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# OCCURRENCE OF VOLCANITES IN THE LOWER SIWALIK FORMATION, AN EVIDENCE OF LATE TERTIARY IGNEOUS ACTIVITY IN THE CENTRAL SIWALIK OF NEPAL.*

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## ABSTRACT

Small bodies of volcanite are recorded in the Lower Siwalik Formation in central Nepal. Petrological and geochemical studies of these rocks confirmed that they are basaltic in composition and possibly formed from the alkaline basaltic magma. Occurrence of these rocks within the Lower Siwalik Formation indicate a late Tertiary volcanic activity in this region.

## INTRODUCTION

Herail et al.(1986) have shown dolerite occurrence in Marin Khola section in their map and section but they did not give the supporting petrographical description of the rock in the text. Kaphle and Pant (1988)discovered a basic intrusive rock body in the Lower Siwalik formation exposed in Dawar Khola, Sindhuli district, Central Nepal. They described it as a basic rock body of doleritic nature. Further investigation by Kaphle and Einfalt (Unger et al. 1991) in the same region was able to trace two separate tabular, bedding concordant volcanic dyke like volcanite bodies (BV1 and BV2 in Fig.1). The occurrence of basalt in the Siwalik of Nepal seems to be a rare phenomena, although there are reports (Prashra, 1986) on the occurrence of basic rocks in the Lesser Himalâya of Himanchal Pradesh. According to him those basic rocks are also of alkaline basalt, however their age is comparatively older than volcanite.

## GENERAL GEOLOGY

The investigated area is a part of Sub- Himalaya (Siwalik Range). It is represented by thick sequence of cyclic deposited fluviatile mollase sediments of Mid- Miocene to Lower Pleistocene age. These ensembles of rocks in Chure range (Siwalik Range) is known as Siwalik Group. This group is mainly composed of shale, claystone,, mudstone, siltstone, sandstone and conglomerate. At few places marl beds and lignite layers and lenses are also recorded. Plant as well as invertebrate and vertebrate fossils and colified plant remains are commonly seen in the Siwalik rocks. Towards north this group is separated from the Lesser Himalayan lowgrade metamorphic rocks by a prominent linear structure known as Main Boundary Thrust (MBT) and towards south there is Indogangetic plane. On the basis of lithology, texture and fossil remains this group is divided into Lower, Middle and Upper Siwalik Formations, however, the passage of one into another is gradational.

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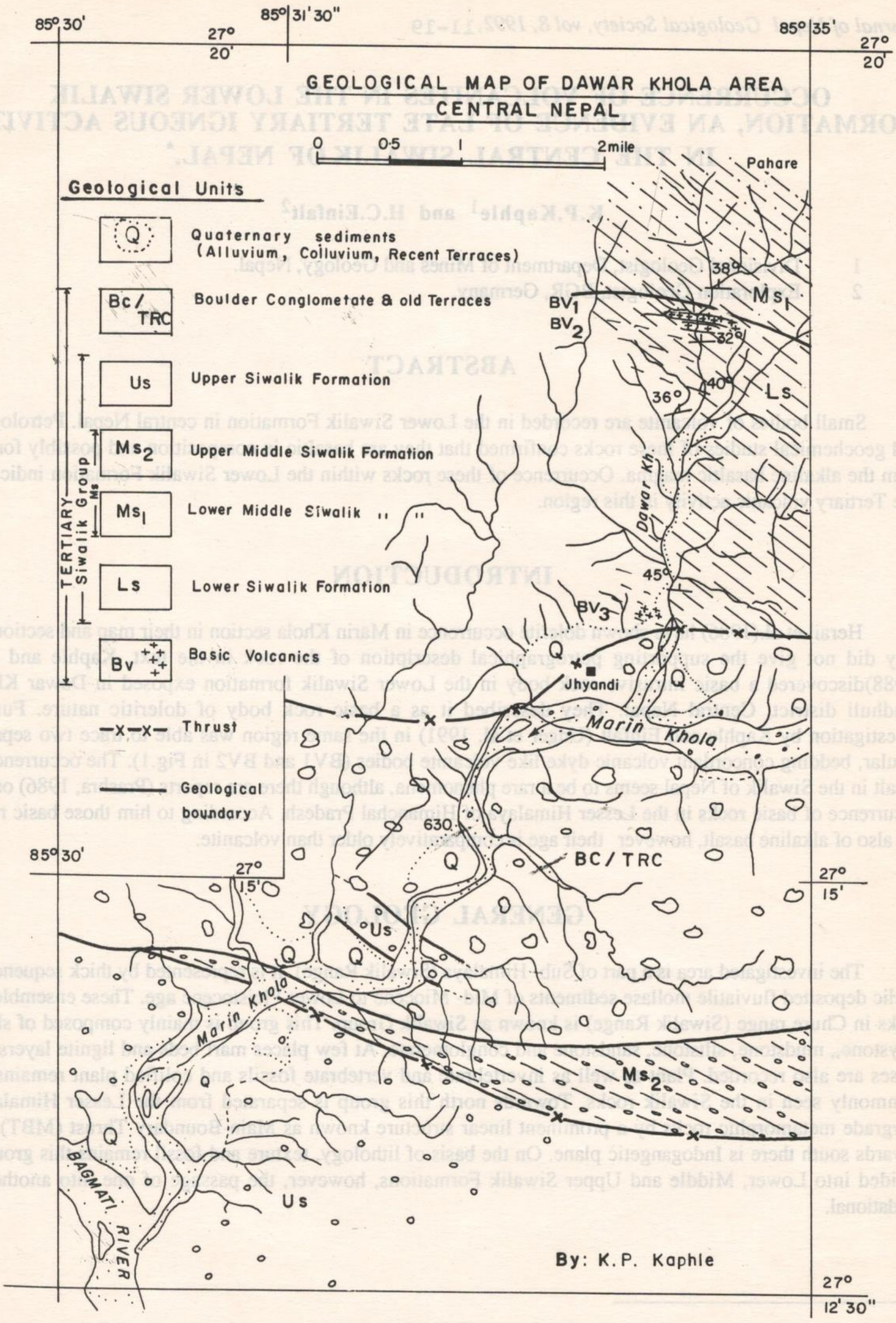


Fig.1 Geological Map of Dawar Khola area, Central Nepal.

In presently investigated Dawar Khola section 3 volcanite bodies BV1, BV2 and BV3 were recorded within the Lower Siwalik Formation (Fig.1). BV3 is a very small deeply weathered volcanite body exposed on the northern slope along the foot track from near to the mouth of Dawar Khola to Jhyandi (Dawar) village. Volcanite bodies BV1 and BV2 occur towards northern part of the investigated area (Fig.1) and they are well exposed in Dawar Khola section. These two bodies are separated by 30m thick sandstone of Lower Siwalik Formation (Fig.2). The lower (southern) body BV2 and upper (northern) body BV1 are about 15m and 80m thick respectively. The lateral extension of these volcanite bodies is not known, however, presence of very few small boulders and pebbles of volcanite in the close by small eastern tributary of Dawar Khola indicates at least 400 to 500m eastward extension. However, it has yet to be confirmed.

## VOLCANITE

In hand specimen it is a fine to medium grained, dark greenish gray to reddish brownish gray coloured basaltic rock (Fig.3). The rock chiefly consists of mm size dark greenish gray (blackish) pyroxene, light grey plagioclase and volcanic glassy matrix with some secondary filling materials (carbonate and chlorite). Large green patches are vesicles filled with radiating aggregates of chlorite. Abundant inclusions of angular rock fragments (xenoliths) of hematitic shale and siltstone are common (Fig.3a). They were possibly engulfed during volcanic activity. Quartz veins are rare, however, very thin carbonate veins are observed.

Under the microscope it is a fine to medium grained rock with subophitic to intergranular texture. It consists of xenomorphic to hypidiomorphic phenocryst of pyroxene (augite), laths of weakly zoned plagioclase (andesine to labradorite) and altered glassy matrix. Vesicles are filled rhythmically with a rim of chlorite and carbonate (calcite) at the centre. In some thin sections small quartz aggregates are also recorded in vesicles. Glassy matrix on alteration give rise to secondary clay minerals (smectite). In most of the samples there is rather high amount of altered glassy matrix (upto 50% by volume) consisting of fine grained vividly greenish minerals (smectite) together with some opaque ore minerals and some unidentified alteration products. Abundant patches of carbonate often with smectite are visible. No free olivine is visible in thin sections. Magnetite, rutile, ilmenite, sulphide ore and sphene occur as accessory minerals. Inclusions of rock fragments like hematitic shale and silty sandstone are common. The strong reddish brown colour of matrix is due to oxidation during cooling of melt (basaltic magma).

Altogether 14 rock samples from these two volcanite bodies were collected for laboratory studies. Out of these only 4 representative samples were analysed for major and trace elements. The chemical composition of this volcanite is basaltic. It is low in $SiO_2$, CaO, $K_2O$ and slightly enriched in $Na_2O$ (Table 1, except in sample V12). FeO : MgO ratio is almost 1:1. As compared to the normal basalt it consists of almost equal amount of $SiO_2$, FeO, MnO, MgO, $TiO_2$ but remains slightly low in CaO, $K_2O$, $Al_2O_3$ and $P_2O_5$ and high in $Na_2O$ (Table.2, Fig.4). It is also slightly rich in Ba, Cr, Ni, Sr and V (Table.1). Plot of chemical data on Le Maitres (1984) classification diagram ($Na_2O + K_2O$) vs $SiO_2$ diagram, (Fig.5) shows that it is a basalt with a tendency to basaltic andesite and Hawaiite. The CIPW norm calculation of the 4 volcanite samples (Table.3) shows two samples (V3 and V14) to be silica under saturated with an amount of >10% normative olivine (Fo and Fy combined) where as the other two samples (V7 and V12) are quartz normative.

Accordingly the volcanite is an olivine tholeiite basalt to quartz tholeiitic basalt. Plot of chemical data on AFM triangular diagram (Fig.6) show that the points scatter around the alkaline trend indicating an alkaline affiliation.

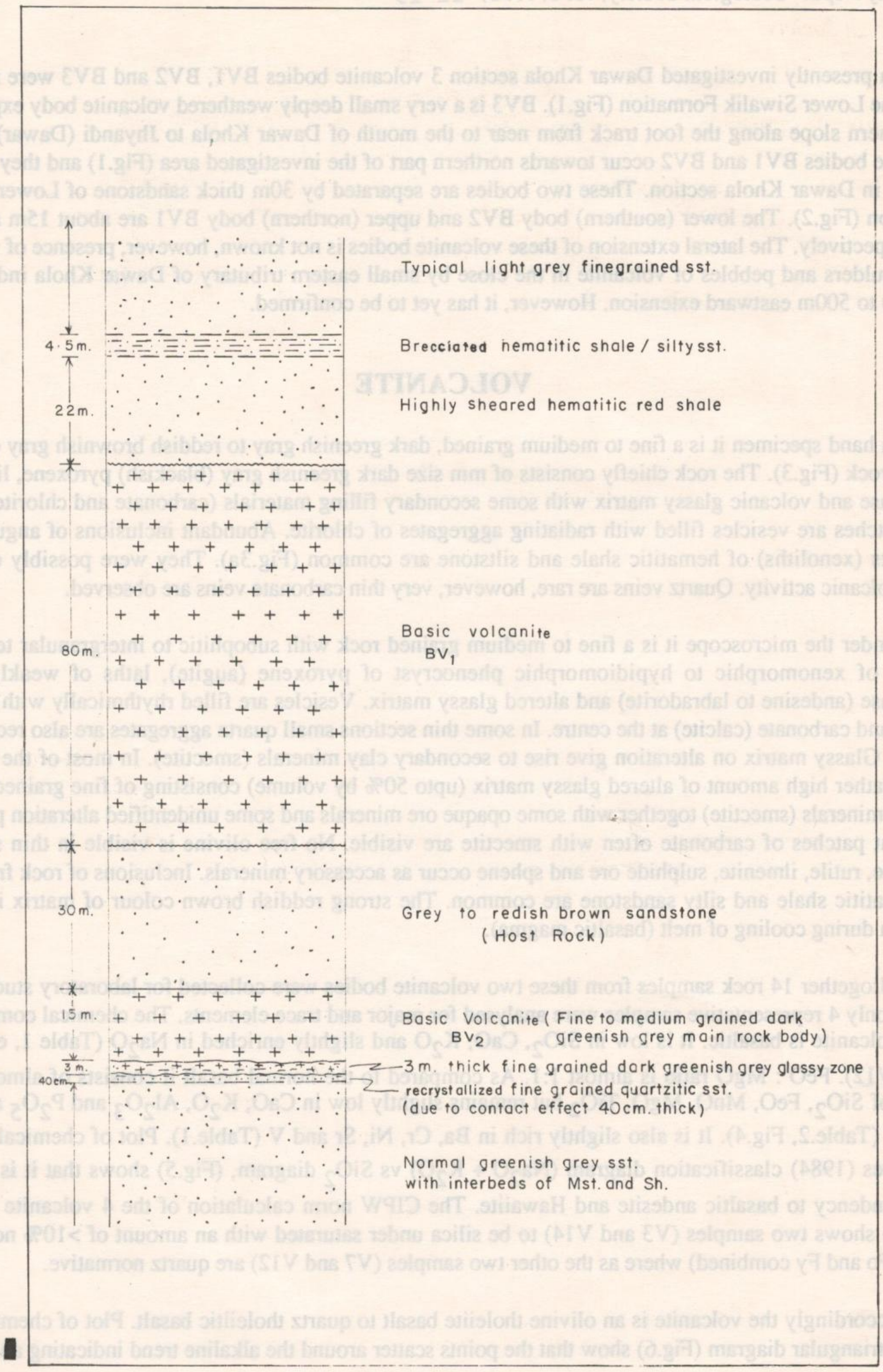


Fig.2 Columnar (vertical) section through the Volcanite bodies in Dawar Khola.


Fig.3 Contact of lower volcanite body BV2 (dark coloured left side) against partially sheared gray sandstone.

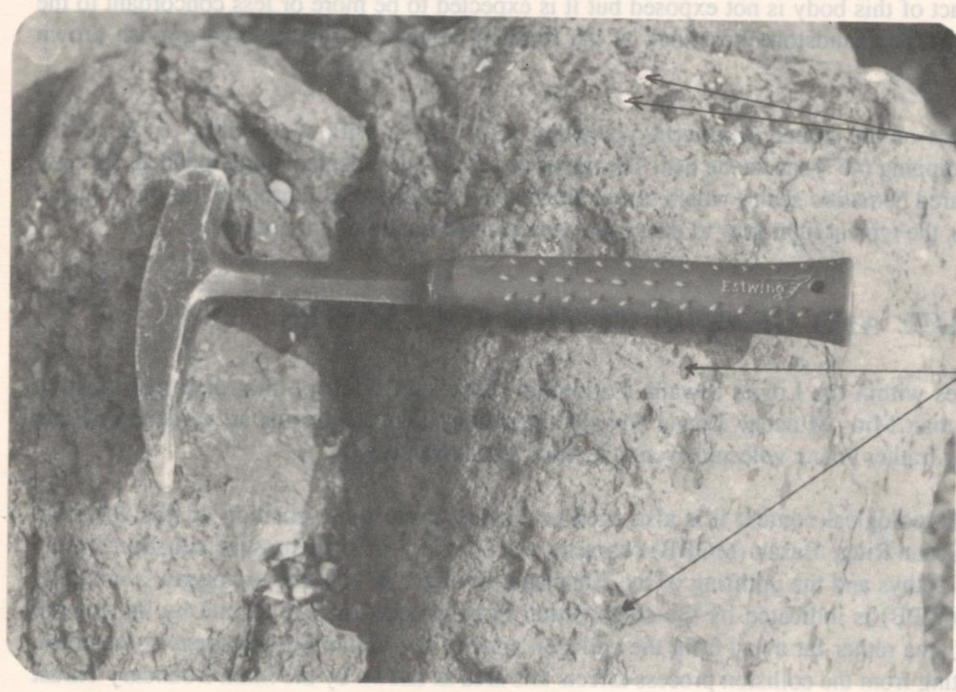


Fig.3(A) Xenoliths of red hematitic shale and carbonate filled vesicles in the upper part of upper volcanite body BV3.

## HOST ROCK

In this area the host rock is represented by repeated north dipping ($30^{o}$ - $45^{o}$) sequence of medium to fine grained gray to light gray sandstone grading upward into siltstone, mudstone and shale successively. These rocks belong to the Lower Siwalik Formation. The sandstone is locally calcareous and light gray to greenish gray and brownish gray in colour. Interbeds or layers of purple, green, and chocolate brown or brownish gray (at places hematitic) mudstone and shale are quite common. Individual sandstone bed ranges in thickness from <50 cm to 15m and shale/ mudstone ranges from few cm to 3m and rarely upto 10m. Plant fossils (leaves and stems) are occasionally seen in gray to dark gray shale beds.

Thin section study of sandstone samples from close to the contact with the volcanite revealed that it consists of dominantly quartz, plagioclase, microcline feldspar and few white mica (muscovite) flakes and disperse carbonate grains. Unidentified clay is the cementing material. In rare amount very fine tourmaline grains are also recorded. The contact metamorphic effects have been observed at the lower contact of BV2 where the sandstone adjacent to the volcanite is strongly recrystallized and some chlorite is developed from the clayey cement of the sandstone further away from the contact in about 2 m wide zone Other metamorphic effects are not displayed because of the unfavourable composition of the sandstone for metamorphic reactions.

## CONTACT RELATIONS

The lower contact of lower (southern) volcanite body $BV_2$ is almost parallel to the host rock (Fig.3). Right at the contact there exists a 2 to 4m thick fine grained dark greenish to nearly black fine grained (glassy) zone and followed by medium grained dark gray main rock body with phenocryst of mafic minerals (pyroxene) whereas the upper contact of this body is not exposed but it is expected to be more or less concordant to the bedding of the host rock. The sandstone host rock at the footwall contact is fine grained grayish brown sandstone.

The lower contact of the upper (northern) volcanite body (BV1) with the country rock is also concordant to the north dipping ($45^{0}$) sandstone bed. The upper contact borders against thinly bedded, strongly purplish redbrown coloured hematitic shales which shows small scale folding related probably to the volcanic events. Further up comes the typical light gray to dirtywhite fine grained quartzitic sandstone.

## AGE AND GENESIS OF THE VOLCANITES

Occurrence of volcanites within the Lower Siwalik Formation (host rock) indicate that their age must be equivalent or younger than Mid- Miocene Lower Siwalik Formation. This indicates an evidence of late Tertiary volcanic activity (rather young volcanic events) in Sub- Himalayan region.

From the general geological context it is also tried to deduce the tectonic position of this volcanite (basaltic rock). A Mid Ocean Ridge Basalt (MORB) character can be ruled out since no such situation existed since the closure of the Tethys and the uplifting of the Himalaya. Similarly a volcanic arc origin is unlikely. A Within Plate Basalt (WPB) is indicated by the composition of this rock (Fig.7 & 8) and by its tectonic situation in an platform area rather far away from the collision zone of the Indian Subcontinent in the north, though southward thrusting from the collision process affects this area as shown by the Main Boundary Thrust (MBT) and some supposed larger thrust in the Siwaliks, resulting in a repetition of the sedimentary sequence of the Siwaliks.

Table 1 Major and trace elements in volcanite.

| S.No | $SI_2O_3$ | $Al_2O_3$ | $Fe_2O_3$ | FeO | MnO | MgO | CaO | $Na_2O$ | $K_2O$ | $TiO_2$ | $P_2O_5$ | LOI % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| V3 | 49.18 | 14.6 | 3.83 | 7.32 | 0.24 | 7.78 | 4.84 | 5.03 | 0.18 | 1.79 | 0.17 | 3.56 |
| V7 | 49.94 | 13.41 | 6.04 | 6.96 | 0.15 | 6.01 | 5.91 | 3.34 | 1.14 | 2.09 | 0.18 | 4.1 |
| V12 | 50.04 | 14.39 | 4.82 | 7.31 | 0.16 | 6.51 | 9.79 | 1.98 | 0.62 | 1.64 | 0.15 | 1.38 |
| V14 | 49.19 | 14.35 | 5.72 | 7.15 | 0.2 | 7.54 | 4.48 | 3.91 | 1.54 | 2.22 | 0.18 | 3.64 |
| Avg. | 49.59 | 14.19 | 5.10 | 7.18 | 0.19 | 6.97 | 6.26 | 3.57 | 0.87 | 1.935 | 0.17 | 3.17 |

| | Ba | Ce | Cr | La | Nb | Ni | Pb | Rb | Sr | V | Y | Zr | (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| V3 | 110 | 43 | 267 | 7 | 15 | 126 | 2 | 5 | 79 | 269 | 17 | 141 | |
| V7 | 309 | 67 | 66 | 4 | 12 | 61 | 7 | 33 | 149 | 315 | 31 | 141 | |
| V12 | 180 | 61 | 156 | 11 | 9 | 73 | 5 | 17 | 236 | 289 | 28 | 119 | |
| V14 | 343 | 76 | 69 | 18 | 12 | 60 | 12 | 40 | 94 | 374 | 28 | 138 | |
| Avg. | 236 | 62 | 140 | 10 | 12 | 80 | 7 | 24 | 140 | 312 | 26 | 136 | |

Table 2 Comparison of volcanite, Normal Basalt* and Hawaiite** (Avg. Values)

| Rock type | $SIO_2$ | $Al_2O_3$ | $Fe_2O_3$ | FeO | MnO | MgO | CaO | $Na_2O$ | $K_2O$ | $TiO_2$ | $P_2O_5$ | LOI % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Volcanite | 49.59 | 14.19 | 5.1 | 7.18 | 0.19 | 6.97 | 6.26 | 3.57 | 0.87 | 1.93 | 0.17 | 3.17 |
| N.Basalt* | 49.2 | 15.74 | 3.79 | 7.13 | 0.2 | 6.73 | 9.47 | 2.91 | 1.1 | 1.34 | 0.35 | 1.49 |
| Hawaiite** | 47.48 | 15.74 | 4.94 | 7.36 | 0.19 | 5.58 | 7.91 | 3.97 | 1.53 | 3.23 | 0.74 | 1.38 |

Data for normal basalt* and Hawaiite** are taken from text book "Igneous and metamorphic petrology"by M.G.Best.

Table 3 CIPW norm calculation of volcanite samples from Dawar Khola (No calcite (cc) calculation is made since no data on CO2 are available)

| Sample No-<br>Normative minerals | V3 | V7 | V12 | V14 |
|---|---|---|---|---|
| Cc | - | - | - | - |
| Ap | 0.39 | 0.42 | 0.35 | 0.42 |
| Ilm | 3.40 | 3.97 | 3.11 | 4.22 |
| Or | 1.06 | 6.74 | 3.66 | 9.10 |
| Ab | 42.56 | 28.26 | 16.75 | 33.09 |
| An | 16.73 | 18.23 | 28.55 | 17.06 |
| Mt | 5.55 | 8.76 | 6.99 | 1.87 |
| Wo | 2.58 | 4.14 | 7.95 | 1.67 |
| En | 1.71 | 2.90 | 5.17 | 0.90 |
| Fs | 0.68 | 0.89 | 2.24 | 0.71 |
| En" | 6.26 | 12.07 | 11.05 | 6.08 |
| Fs" | 2.51 | 3.72 | 4.78 | 4.78 |
| Fo | 8.00 | - | - | 8.27 |
| Fa | 3.53 | - | - | 7.17 |
| Qz | - | 5.08 | 6.81 | - |

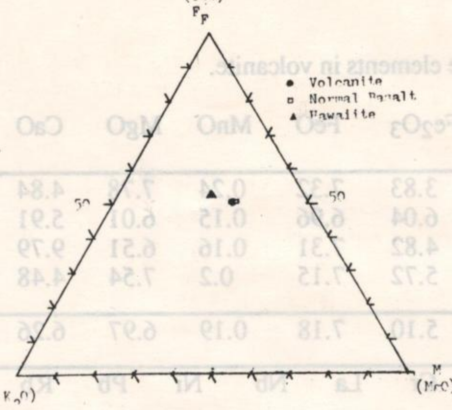


Fig.4 Plot of chemical data of three different volcanic rocks in FAM triangular diagram. The volcanite falls very close to the normal basalt.

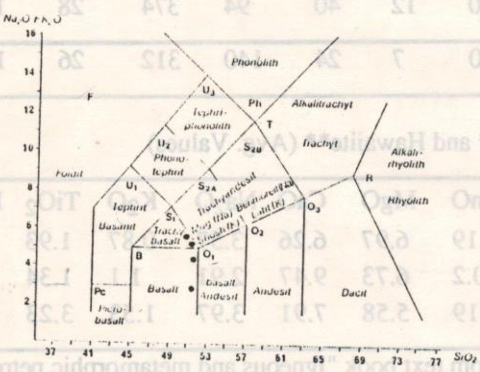


Fig.5 Division of volcanic rocks according to Le Maitre (1984). (The four analyses of table.1 are plotted after recalculation to 10t/% on a LOI free basis. Element concentrations are in weight %)

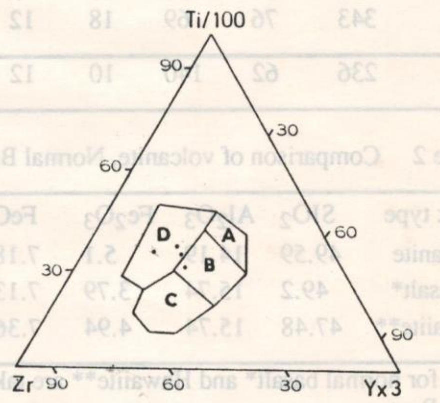


Fig.7 Zr - Ti - Y discrimination diagram after Pearce & Cann (1973).
A: Low K tholeiites; B: Ocean floor basalts. C: Calc. alkali basalts, D: Within Plate Basalts. (sample points of volcanite from Dawar Khola).

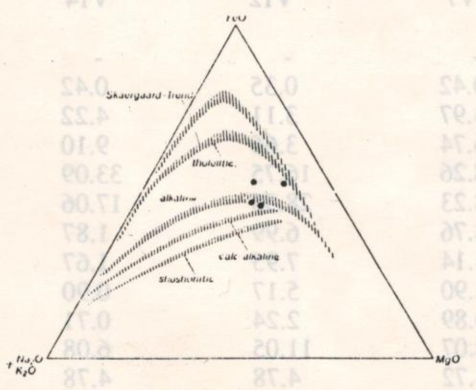


Fig.6 Trend of differentiation of various magmatic series in the (Na2O + K2O) - FeO - MgO diagram. Samples of Table 1 scatter around the alkaline trend.

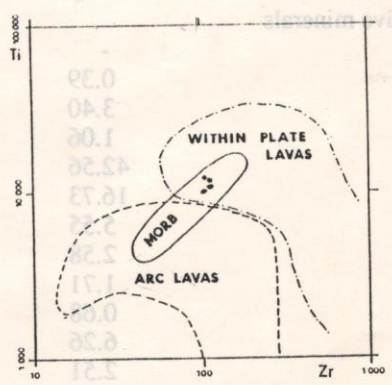


Fig.8 Ti - Zr diagram after Pearce (1982) with plot of the four volcanite samples from Dawar Khola. (Element concentration in ppm).

Plot of trace elements Zr, Ti, Y data on Zr - Ti - Y*3 diagram of Pearce and Cann, (1973) shows that they (except sample no V12) fall within the Within Plate Basalt field (Fig.7). Similarly in Ti - Zr diagram of Pearce (1982) they fall in the area where MORB and WPB overlap (Fig.8).

Somewhat contradictory to an within plate situation is the fact, that usually a dilatation tectonic like incipient rifting is the reason for within plate basalt generation, whereas in this area compressive tectonic still seems to prevail due to the continuing collision process.

## CONCLUSION

From mineralogical observation and chemical composition and comparison with normal basalt and Hawaiite it is concluded that it is a basalt possibly formed from the alkaline basaltic magma.

Its age is younger than Mid- Miocene host rock (Lower Siwalik Formation).

From the tectonic position of this rock it appears to be a within Plate Basalt.

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