INTRODUCTION

The deposition of Fenestella-shale beds in the Upper-Middle Carboniferous period in northwestern end of the Himalayan chain and the northeastern parts of Hazara was followed by a period of great vulcanicity whereby an enormous volume of pyroclastic and liquid products were spread over a vast expanse of Kashmir. The activity continued unabated through whole of the Permian period, after which it diminished greatly, although it persisted locally at a few places upto the Upper Triassic period.

The manifestation of this igneous activity is seen in the form of a thick volcanic formation, the "Panjal Volcanic Series" which constitute the lower pyroclastic portion, called the Agglomeratic slate, and the upper bedded flows, the Panjal Traps (Middlemiss, 1910). The whole thickness of the Panjal Volcanic Series reached to a maximum of 2,100 meters, of course locally, in Uri district (Krishnan, 1968).

Though constituting a fairly large portion of the stratigraphic column of Kashmir, the Panjal Volcanic Series did not attract much attention of the geologists. The work carried out on these rocks is largely confined to discussions on the age of this series and to resolve the igneous versus

glacial origin of the Agglomeratic slate (Middlemiss, 1910; Wadia, 1934; Ganju and Srivastava, 1961; Srikantia, 1973; Gupta, 1975). Bion (1928) and Reed (1932) compiled a large data on the fossil assemblage found at certain localities in the Agglomeratic Slate. A few reports on the petrology of the Panjal Traps were also published (Middlemiss, 1910; Wadia, 1934; Ganju, 1943; Ganju and Rajnath, 1969; Wakhloo, 1969; Singh et al., 1976). However, in recent years, cursory attempts towards the geochemistry of the Panjal Traps were made by a few workers.

Purpose and Scope of the Present Study

Whatever little is known about the geochemistry of the Panjal Traps is based on the results of a few analyses carried out on these rocks by Nakazawa and Kapoor (1973) and Pareek (1976). No systematic investigation of these rocks from base to top involving the changes in the mineral phases, the variation in major and trace element chemistry, the nature of lava, and the attendant physico-chemical conditions, was carried out. The present investigation based on the petrology and geochemistry of these rocks is an attempt to resolve some of the above mentioned problems.

The Panjal Traps occupy the critical position on the northern boundary of the Indian plate. The geochemistry of these rocks may prove helpful in resolving many tectonic problems like the depth of magma generation, environment and

tectonic set-up of lava eruption in this part of Himalaya during Permo-Carboniferous period.

Geography

Lidderwat area, situated in the Anantnag district, Jammu and Kashmir, about 120 km from Srinagar, lies in the intervening synclinal trough between the southeast pitching Basmai anticline in the north, and northwest pitching Eishmuquam or Lidder anticline in the south. The name "Lidderwat" is derived from the river Lidder whose western tributary, flowing from Tar Sar lake, disects this region and joins Kolshai Nala (stream) at this point. The entire area falls within 43 N/4 and 43 N/8 topographic sheets of the survey of India. The area is encompassed by latitudes 34°7'N to 34°12'N and longitudes 75°11'E to 75°15'E. Mount Kayol in Lidderwat, selected for detailed study of the Panjal Traps, is situated near Public Works Department Rest House on the left bank of West Lidder river. Figure 1 shows the location of the area studied.

The relief of the area is high. The lowest elevation in the area is 2,729 m above sea level. Mount Kayol rises to a height of 3,759 m. The highest elevation in the region forms the Kolahai peak which is 5,425 m high. The Tar Sar lake to the southwest of Lidderwat is situated at 3,795 m.

Lidderwat is accessible during dry seasons by a jeepable road from Pahalgam upto Aru, and afterwards there is

GEOLOGICAL MAP OF THE LIDDERWAT AND SURROUNDING AREAS SHOWING LOCATION OF MOUNT KAYOL

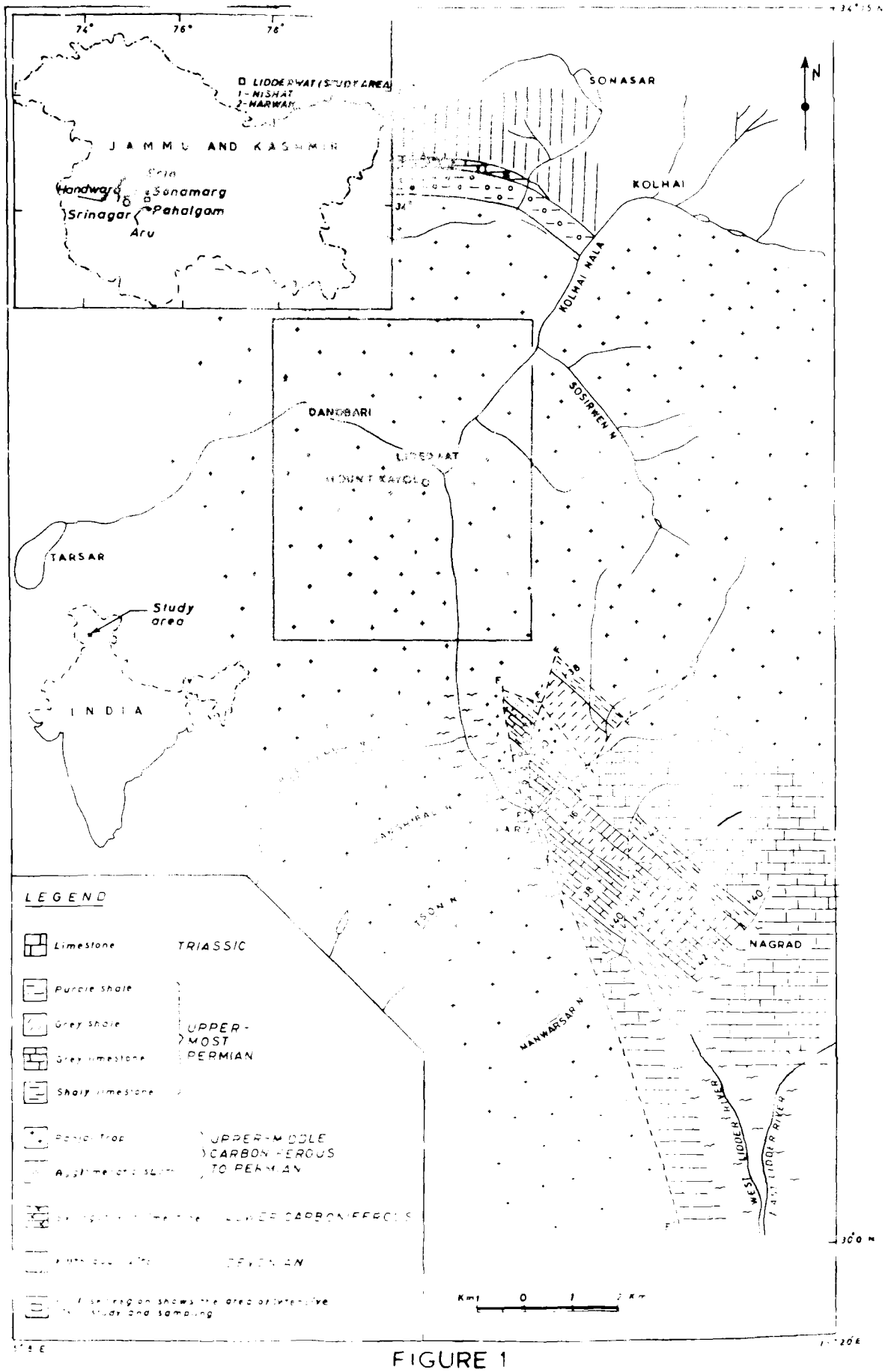

FIGURE 1

a hilly tract to Lidderwat. The whole region is covered by a fairly dense pine forest which, along with Pleistocene glacial deposits, cover the basal flows of the Panjal Traps along the stream valleys. About half of the thickness of the Panjal Traps on Mount Kayol is soil covered but stream cuts have exposed the flows at some places. The upper flows are devoid of any soil cover and vegetation; the various flows showing prominent bedded character are well exposed on the steep cliff. However, on the surrounding hills, the Panjal Traps do not exhibit a clear bedded character.

Geological Setting

The significant feature of the geology of Lidder Valley is the exposure of the complete sequence of Paleozoic rocks within a small area which prompted many early workers to a detailed investigation of this part of Kashmir. Lydekker (1883), Middlemiss (1909, 1910), Bion (1928), Dienner (1928), Reed (1932), Wadia (1934), and De Terra (1939) are among the pioneer geologists who mapped this area and discussed the lithology, paleontology, and structural features of the various formations. Middlemiss, Read, and Rion compiled a comprehensive data on the fauna of this region, especially that of Carboniferous formations. The geological succession of the various formations in the area is given in Table I.

The whole Paleozoic formation is exposed in the denudated anticlinal flexure of Lidder Valley; the Cambrian and Ordovician,

TABLE I. Age relationship of various rock formations in Lidder Valley.

Era	Period		Formation
Mesozoic	Triassic		Limestone
Paleozoic	Permian	Upper-most	Grey and purple shale
		Part of Upper Middle Lower	Panjal Trap
	Carboniferous	Upper Upper-Middle	Agglomeratic slate
		Lower-Middle	Fenestella shale
		Lower	Syringothyris-limestone
	Devonian		Muth-quartzite

lying in the central part of this anticline, are flanked successively by thinner bands of younger formations of Silurian, Devonian, and Carboniferous age. A similar section is exposed in the Basmai anticline of Sind Valley between Sonamarg and Kolahai towards north of this area.

Lidderwat area is dominantly composed of the Panjal Traps. Towards Pahalgam town, younger formations of Upper Permain and Triassic periods are encountered, whereas older formations are exposed towards northeast near Satlanjan and Kolahai. The dip of the lava beds on Mount Kayol is 10° towards southwest; basal beds are exposed towards northeast of this area.

The age of the Panjal Volcanic Series is defined both at the base and at the top by intercalations of fossiliferous beds of known ages. The earliest manifestation of activity seem to be of Middle to Upper Carboniferous age, i.e., as early as later part of Moscovian, in the Lidder Valley and Upper Carboniferous near Nagmarg. Though Agglomeratic slate is generally unfossiliferous throughout, at certain localities, several forms have been discovered (Bion, 1928; Reed, 1932) which are identical to the forms found in Fenestella-shale. The most common fossils are Productus, Spirifer, Chonets, Eurydesma, Aviculopecten, Fenestella, and Euphemus. The end of this igneous activity is more variable in age. In Khunmu the eruptions died out with Lower Permian, in the Lidder Valley

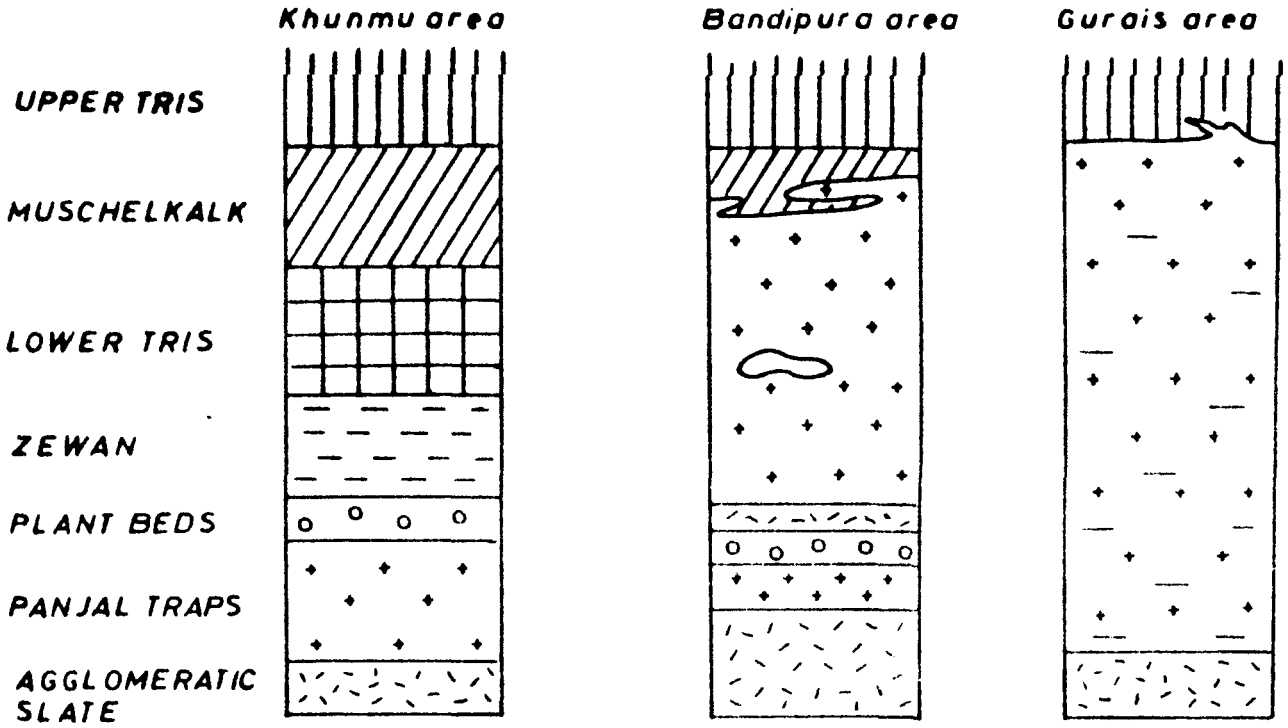

Figure. 2 Showing the variability of the Panjal Trap activity through geological ages in different regions of Kashmir (after Wadia, 1934, Fig. 3, p. 158)

with the end of Permian, while in Gurez the eruptions did not end till the Upper Triassic (Wadia, 1934). This variability of the Panjal volcanic activity through various geological ages has been graphically illustrated by Wadia (1934) as shown in Figure 2.

Field Mapping

Field work for this investigation was carried out during the summers of 1975, 1976 and 1977. An area of 750 square kilometers covering Aru, Lidderwat, Tar Sar and Kolahai was studied. Survey of India topographic sheets on 1 : 50,000 scale were used as base maps.

Considering the problem and the nature of the work to be carried out in this study, a detailed geological mapping of the region was not considered essential. For intensive field study and sampling of the Panjal Traps, Mount Kayol was selected because of easily discernable bedded sequence exposed on this mountain. Thirty-three flows were delineated from base to the top on Mount Kayol. The flows were demarcated on the basis of the nature of columnar and conjugate joints, and amygdular structure of the lava beds. The basal two flows immediately overlying Agglomeratic slates are porphyritic in nature whereas the rest of the flows are very fine grained. The total thickness of the traps on Mount Kayol exceeds one thousand feet.

During sampling the suggestion of Watkins et al. (1970), "crushing and homogenizing of several samples from different parts of a lava flow should be undertaken to obtain representative chemical data", was considered. Samples were collected generally from three locations, bottom, middle, and top of each flow; several samples were collected at each location so that equal portions of all samples after crushing and homogenization may give representative chemical composition of that particular part of the flow. However, the number of locations sampled on each flow varied depending upon the thickness of a particular flow. Due to the steep slope of rock exposures, certain portions of the flow were inaccessible for sample collection. For the study of the lateral variation in chemistry of these rocks, a few samples were collected from a single flow at about 15 feet intervals. Samples were also taken from Aru, Nishat Harwan, and Handwara to investigate the regional variation in geochemistry of these rocks. However, the position of these samples in the order of flow sequence could not be ascertained because of the lack of basal exposures and bedded character of the Panjal Traps in these areas.