowish brown colour, very high relief with typical wedge shape, having well developed face boundary. Pleochroism is feeble.

Ilmenite Ilmenite is a common opaque mineral. It is black, opaque, subhedral to anhedral and shows very high relief. The ilmenite grains are normally rimmed by leucoxene. This mineral is also intimately intermixed with chlorite in the groundmass.

Stilpnomelane This mineral although usually not very common, but in some varieties it is strikingly found in abundance and occurs as either small granules associated with opaques or as long radiating aggregates. It shows pleochroism in shades of greenish yellow to pale yellow and straight extinction.

Chert Fine grained quartz (cherty) is fairly common in the spilitic basalt and less common in diabasic variety. They are found disseminated in the groundmass. They are possibly

introduced during the penecontemporaneous deposition with the sediments.

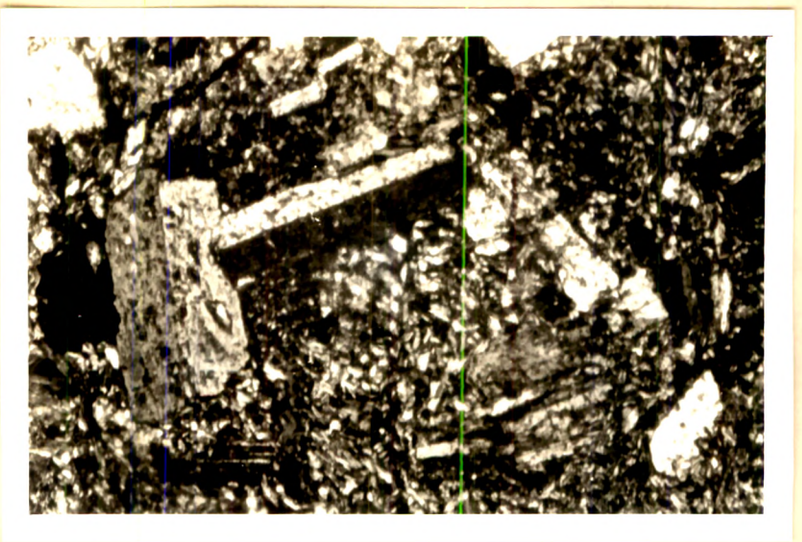
Magnetite Magnetite is commonly present in these rocks as a opaque mineral and interspersed in the groundmass.

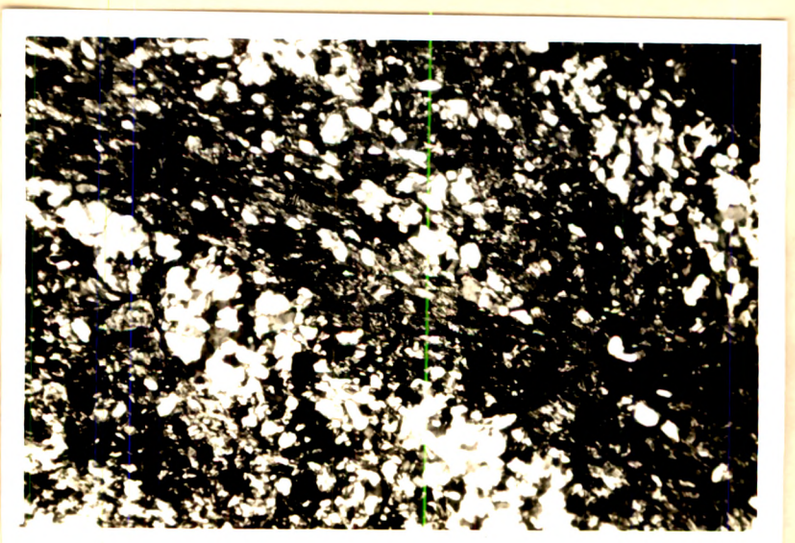
SPILITIC BASALT

Spilitic diabase and spilitic basalt are distinguished on the basis of textural characters under microscope. Both the varieties are mineralogically as well as chemically similar. Spilitic diabase is coarse in handspecimen as well as under microscope with relict ophitic texture. Plagioclase laths are larger in diabasic variety than in spilitic basalts. Spilitic basalt, on the other hand, is fine grained with tiny laths of plagioclase embedded in the fine grained matrix of chlorite and chert with subordinate amount of opaque minerals. Occasionally big laths of plagioclase form the porphyritic texture (Plate VIII.3A). Compared to diabasic rock, basaltic variety contains more chlorite in groundmass. Hornblende and uralite are less commonly encountered in basaltic variety. Intersertal texture is common. The plagioclase shows the same composition (albite-oligoclase) as in diabasic variety.

Plate VIII.3A Photomicrograph of spilitic basalt with porphyritic texture (crossed nicols, x 85).

Plate VIII.3B Photomicrograph of tuff showing fine grained foliated mass of alternate siliceous and chloritic layers (crossed nicols, x 50).





TUFFS AND TUFFITES

Tuffs and Tuffites are not very commonly encountered but sometimes layers of these rocks occur within the spilites. They are fine grained dark greenish in colour and highly weathered. Tuffs show fine grained foliated mass of alternate siliceous and predominantly chloritic layers (Plate VIII.3B). Tuffites comprise a mixture of volcanogenic material and clastic sediments (Plate VIII.4).

PETROCHEMISTRY

The chemical data on the basic rocks of the Kali Gandaki area (Table VIII.1) clearly points to their relatively higher alkali content and impoverishment in calcium as compared to the normal diabase and basalt. The author has chemically analysed nine representative rock samples of spilitic diabase and basalt. The soda and potash content have been determined by flame-photometer. The values of various constituents are plotted in a number of binary and triangular diagrams. These plots fall within the spilitic suite of rocks and are well comparable with the previously described spilites from Kumaon and Himachal Pradesh and the average spilites of other parts of the world (Table VIII.2). The Niggli values calculated from the chemical analyses are shown in table VIII.3.

Plate VIII.4 Photomicrograph of tuffite showing a mixture of volcanogenic material and clastic sediments (crossed nicols, x 50).

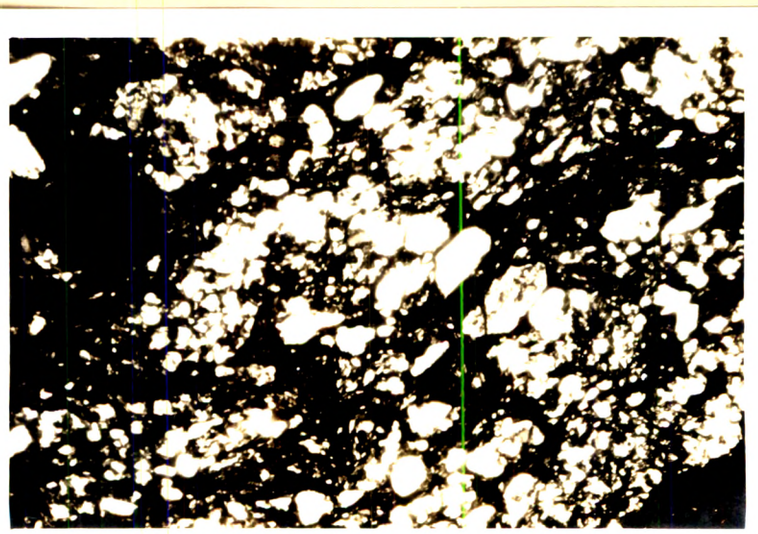


Table VIII.1 Chemical analysis of Basic rocks of Kali Gandaki valley (Weight percent)

Oxides	333B	337A	337D	339	340A	911	927	1181	1206
SiO_2	50.45	51.20	46.70	44.90	46.53	48.10	50.90	53.35	45.90
Al_2O_3	13.96	13.03	15.58	14.48	14.51	12.96	14.97	12.84	12.83
Fe_2O_3	7.29	4.76	7.79	9.72	6.18	8.88	8.55	7.57	10.28
FeO	5.08	5.88	7.18	6.05	8.25	10.08	5.02	6.92	7.68
CaO	1.19	1.82	2.10	4.20	1.40	2.45	1.05	1.05	6.30
MgO	12.40	12.86	7.60	9.24	12.14	8.24	10.59	7.60	7.16
Na_2O	2.44	2.68	5.60	4.42	2.28	1.61	1.24	3.22	3.25
K_2O	1.30	1.63	2.54	2.39	1.04	0.54	0.97	0.68	2.21
TiO_2	1.66	2.08	1.45	1.25	2.28	2.08	1.45	1.66	1.45
Loss on ignition	4.77	4.90	5.86	2.98	4.92	5.50	6.16	3.54	1.54
Total	100.85	100.83	102.39	99.63	99.53	100.44	100.90	98.42	98.59
K_2O/Na_2O	0.53	0.60	0.45	0.54	0.46	0.33	0.78	0.21	0.68
$Na_2O + K_2O$	3.75	4.31	8.14	6.81	3.32	2.15	2.21	3.90	5.46
$FeO + Fe_2O_3$	12.38	10.64	14.97	15.76	14.43	18.96	13.57	14.49	17.96
$CaO/CaO+Na_2O+K_2O$	0.24	0.29	0.20	0.38	0.30	0.53	0.32	0.21	0.54
$Na_2O/Na_2O + K_2O$	0.65	0.62	0.68	0.65	0.69	0.75	0.56	0.83	0.60

Analyst: B.N. Upreti

Table VIII.2 Average spilites (cf. Patwardhan and Bhandari, 1974, P.183)

Oxides	A	B	C	D	E
SiO_2	51.22	48.60	53.15	54.20	49.65
TiO_2	3.32	1.94	1.50	1.31	1.57
Al_2O_3	13.66	16.10	14.39	17.17	16.00
Fe_2O_3	2.84	7.60	1.28	3.48	3.85
FeO	9.20	4.00	9.33	5.49	6.08
MnO	0.25	0.34	0.14	0.15	0.15
MgO	4.55	3.66	4.74	4.36	5.10
CaO	6.88	6.20	7.04	7.92	6.62
Na_2O	4.93	4.50	4.58	3.67	4.29
K_2O	0.75	1.76	1.01	1.11	1.28
P_2O_5	0.29	0.34	0.19	0.28	0.26
H_2	2.90	2.54	2.02	0.86	3.49
Co_2	0.94	1.45	0.10	-	1.63
Total	100.72	99.60	99.60	100.00	99.97

A Average spilite (Sandius, 1930)

B Somewhat potassic spilite; Wellington, New Zealand (Reed, 1957)

C Spilite somewhat high in potash, eastern orogen (Gilluly, 1935)

D Andesite (Nockolds, 1954)

E Average spilite (Vallance, 1960).

Table VIII.3 Niggli Values

	333B	337A	337D	339	340A	911	927	1181	1206
Si	120.2	124.8	109.8	98.15	109.16	121.55	133.1	152.10	109.16
Al	20.02	18.68	21.99	18.92	20.02	19.27	23.03	21.54	17.27
fm	69.06	67.69	55.71	58.18	69.72	69.28	69.27	65.14	56.86
c	3.11	4.75	5.40	9.99	3.52	6.63	2.94	3.21	15.44
alk	7.79	8.86	16.89	12.89	6.73	4.80	4.75	10.11	10.41
c/fm	0.05	0.07	0.09	0.17	0.05	0.09	0.04	0.04	0.27
(al + fm) - (c + alk)	78.18	72.76	55.41	54.21	79.49	77.12	84.61	73.36	48.28

Table VIII.4 Values of $CaO-Na_2O-K_2O$ and $(FeO + Fe_2O_3) - (Na_2O + K_2O) - (MgO)$ for triangular diagrams

CaO	24.11	29.67	20.50	38.14	29.66	53.23	32.23	21.22	53.58
Na_2O	49.54	43.69	54.68	40.15	48.30	34.94	38.04	65.02	27.63
K_2O	26.34	26.62	24.81	21.69	22.03	11.82	29.72	13.74	18.78
$FeO + Fe_2O_3$	43.39	38.26	48.74	49.55	48.27	64.60	51.46	55.76	58.74
$Na_2O + K_2O$	13.13	15.47	26.50	21.40	11.10	7.33	8.36	14.99	17.84
MgO	43.47	46.23	24.74	29.03	40.61	28.06	40.16	29.24	23.40

Ternary diagrams

(a) Diagram based on $CaO-Na_2O-K_2O$ wt. percent

The triangular diagram (Fig.VIII.1) based on $CaO-Na_2O-K_2O$ weight percent (Table VIII.4) ideally reveals the spilitic nature of the rocks of the study area. The author has compared these values with that of spilitic rocks of Patwardhan & Bhandari (1974), Shah & Merh (1976) and the average spilites of Sundius, 1930; Reed, 1957; Gilluly, 1935; Nockolds, 1954; and Vallance, 1960 (cf. Patwardhan & Bhandari, 1974, P.183). The various plots of the study area convincingly fall within the field of spilitic rocks reported from other parts of the world.

(b) Diagram based on $(FeO + Fe_2O_3) - (Na_2O + K_2O)-MgO$ (F.A.M.diagram)

The F.A.M. diagram (Fig. VIII.2) shows the compositional field of spilites with respect to total iron, magnesia and alkalies. The spilitic rocks are somewhat richer in total iron and magnesia and relatively poorer in alkalies (Table VIII.4). The plots of the basic rocks of the study area show the same compositional field as that of spilites of Mandi trap (Patwardhan & Bhandari, 1974) and the average spilites of various workers, indicating their spilitic nature.

FIG. VIII.1

CHEMICAL FIELD OF KALI GANDAKI SPILITES WITH RESPECT TO $CaO-Na_2O-K_2O$ WT. PERCENT

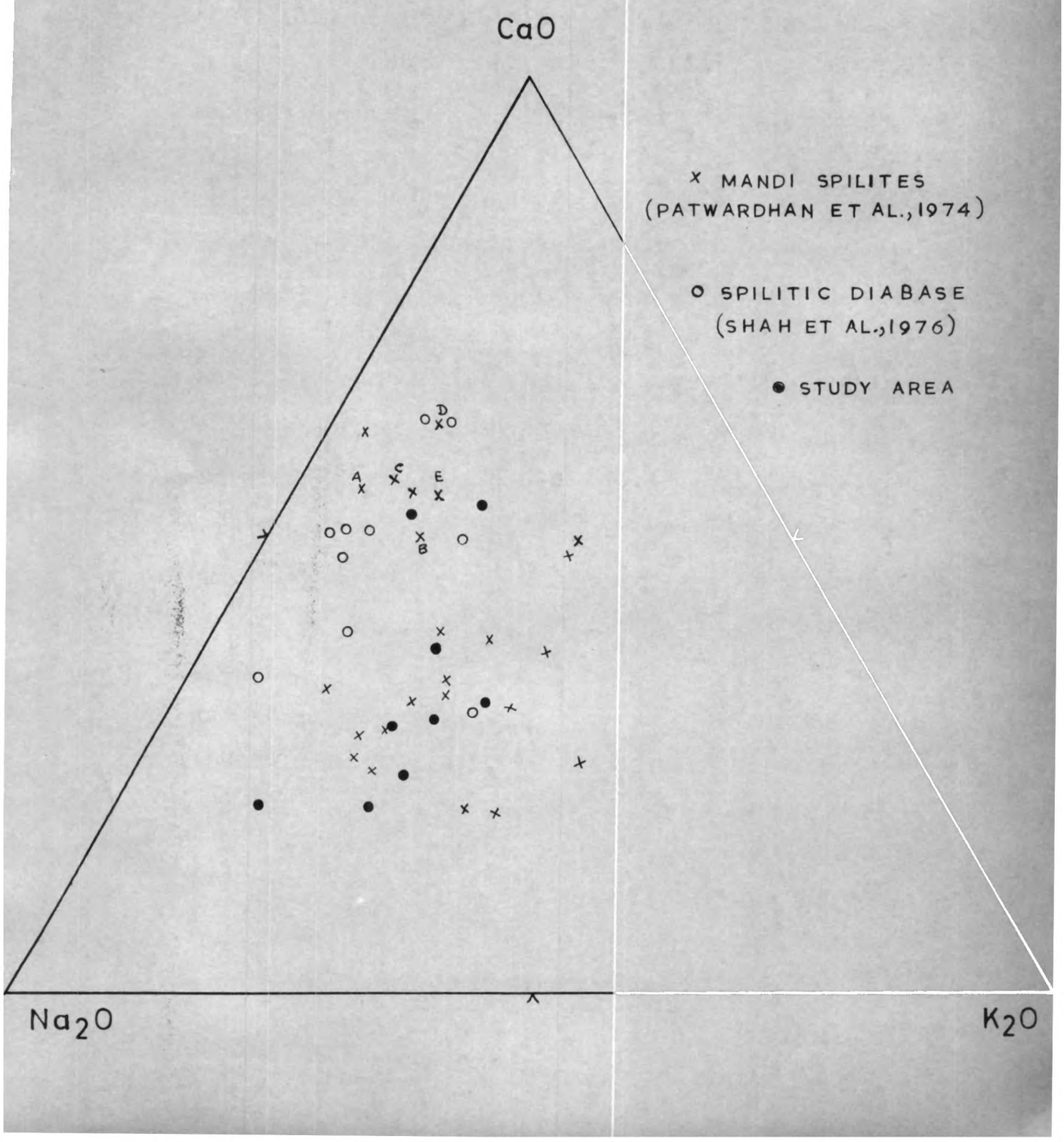
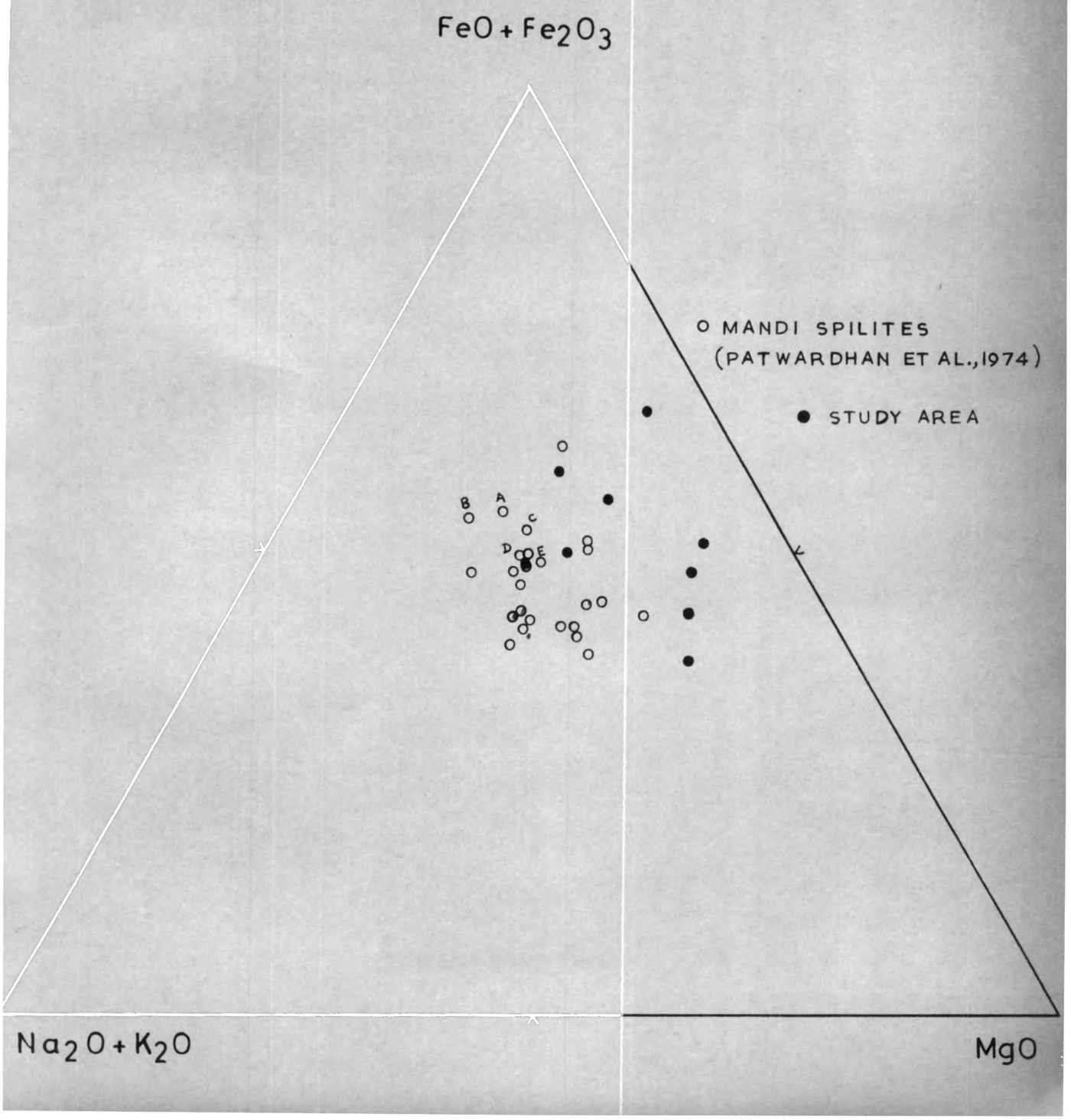


FIG. VIII. 2

CHEMICAL FIELD OF KALI GANDAKI SPILITES WITH RESPECT TO $FeO+Fe_2O_3-Na_2O+K_2O-MgO$ WT. PERCENT



(c) Diagrams based on

Mg - Fe - Al cations

Mg - Ca - Al cations

Ca - Fe - Al cations

The triangular diagrams (Fig. VIII.3,4,5) based on the above cations (Table VIII.6) which are computed from the cation values per 100 Oxygen anions (Table VIII.5), are compared with the plots of spilites from Bhowali-Bhimtal area (Shah & Merh, 1976). From the diagrams it is clear that these basic rocks of Kali Gandaki area are impoverished in CaO and contain slightly more proportion of MgO than the spilitic rocks of Bhowali - Bhimtal area. These differences are directly related with the mineralogical composition. As the rock is almost exclusively made up of chlorite and albite-oligoclase, the source for CaO is meagre, whereas MgO is higher due to presence of chlorite and other flaky minerals in abundance. The samples containing more of epidote and hornblende, show increase in CaO content.

Binary diagram

(a) Diagram based on SiO_2 vs. $(Na_2O + K_2O)$
(Kuno's diagram)

The weight percentages of the total alkalies and silica plotted on the diagram of Kuno (1959) indicate that

FIG. VIII. 3

CHEMICAL FIELD OF KALI GANDAKI SPILITES WITH RESPECT TO Mg — Fe — Al CATIONS

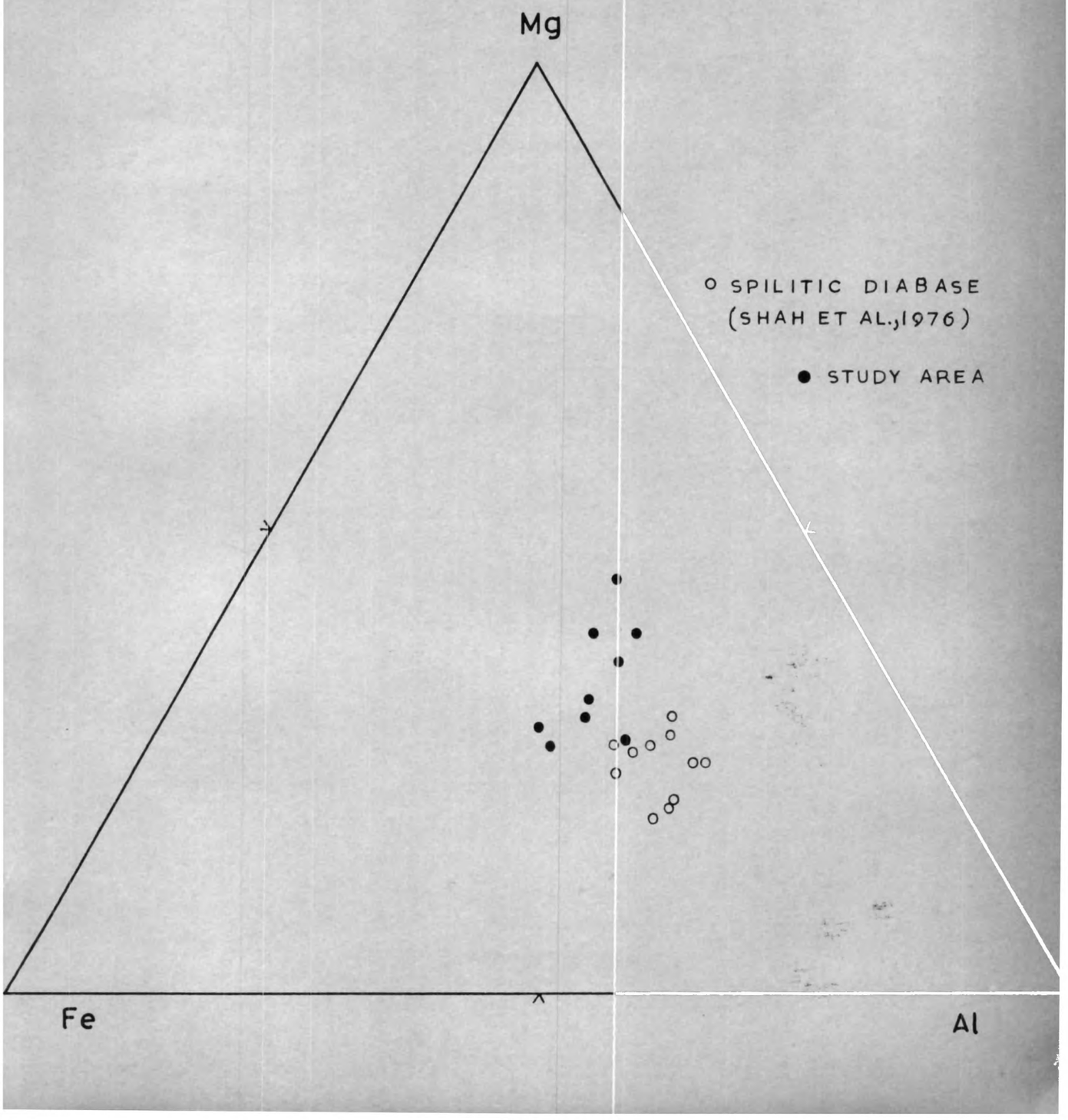


FIG. VIII. 4

CHEMICAL FIELD OF KALI GANDAKI SPILITES WITH RESPECT TO Mg – Ca – Al CATIONS

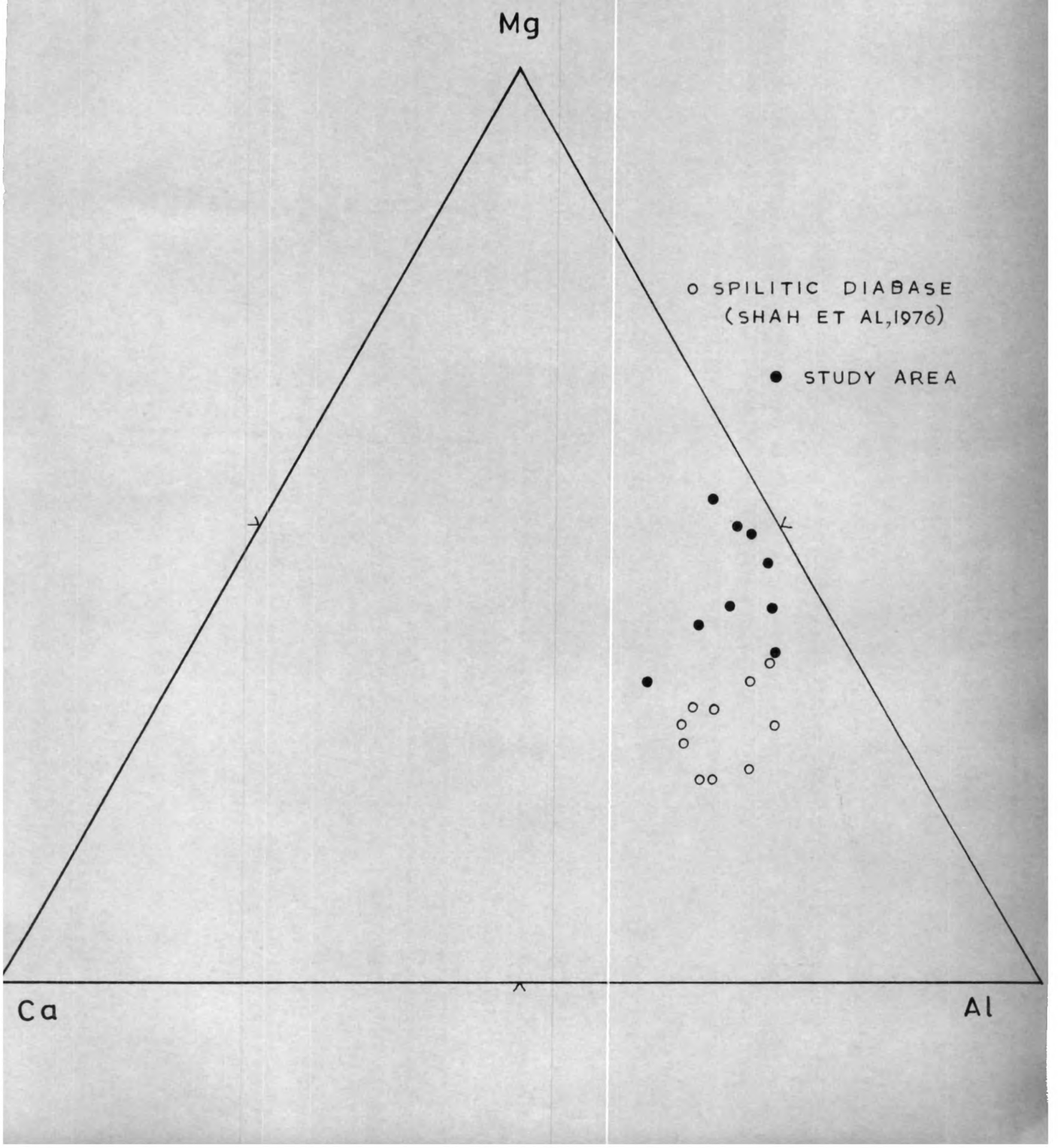


FIG. VIII. 5

CHEMICAL FIELD OF KALI GANDAKI SPILITES WITH RESPECT TO Ca — Fe — Al CATIONS

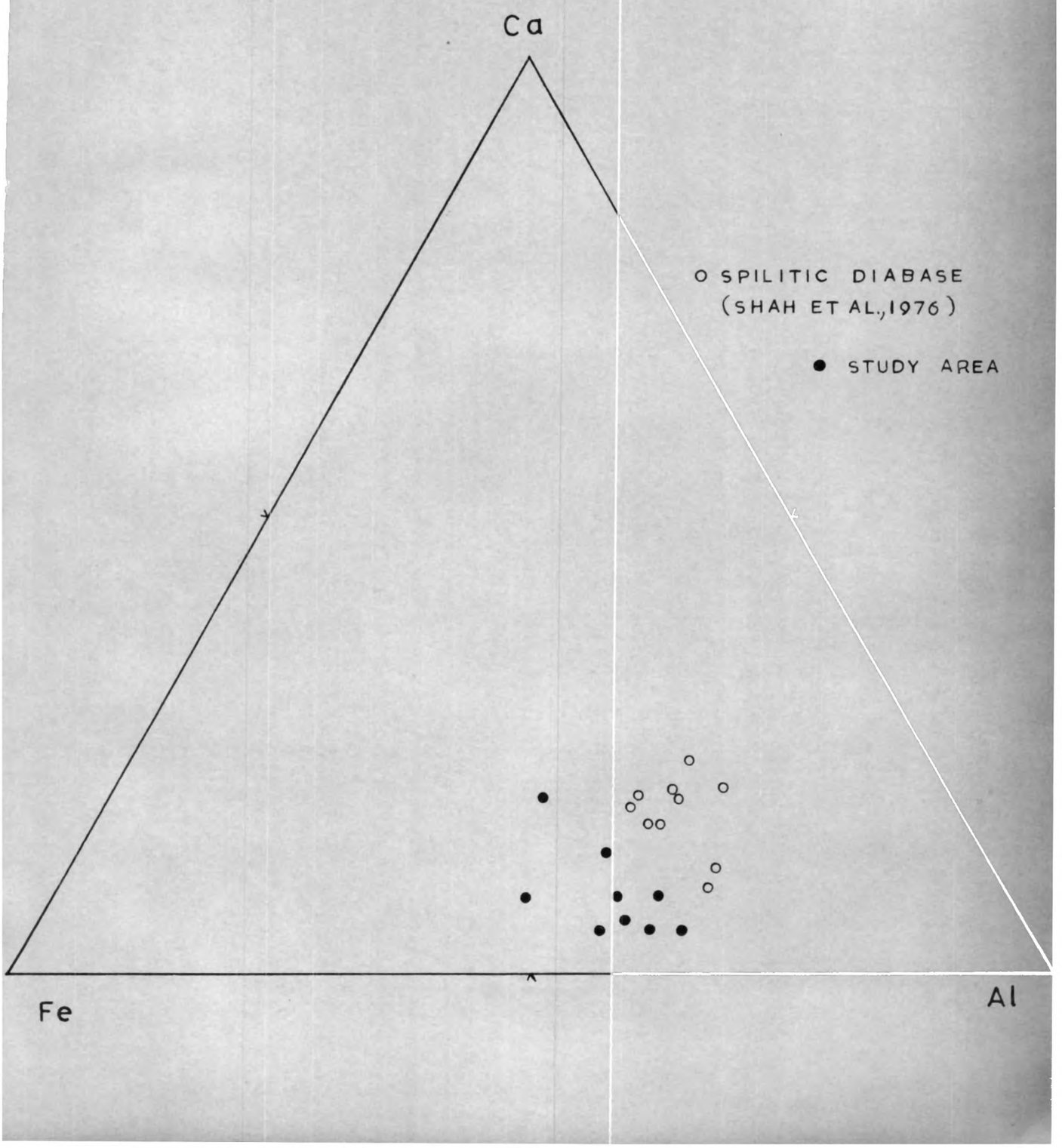


Table VIII.5 Cation values per 100 Oxygen anions

	333B	337A	337D	339	340A	911	927	1181	1206
Si	27.7	28.4	26.2	27.9	26.6	27.3	27.7	30.7	28.4
Al	10.1	8.5	10.3	10.2	9.8	8.7	9.5	8.7	9.3
Fe^{+++}	3.0	2.0	3.3	4.4	2.7	3.8	3.5	3.3	4.8
Fe^{++}	2.3	2.7	3.4	3.0	3.9	4.8	2.3	3.3	4.0
Ca	0.7	1.1	1.3	2.7	0.9	1.5	0.6	0.7	4.2
Mg	10.2	10.7	6.4	8.3	10.4	7.0	8.6	6.6	6.6
Na	2.6	2.9	6.1	5.1	2.5	1.8	1.3	3.6	3.9
K	0.9	1.9	1.9	1.8	0.8	0.4	0.7	0.5	1.7
Ti	0.7	0.9	0.6	0.6	1.0	0.9	0.6	0.7	0.7
Loss on ignition	17.4	18.1	21.9	11.9	18.8	20.8	22.3	13.6	6.3

Table VIII.6 Values of various cationic ratios for triangular diagrams

Sample No.	333B	337A	337D	339	340A	911	927	1181	1206
Mg	39	45	27	32	39	29	36	30	27
Fe(Total	21	20	28	29	25	35	24	30	35
Al	40	35	45	39	36	36	40	40	38
Mg	49	53	36	39	50	41	46	41	33
Ca	03	05	07	13	04	09	03	05	21
Al	48	42	57	48	46	50	51	54	46
Ca	04	08	07	13	05	08	04	04	19
Fe(Total)	33	33	37	36	38	46	36	41	39
Al	63	59	56	51	57	46	60	55	42

they show an overall richness in alkalies, and lie above the Kuno's line that demarcates the alkali basalt field from the tholeiitic basalt field (Fig. VIII.6). The samples of the study area fall within the alkali basalt field. It also compares well with the plots of spilites from Mandi trap (Patwardhan & Bhandari, 1974).

(b) Diagram based on K_2O vs. Na_2O

The plots of K_2O vs. Na_2O in a binary diagram (Fig. VIII.7) show that all the points lie above the 1 : 1 line showing the richness of Na_2O over K_2O, which is also one of the characteristic chemical behaviour of spilites. The Bhimtal - Bhowali spilites (Shah & Merh, 1976) also show similar nature.

DISCUSSION

Spilites are being reported from this part of Nepal for the first time. From Indian Himalaya, a number of occurrences of spilitic rocks has been described. Spilites have been studied from Darla (Pareek, 1973) and Mandi traps (Patwardhan et al., 1970 ; Patwardhan & Bhandari, 1974) of Simla Himalaya, both having been considered as Late Precambrian in age. In Kumaon, basic rocks of Bhimtal-Bhowali

FIG. VIII. 6

KUNO'S DIAGRAM SHOWING ALKALI BASALT FIELD OF KALI GANDAKI SPILITES

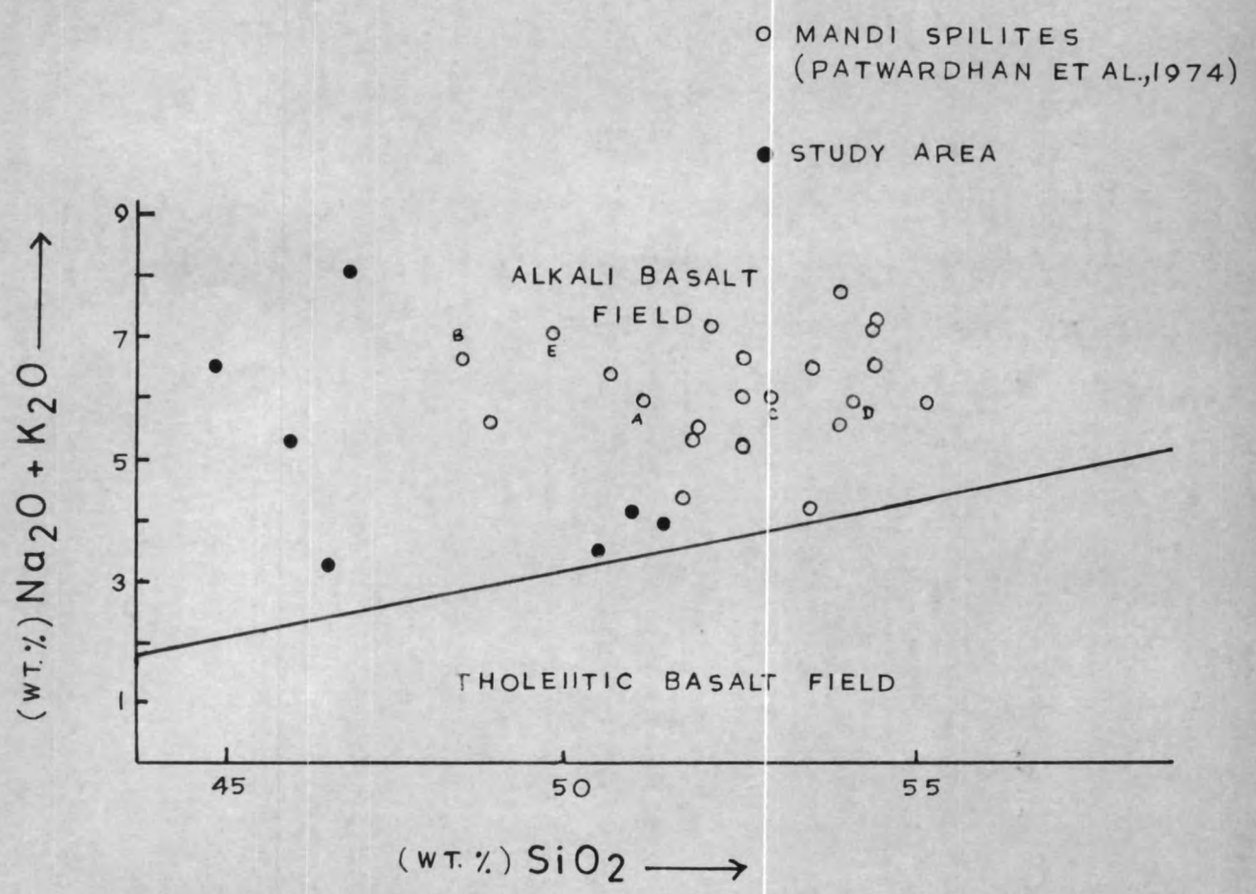
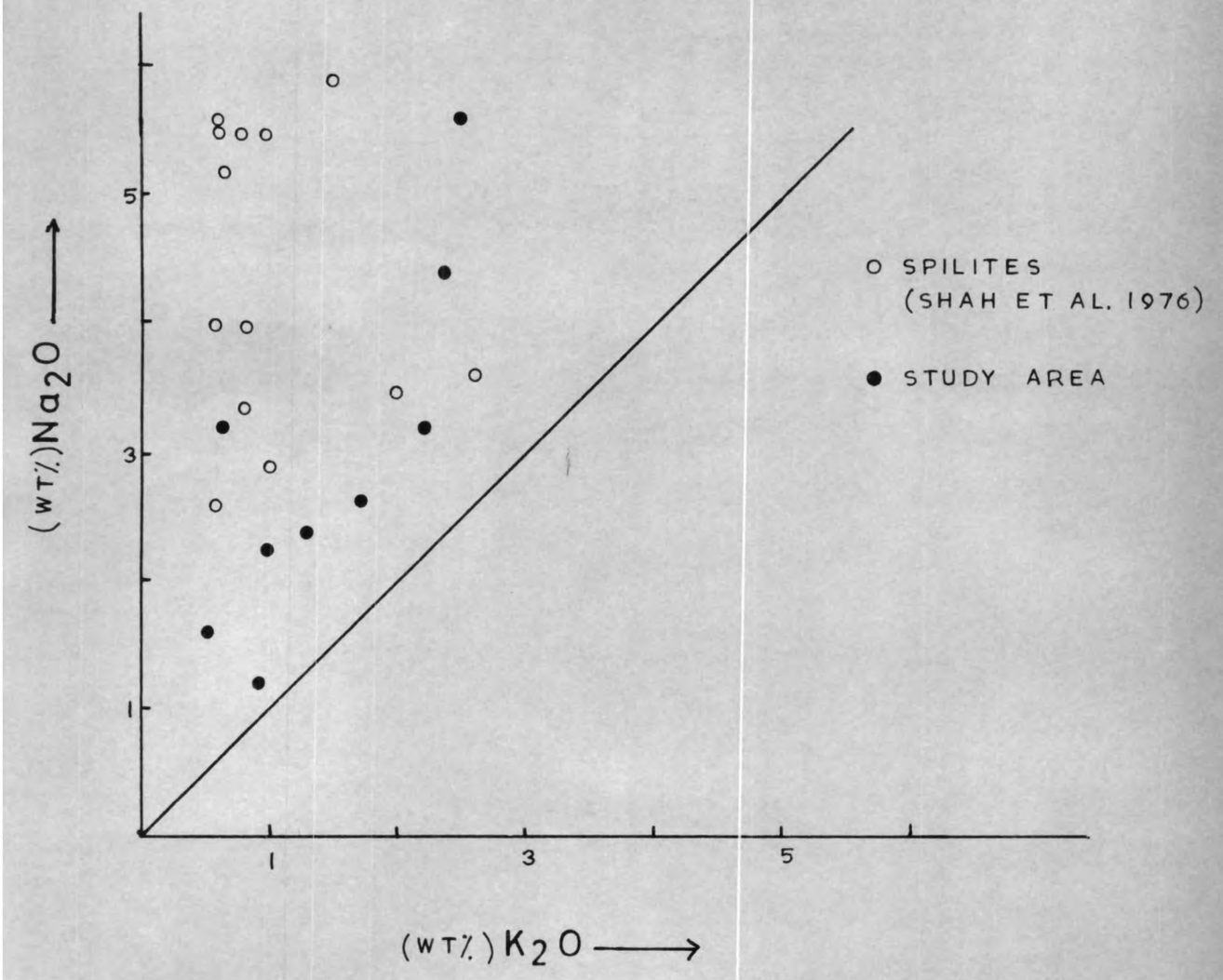


FIG. VIII. 7

RELATION BETWEEN K_2O AND Na_2O WT. PERCENT OF KALI GANDAKI SPILITES



and neighbouring areas have also been found to be spilitic in nature (Vardarajan, 1974 ; Diwakar Rao, 1974; Shah & Merh, 1976 ; Desai et al., 1976). According to Shah & Merh (1976) these spilites could be of Hercynian age.

The origin of spilites has been a subject of great controversy for long. Various modes of origin of these rocks have been proposed, viz., (i) Primary, autohydrothermal or autometamorphic, origin (ii) Secondary (diagenetic or metamorphic) origin. Equally strong arguments in favour of each of these modes of origin have been propounded. However, the present author does not like to go into details about the origin of the spilitic rocks of Kali Gandaki valley. But, some of the petrographic evidences outlined below do suggest that they are possibly of primary in origin.

(a) Complete absence of calcic plagioclase,

(b) Presence of relative freshness of albite-oligoclase,

(c) Inclusions of fine crystals of chlorite in albite-oligoclase,

(d) Plagioclase laths enclosed in larger calcite grains with sharp crystal faces, and

(e) Presence of primary igneous textures, viz., ophitic and intersertal textures.

So far as the spilites of the study area are concerned, they are considered to be of Precambrian age. Considering the position of stromatolitic dolomites, which stratigraphically overlie the quartzites in which these spilites occur (Kusma Quartzite and Balewa Formation), the age of the basic rocks may be taken as at least Late Precambrian. Although, little systematic geochronological work is done on these or similar rocks of Nepal, whatever scanty data is available, point to a Late Precambrian age of these spilites (819 ± 80 my - Krummenacher, 1966; 640 my - Talalov, 1972).

The spilitic rocks of Kali Gandaki valley, thus obviously represent the Pre-Himalayan submarine volcanism, that accompanied the shallow-water deposits along the northern fringe of the Indian shield, and heralded the deposition of a vast Late Precambrian sequence in this part of Nepal Himalaya. At this stage of investigation, however, the present author would only prefer to content himself merely by reporting the true nature and salient features of this interesting volcanic association and does not wish to delve into the more detailed aspects of these spilitic rocks.