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A REVIEW OF THE STRATIGRAPHY AND STRUCTURE OF A PART OF KASHMIR BASIN IN BANIHAL-RAMBAN-DESA-CHHATRU BELT, DODA DISTRICT, JAMMU AND KASHMIR, INDIA

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ABSTRACT

The paper reviews the stratigraphy and structure of southeast part of NW-SE trending Kashmir Synclinorium and describes the lithostratigraphy of Precambrian and Lower Palaeozoic formations in detail. The area reveals a normal Precambrian to Triassic succession, delimited to the south by the regional tectonic plane - the Panjal Thrust, along which it is juxtaposed against the Parautochthon. A low to high grade psammo-pelitic suite, with occasional limestone-gypsum association, characterises the oldest Precambrian Salkhala Formation. This is followed unconformably by either Dumgali Quartzite or Ramsu Formation, the latter a thick pelite-quartzite-diamictite sequence, being described from its proposed type area. The next Machhal, a dominantly argillaceous suite, has yielded microfossils of topmost Precambrian affinity from its lower Brarsul Member. The succeeding Palaeozoic and Triassic formations of the Kashmir basin are all represented here. A marked stratigraphic break occurs at places above Late Precambrian - Early Cambrian Machhal or Lolab formations, when the next succeeding sequence belongs to either Lower Carboniferous Syringothyris Limestone or Lower Permian Panjal Volcanic. A biotite granite,intrusive into Salkhala-Dumgali-Ramsu, is considered to be of Cambrian age. At least four phases of deformation are recognised in the area, which in order of their antiquity are NW-SE (F_1), NE-SW (F_2), E-W (F_3) and N-S (F_4).

INTRODUCTION

The geological picture of the southeast part of Kashmir basin, covering the rugged south and southeast flanks of Pir Panjal and Saribal ranges, to north of Panjal 'Thrust' (*sensu* Jangpangi *et al.*; 1986), in the Banihal-Ramban-Desa-Chhatru belt of Doda district, has remained vague and controversial, particularly its Precambrian-Lower Palaeozoic stratigraphy. Mapping of about 1300 km^2 of this area in recent years on 1:50,000/ 1:25,000 scales, with emphasis on lithostratigraphic classification, has revealed a stratigraphic set up ranging in age from Precambrian to Triassic. The stratigraphy of the area assumes significance because of the recent record of small shelly fauna of Precambrian-Early Cambrian affinity recorded from the base of Machhal Formation.

Lydekker (1876) recognised schists, slates, intrusive gneiss, amygdaloids, sandstone and grit in the Ramban-Banihal Pass section in the west. Middlemiss (1910) established Cambrian-Trias stratigraphy of Southeast Kashmir, adjoining the present area in the northeast. Wadia (in Heron, 1937) referred the succession in Digdual-Banihal to Precambrian Salkhala Series with biotite-gneiss injections. These along with the 'Dogra Slate' of Ramban form part of his (Wadia, 1931) 'Nappe Zone' which, according to him, override the 'Autochthonous folded belt' to the south along "Panjal Thrust". Vohra (1966) separated out a stratigraphically younger pebble-bearing 'Ramsu Formation' from the 'Salkhala Series' near Ramsu, to which he assigned a probable Palaeozoic age. Bhatia and Bhatia (1973) identify Salkhala, Ramban, Chamalwas and Ramsu formations in the Ramban-Chamalwas sector. They assign Precambrian age to all these formations and equate Ramsu with Saline Series.

Wakhaloo and Dhar (1971) assigned the sequence in Kishtwar-Singpor belt to Precambrian Kishtwar Group and Permo-Carboniferous Sinthan Group with a tectonic junction between the two. Srivastava (1979) classified the same area into Archaean Salkhala, Precambrian Chamalwas which he equated with Dogra Slate, and Cambro-Silurian Ramsu, besides the usual Middle-Upper Palaeozoic formations of Southeast Kashmir. Gupta and Dutta (1979) intro-

[1] Our dear colleague and friend - B.L. Sharma expired tragically along with three other members of the 9th Indian Antarctic Expedition in the Humboldt region of Antarctica on January 8, 1990.

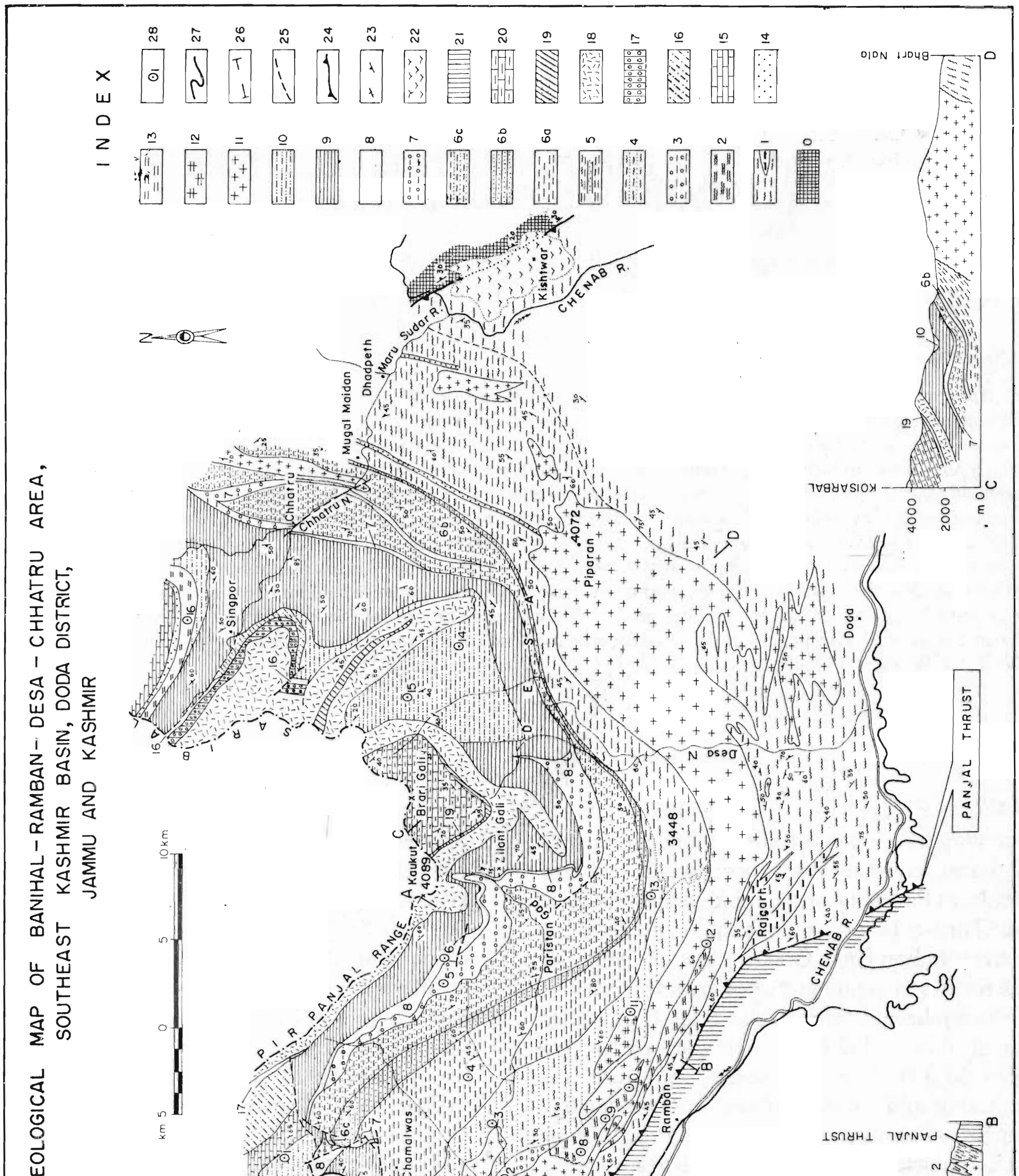
GEOLOGICAL MAP OF BANIHAL-RAMBAN-DESA-CHHATRU AREA, SOUTHEAST KASHMIR BASIN, DODA DISTRICT, JAMMU AND KASHMIR
INDEX
PANJAL THRUST
PIR PANJAL RANGE
CHENAB R.
Banihal
Ramban
Desa
Doda
Kishtwar
Chhatru
Singpor
Rajgarh
Pariston
Chamalwas
Nachlana
Ramsu
Kaukut Gali
Brari Gali
Zilani Gali
Mugal Maidan
Dhadpeth
Piparan
Maru Sudar R.
Bichlari R.
SRINAGAR
ANANTNAG
BANIHAL
KISHTWAR
DODA
UDHAMPUR
JAMMU
Area mapped
INDIA
Srinagar
KOISARBAL
Bhart Nala

Fig. 1

duced the name Chingam Formaation for Cambro-Silurian sequence in Chhatru-Singpor with 'Chatru Pebbly Phyllite' at its base marking an unconformity with underlying Precambrian Salkhala. Gupta, Srivastava and Datta (1979) also record Permian Zewan Formation in the same area.

Sharma, Verma and Sharma (1979) recognise Cambro-Silurian succession as Bhadarwah Formation, being the oldest formation in Banihal-Ramban-Kaukut area, followed by Devonian Muth Quartzite and Upper Palaeozoic-Triassic succession, with post-Carboniferous granitic intrusives. They refute the existence of Panjal Thrust and regard Wadia's 'Nappe' and 'Autochthon' as a single structural entity. Subsequently, however, Sharma *et al.* (1982) recognise Panjal Thrust.

Jangpangi *et al.* (1986) redefine the position of Panjal 'Fault' (Thrust) in the Chenab valley near Ramban, which, according to them, occurs to the north of Ramban and Sincha formations of the Parautochthon.

Raina, Bhatt and Gupta (1988) record skeletal microfossils of Precambrian-Early Cambrian affinity from the base of their Zilant (= Machhal) Formation in the Paristan area.

STRATIGRAPHY

A more or less complete strike continuation of various lithounits is obser ved from Digdual-Banihal along National Highway in the west/northwest, through Desa nala in the east/southeast, to Chhatru-Maru Sudar and beyond in the northeast (Fig. 1). An account of the stratigraphic set up of the area and its correlation with adjoining Bhadarwah-Chamba basin is given in Table I.

SALKHALA FORMATION: (Wadia, in Heron, 1937; Bhatia and Bhatia, 1973; 'Kishtwar Group'-Wakhaloo and Dhar, 1971; Srivastava, 1971; 'Salkhala and Bhadarwah formations'-Sharma *et al.*, 1979); This constitutes the oldest formation in this part of Kashmir basin. It is bounded by Panjal Thrust in the southwest along which it is juxtaposed against Sincha Formation (Raina and Gupta, 1984-85, unpublished; Jangpangi *et al.*, 1986) of the 'Parautochthon'. The Salkhala is exposed along the narrow Digdaul-Rajgarh belt in the northwest, it widens in the southeast towards Doda, where it swings towards Maru Sudar-Chenab rivers in the northeast. It is a low to high grade metasedimentary suite comprising phyllite, schist, quartzite, limestone and gypsum. The phyllites are frequently carbonaceous, schist are graphitic, garnetiferous and in the sections northeast of Doda, are kyanite and staurolite bearing. Quartzites are massive and flaggy, limestone usually crystalline and rarely bituminous, whereas gypsum is lenticular (1-25 m). In Kishtwar area, the Salkhala becomes coarse crystallines with gneissic bands, and abut against the orthoquartzite-basic metavolcanic-argillite suites of Dul area ('Kishtwar Window' of Fuchs and Gupta, 1971).

The lithostratigraphy in this Formation as observed along Jowartha nala near Rajgarh is as follows:

6. Garnetiferous mica schist, with lenticular, dark grey, carbonaceous/-graphitic, pyritous phyllite and grey, bluish grey, whitish limestone/-crystalline limestone, and rare dark quartzite bands. (550 m)
5. Grey, thinly bedded quartzite, occasional calcareous quartzite bands. (10 m)
4. Garnetiferous mica schist, with occasional quartzite bands; dark grey, carbonaceous, pyritous phyllite; lenticular, grey limestone, and occasional gypsum lenses. (140 m)
3. Grey, greenish grey, thinly bedded quartzite. (15 m)

Fig. 1. Geological map of Banihal-Ramban-Desa-Chhatru Area, Southeast Kashmir Basin, Doda District, Jammu and Kashmir. O, Orthoquartzite, basic metavolcanic and argillite of Dul area; 1, Salkhala Formation-phyllite, schist, paragneiss, quartzite, limestone and gypsum, lenticulaar carbonaceous/graphitic phyllite; 2, Dumgali Quartzite-quartzite, chist; 3-7, Ramsu Formation; 3, Khaura Member-phyllite, diamictite, quartzite, limesotne, dolomite; 4, Batrau Member- phyllite, arenaceous phyllite, quartzite, diamictite, crystalline limestone; 5, Dhadpeth Member-more metamorphosed extensions of Batrau and Lower Pogul member in Jowartha-Maru Sudar section in the northeast-garnet schist, quartzite, calc-silicate, marble; 6a-6c, Pogul Member; 6a-slate, phyllite, occasional quartzite; 6b-quartzite, argillite, gritty lenses; 6c-slate, phyllite, quartzite, pebbly and gritty lenses; 7, Zor Member-diamictite; 8-9, Machahal Formation; 8, Brarsul Member-limestone-slate-chert and pinching unit of tuff, agglomerate, argillite in upper part; 9, Zilant Gali Member-slate, phyllite, occasional quartzite; 10, Lolab Formation-quartzite, slate; 11, Piparan Granite- biotite granite; 12, Gabbroid-leuco/mesogranite intrusive; 13, Karihul Formation-shale, slate, arenite, limestone; 14, Muth Quartzite-orthoquartzite; 15, *Syringothyris* Limestone-limestone, arenite, shale, calc-shale, conglomerate; 16, *Fenestella* Shale-shale, arenite, conglomerate; 17, Agglomeratic Slate-diamictite, slate, arenite, conglomerate; 18, Panjal Volcanic-andesite, basalt; 19, Zewan Formation-shale, sandy shale, calc-shale, limestone; 20, Khunamuh-Khreuh-Wuyan Formations, undifferentiated-limestone, shale, arenite; 21, Parautochthonous Zone; 22, Terrace material, alluvium etc.; 23, Bedding, foliation; 24, Thrust; 25, Fault; 26, Section Line; 27, Road; 28, Localities mantioned in text-(1,Hale Maidan; 2, Makarkot; 3, Batrau; 4, Pogul; 5, Zor; 6, Brarsul; 7, Digdaul; 8, Gindhot; 9, Mogi; 10, Biba; 11, Naghal; 12, Modisira; 13, Dhumini; 14, Shapurshal; 15, Trajwas; and 16, Sar).

2. Grey, dark grey to black, carbonaceous, pyritous, phyllite, calc-phyllite; lenticular, grey, dark grey, sometimes bitumonous, thinly bedded limestone/crystalline limestone (upto 25 m), occasional gypsum lenses. (320 m)
1. Grey, monotonous phyllite with vein quartz, garnetiferous phyllite towards upper part; occasional siltstone-quartzite bands. (200 m)

DUMGALI QUARTZITE ('Salkhala Formation' – Wadia, in Heron, 1937; Vohra, 1966; Bhatia and Bhatia, 1973; 'Muth Quartzite' Sharma *et al.*, 1979): This formation overlies Salkhala and is a dominantly psammitic suite. The term 'Dumgali Quartzite' was first used by Sharma *et al.* (1976, unpublished) in Budhal-Gulabgarh area of Rajauri district which was revised by Sharma *et al.* (1979) as 'Muth Quartzite' of Devonian age in that and present area. Verma and Sharma (in press) also adopt 'Dumgali Quartzite' in adjoining Gulabgarh area. An unconformity marks the base of Dumgali in Budhal-Gulabgarh area (Verma, S.N., personal communication).

This Formation occurs as linear enclaves within Piparan Granite, hence most of its lithostratigraphy as well as contact relationship with underlying Salkhala and overlying Ramsu formations is obliterated. A better section of Dumgali Quartzite, however, is exposed in Gindhot-Biba and Dyula Forest-Modisira belt, where it is constituted of white, greenish, buff, thin to thick and occasionally cross-bedded quartzite with subordinate phyllite, schist and garnetiferous schist and rare lenticular crystalline limestone. Feldspathised quartzite enclaves of this formation are common within the granite.

This formation apparently pinches out further east, as its supposedly strike continuation is not recognised beyond Piparan Granite in Maru Sudar section in the northeast.

RAMSU FORMATION: (Vohra (1966) distinguished a narrow zone of pebbly phyllite-phyllite-carbonaceous phyllite-limestone from the underlying 'Salkhala Series' of Wadia (in Heron, 1937) near Ramsu, which he assigned to 'Ramsu Formation' of probable Palaeozoic age. He again referred the 'pebbly phyllite' of Paristan area in the east to this formation. Srivastava (1979) also recognised 'Ramsu Formation' with basal pebbly phyllite in the Chhatru area to the far northeast and regarded it to be Cambro-Silurian in age. Sharma *et al.* (1979), however, referred it to as 'Chamalwas Slates', forming the basal part of Lower Carboniferous *Syringothyris* Limestone.

The present work recognises 'Ramsu' as a distinct formation in the Kashmir stratigraphy and enlarges its scope to incorporate a huge pile of slate, phyllite, schist and quartzite with diamictite, grit and conglomerate occurring throughout its succession. The Ramsu-Paristan Gad can be referred to as the type section of Ramsu Formation, where it occurs between Dumgali and Machhal formations. In the absence of any recognisable megafossils and its position below Late Precambrian-Early Cambrian Machhal Formation, the age of Ramsu is assigned as Precambrian.

The Ramsu Formation is divisible into four well-defined mappable Members in the area, namely Khaura, Batrau, Pogul and Zor in the ascending order. The more metamorphosed strike extensions of Batrau and lower unit of Pogul Member in Jowartha (3448)-Maru Sudar section in the northeast, are, however, together referred to as 'Dhadpeth Member'.

Khaura Member ('Ramsu Formation'-Vohra, 1966; Bhatia and Bhatia, 1973; 'Chamalwas Slates'-Sharma *et al.*, 1979): The basal Member of Ramsu Formation is named after Khaura (33°20′:75°13′), southeast of Ramsu. It is found to pinch out near Nunakot in the southeast, where its contact with the underlying Dumgali Quartzite is unconformable. It is characterised by grey, dark grey phyllite, carbonaceous and pyritous phyllite, flaggy, sericitic, chloritic and talcose quartzite, and lenticular diamictite, limestone and dolomite. The diamictite bears grit to pebble, occasional cobble size clasts of quartzite and vein quartz in an argillaceous matrix.

The following lithostratigraphy of Khaura Member is recognised along Pogul Gad near Makarkot:

8. Grey, dull brownish diamictite with granule to pebble size clasts of quartzite and vein quartz in argillaceous matrix faintly calcareous. (10 m)
7. Whitish quartzite. (2 m)
6. Grey, dark grey phyllite, carbonaceous, pyritous phyllite. (50 m)
5. Whitish, greenish, grey, flaggy quartzite, sericitic quartzite, calcareous quartzite. (30 m)
4. Grey, dark grey phyllite, carbonaceous, pyritous phyllite (bearing lenticular, massive dolomite due northwest). (60 m)
3. Whitish, greenish, sericitic, schistose and flaggy quartzite, calcareous quartzite. (50 m)

Fault

2. Grey, dark grey phyllite, carbonaceous phyllite (becoming diamictite laterally due northwest).
1. Whitish, greenish, buff, flaggy, schistose quartzite, sericitic, chloritic and talcose quartzite, feldspathic near granite contact to the south. (50 m)

Batrau Member ('Salkhala Formation'-Vohra, 1966; Bhatia and Bhatia, 1973; 'Bhadarwah

Formation-Muth Quartzite-Chamalwas Slates'-Sharma *et al.*, 1979): Succeeding Khaura or else resting unconformably over Dumgli Quartzite, is an argillo-arenaceous suite, designated as Batrau Member, after Batrau (33°20′:75°14′) locality in Pogul Gad. It comprises grey, buff and greenish, flaggy and schistose quartzite, light grey arenaceous phyllite, phyllite, carbonaceous phyllite, lenticular diamictite and crystalline limestone. Also present are thin to massive, occasionaly cross-bedded quartzite bands (100-200 m) best exposed in Pogul Gad. A quartz conglomerate (3-10 m) is exposed in Randgali-Talai section in the southeast.

The lithostratigraphy of the Batrau Member in the Pogul Gad section is as follows:

7. Grey, greenish, buff, flaggy quartzite with grey phyllite interbands. (+ 500 m)
6. Grey, greenish, buff, thin to thick-bedded quartzite, subordinate phyllite/arenaceous phyllite as intercalations. (100 m)
5. Grey, dark grey, carbonaceous phyllite, phyllite, diamictite, occasional quartzite interbands. (110 m)
4. Grey, buff, whitish, thin to thick-and occasionally cross-bedded quartzite. (100 m)
3. Grey, phyllite, arenaceous phyllite, grey and greenish grey quartzite interbands. (80 m)
2. Grey, whitish, greenish, thin to thick-, locally cross-bedded quartzite, subordinate phyllite, arenaceous phyllite, occasional lenticular, crystalline limestone. (150 m)
1. Grey phyllite, arenaceous phyllite, calcareous phyllite, grey, greenish quartzite interbands. (300 m)

Dhadpeth Member ('Kishtwar Group' - Wakhaloo and Dhar, 1971; 'Salkhala Formation' - Srivastava, 1979): The more metamorphosed lateral extensions of Batrau and lower argillite unit of Pogul Member in Jowartha (3448) - Maru Sudar section in the east/-northeast together are designated as Dhadpeth Member, after licality of that name (33°23′:75°21′) on Maru Sudar. Piparan Granite and its off-shoots obliterate much of its lothology in the area. An unconformity is inferred between Dhadpeth Member of Ramsu Formation and underlying Salkhala in the section east and northeast of Piparan, as the intervening Dumgali Quartzite is found missing here. This unconformity, however, is obliterated due to high metamorphic imprint of the formations here.

This Member is dominated by muscovite-biotite schist with ubiquitous garnet, besides quartzite bands and occasional calc-silicate and marble lenses. A grey to white, thin to thick-bedded quartzite (200 m) with gritty lenses and schistose intercalations, is exposed in the upper part of this member. Quartzo-feldspathic and occasional quartzkyanite veins besides thin amphibolitic intrusives are also noticed.

Pogul Member ('Chamalwas Formation' - Bhatia and Bhatia, 1973; 'Salkhala and Chamalwas Formation' - Srivastava, 1979; 'Bhadarwah Formation-Muth Quartzite-Chamalwas Slates'-Sharma *et al.*, 1979): Named after Pogul (33°21′:75°18′) in Pogul Gad, this is the best developed member of Ramsu and is further classified into three sub-units.

The lower unit, best exposed in Chamalwas-Dhaumini, is a grey, greenish or dark grey slate, laminated slate, phyllite, occasional quartzite intercalation or bands, rarely gritty, with a calc-tremolite phyllite (3-10 m) in the basal part in Dhundrat area. The more metamorphosed lateral extensions of this unit form upper part of Dhadpeth Member in Jowartha - Mughal Maidan in the east/northeast. The middle marker unit is represented by grey to white, greenish, thin to thick-bedded orthoquartzite ('Muth Quartzite'-Sharma *et al.*, 1979). Cross-bedding and assymmetrical ripple marks are occasional and so are gritty and conglomeratic lenses (3-25cm). Slate, phyllite or schistose phyllite occur as intercalations or bands. The upper unit is essentially a slate-quartzite suite, also with few gritty or conglomeratic lenses and stray clasts of quartzite.

Zor Member ('Ramsu Formation' - Vohra, 1966; Srivastava, 1979; 'Chhatru Pebbly Phyllite '- Gupta and Datta, 1979; '*Syringothysis* Limestone' - Sharma *et al.*, 1979): Named after Zor (33°22′:75°20′) in Pogul Gad, the youngest Member of Ramsu comprises exclusively grey to steel grey diamictite. It has a sharp and unconformable contact with the underlying Pogul, and is exposed throughout the belt though with a variable thickness (0-800 m). This marker horizon is frequently folded in Paristan Gad-Chhatru and is found missing in Thana-Dobaggi Gali Section. The diamictite bears rounded to angular, sometimes flattened, granule to pebble and occasionally cobble size clasts of quartzite, vein quartz,limestone and argillite, distributed randomly in a silty, sometimes gritty, calc-argillaceous matrix, weathering to faint brownish. Few clast-free argillite and rare limestone lenses are also noticed within Zor. Kaul *et al.* (1986) consider the diamictite in Pogul-paristan-Dasaa area to be 'agglomeratic', for which, however, the present workers found no evidence.

MACHHAL FORMATION: (Zilant Formation'-Vohra, 1964, unpublished; Raina *et al.*, *in press*; 'Fenestella Shale' - Sharma *et al.*, 1979; 'Ramsu Formation'-Srivastava, 1979; 'Chingam Formation' - Gupta *et al.*, 1979): The

Ramsu Formation is overlain by a dominantly argillaceous suite which in turn is succeeded by Lolab Formation or overlapped by Panjal Volcanic. This characteristic sequence is correlatable to Machhal Formation (Raina and Razdan, 1983; Kumar *et al.*, 1984) of Northwest Kashmir. The base of Machhal is marked by an unconformity as it rests either over Zor or directly above Pogul members of Ramsu Formation. This formation is divisible into Brarsul and Zilant Gail members.

Brarsul Member: This intermittently exposed basal member, best developed near Brarsul (33°22′:75°20′ in Pogul Gad, comprises a lower limestone-argillite chert and an upper pinching volcanic clastic suite.

The lithostratigraphic sequence of lower unit of Brarsal Member as recorded near Brarsal is as follows:

5. Grey, brown-weathered, thinly bedded limestone, with argillaceous intercalations. (25 m)
4. Grey to light grey argillite, with a grey limestone band (1 m) in the lower part. (70 m)
3. Grey, brown-weathered, very thinly bedded limestone, with argillaceous partings. (35 m)
2. Dark grey, black, carbonaceous argillite, bleaching to ash grey, with occasional thin quartzite. (45 m)
1. Light grey to whitish, thinly bedded limestone. (15 m)

A limestone usually marks the base of the lower unit which is siliceous and massive at places. Kaul *et al.* (1986) regard this basal carbonate in Brarsul-Zor-Hinzan Gali section as 'remobilised limestone' for which, however, no field evidence is forthcoming. A dark chert (0-20 m) is exposed towards the upper part at places. This chert has yielded shelly microfossil *Coleoloides typicalis* Walcott near Hinzan Gali in Paristan area (Raina *et al.*, in Press). In Desa-Chhatru section, the lower unit has a much reduced development (5-50 m). The upper unit is exposed between Banihal and Pogul Gad only. It is a jet black tuff, bleached to ash grey, lithic and lapili tuff, associated with slates and occasional quartzite.

Zilant Gali Member: Named after a pass of that name, this thicker and well developed argillite member rests either over upper volcanoclastic or directly above limestone-argillite-chert unit of Brarsul with a disconformity. It is a monotonous pile of grey, greenish, dark grey, carbonaceous and pyritous, slate, laminated slate and phyllite, with occasional quartzite intercalations or bands and rare calcareous lenses.

Vohra (1964, unpublished) assigned Machhal (= Zilant) to Carboniferous, while Sharma *et al.* (1979) considered it to be Middle Carboniferous *Fenestella* Shale. Srivastava (1979) and Gupta *et al.* (1979) incorporate it respectively under Ramsu and Chingam formations of Cambro-Silurian age. Kaul *et al.* (1986) refers it to Ordovician-Silurian on the basis of reported 'graptolites' from it. The present workers do not recognise any graptolites from this member. However, due to absence of recognisable megafossils throughout this formation, but presence of shelly microfauna of topmost Precambrian affinity in its lower part, the age of Machhal is tentatively assigned to Late Precambrian-Early Cambrian.

LOLAB FORMATION ('Lower Cambrian' – Wadia, in Heron, 1937; 'Agglomeratic Slate' – Wakhaloo & Dhar, 1971; 'Chamalwas Slate' – Sharma *et al.*, 1979; 'Ramsu Formation'-Srivastava, 1979; 'Chingam Formation'-Gupta *et al.*, 1979): This formation succeeds Machhal conformably and is in turn succeeded by Karihul in Singpor, overlain unconformably by Margan or *Syringothyris* Limestone in Banihal, or else overlapped by Panjal Volcanic in Desa where it is best developed in Shapurshal-Trajwas section. It is characterised by grey, greenish, thin to very thin-bedded quartzite with argillite intercalations in the lower part and grey, dark grey, carbonaceous, laminated, shale-slate with few quartzite interbands in the upper part. These lower and upper units are correlatable respectively to Razdain and Vel Members (Kumar *et al.*, 1984) of Lolab Formation. The lower rhythmites bear trace-fossils, frequently on ripple-marked surfaces, so characteristic of Lolab Formation. Only the upper argillite is exposed at Banihal, forming the core of Banihal anticline here.

The present area has not yielded any megafossils so far but based on the occurrence of redlichid trilobites elsewhere in the Kashmir basin (Raina and Razdan, 1975; Shah *et al.*, 1980; Kumar and Verma, 1987), the age of Lolab is considered to be Early Cambrian. Dhall and Pal (1981) assign an Ordovician age to the upper part of Lolab near Rollu in Banihal on the basis of reported graptolite fauna and also regard its top quartzite (12 m) here as Muth. The authors, however, failed to recover any such fauna in the area.

KARIHUL FORMATION: ('Agglomeratic Slate' - Wakhaloo and Dhar, 1971; 'Chingam Formation' - Gupta *et al.*, 1979): This formation succeeds Lolab conformably and is in turn followed directly by Muth Quartzite without the intervening Margan Formation in the sec-

tion north of Singpor. It consists of grey, greenish shale, siltstone, micaceous arenite and limestone, which yield ill-preserved crinoids and brachiopods. An intraformational conglomerate (5 m) is exposed locally near Sar. Kumar and Singh (1983) assign a Middle Cambrian age to Karihul in Liddar on the basis of trilobite *Ptychoparia* sp.

MARGAN FORMATION: Sandwitched between Lolab and *Syringothyris* Limestone, this formation (30 m) is locally exposed near Hale Maidan in Banihal where it has an unconformable contact with either of these formations. It comprises conglomerate, shale, siltstone, arenite and quartz arenite. Shah (1972) assigns Ordorician-Lower Devonian age, while Kumar *et. al.* (1987) consider Siluran-Devonian age for Margan.

The succeeding formation like Muth Quartzite *Syringothyris* Limestone, *Fenestella* Shale, Panjal Volcanic and Zewan, have already been dealt with by Wadia (in Heron, 1937), Pal (1978), Sharma *et. al.* (1979), Srivastava (1979), Gupta *et al.* (1979), Gupta *et al.* (1984), etc. However, some of the Upper Palaeozoic formations of Southeast Kashmir basin are found to be absent in the present area. These include plant-fossil bearing Upper Devonian Aishmuqam Formation as well as Lower Permian Nishaatbagh and Mamal formations (Kumar *et. al.*, 1987; Singh *et. al.*, 1982), that underly and overly Panjal Volcanic Formation respectively.

KHUNAMUH-KHREUH-WUYAN FORMATIONS: (UNCLASSIFIED): A limestone-shale-arenite suite succeeds Upper Permian Zewan in Chandren area of Upper Desa. It occupies a synclinal core here and is the continuation of 'Triassic' (Sharma *et al.*, 1979) exposed further northwest. Its lower part is a grey, dark grey shale and grey, bedded limestone with shale intercalations which is rich in ammonoids. The middle part is grey to dark grey limestone, siliceous and argillaceous limestone, shale and arenite. The limestone has yielded ammonoids. The upper part is a dull white quartz arenite with limestone and shale, followed upward by grey, hard, massive limestone. It yields rare, fragmentary brachiopod and lamellibrach fossils. The above three units may be correlatable respectively to Lower Trias Khunamuh, Middle Trias Khreuh and Upper Trias Wuyan formations (Nakazawa and Kapoor, 1981) of Kashmir.

Piparan Granite ('Piparan Member' - Srivastava, 1979; 'Dhundrat Granite' - Sharma *et al.*, 1979): This granite of batholithic dimensions, also occurs as linear, sub-concordant, stock-like bodies within Salkhala, Dumgali and Ramsu. It is a leucocratic, medium to coarse, porphyritic biotite granite, frequently foliated or gneissose. Microscopic studies reveal orthoclase and albite-oligoclase phenocrysts, generally altered, quartz, biotite, perthite, occasional microcline, and muscovite, with accessories as apatite, garnet, hornblende, magnetite, ilmenite, sphene etc. Microgranitic and sometimes aplitic differentiates are common along its southern fringe as in Bagna-Sildhar and Dhandal nala sections. It has a sharp to diffused, sometimes granitised contact zone which also bears quartzo-felds-pathic or quartz-tourmaline veins. The granite lacks a distinct thermal aureole. Xenoliths of country rock, generally granitised, are common within this granite. Biotite-rich mesocratic differentiate is noticed in Pogul Gad sections.

A gabbro-hornblende gabbro body, associated with subordinate leuco-and mesogranite, microgranite etc., is exposed near Naghal and also near Mogi in Balhot nala, as intrusive within Ramsu Formation and Piparan Granite respectively. This suite could be the possible differentiate of Piparan Granite. Petrographic studies of a hornblende gabbro from Naghal body revealed labrodorite-andesine, usually altered, hornblende, biotite, augite, iron-ore, chlorite, quartz and apatite as its constituents.

Vohra (1966) regards this intrusive to be post-Salkhala, while Sharma *et al.* (1979) regard it as post-Carboniferous. Srivastava (1979) considers it to be of Archaean age. The field disposition reveals it to be intrusive into strata not younger than Precambrian Ramsu. The Piparan Granite shows a marked compositional similarity and field disposition with that of Kaplas Granite of Bhadarwah and Dalhousie Granite of Chamba (H.P.), with which it is equated. A Rb-Sr whole rock date of 456 ± 50 m.y. (Bhanot *et al.*, 1974) is indicated for Dhalhousie Granite. The age of Piparan Granite, therefore, could also be Cambrian.

Basic Intrusives: Sills and occasional dykes of dolerite, metadolerite and amphibolite occur in all the formations older to Panjal Volcanic as well as in Piparan Granite. These could be hypabyssal derivatives of Lower Permian Panjal Volcanic.

STRUCTURE

The Banihal-Ramban-Desa-Chhatru area from part of Wadia's (1931) 'Nappe Zone' and represent southeastern part of NW-SE trending Kashmir Synclinorium.

Folds: At least four sets of fold generations are recognised in the area which in order of their antiquity are NW-SE (F_1), NE-SE (F_2), E-W (F_3) and N-S

(F_4). In addition, the Precambrian metasediments reveal rare, tightly appressed intrafolial folds with isolated closures, perhaps related to some earlier deformation.

The NW-SE trending folds (F_1) are the most common which are open to tight, upright to overturned and north-westerly plunging types. These folds are well reflected in Banihal-Pir Panjal section. Tight, assymmetrical and plunging, mesoscopic folds of this generation are present throughout the area. The second generation folds (F_2) are localized in Paristan Gad-Galeran *nala* area, though their mesoscopic manifestaions are more common. These folds are open to tight, occasionally assymmetrical, and south-easterly plunging with axial trace variation of N45-55°E-S45-55°W. The E-W trending folds (F_3), represented more on meso-scale in Pogul Gad-Desa nala area, are open to tight, assymmetrical and plunge in either direction. The youngest N-S deformation (F_4) is relatively more frequent than the preceding two, both on larger and meso-scale. These are tight, upright, northerly plunging folds, commonly met with in Paristan Gad and Chhatru-Maru Sudar areas.

Panjal Thrust: ('Panjal Fault' *sensu* Jangpangi *et al.*, 1986): This plane delimits the Proterozoic-Phanerozoic succession of Kashmir basin to the south and juxtaposes it against the Parautochthon. Though this plane is a high-angle reverse fault, the term 'Panjal Thrust' may be preferred to 'Panjal Fault' (Jangpangi *et al.*, 1986) because of its regional character and long usage.

Metamorphism: The Salkhala-Dumgali-Ramsu metasedimentaries display a subtle increase in the grade of metamorphism laterally due southeast and then towards Chhatru-Maru Sudar river on the northeast. This variation is from low greenschist to high almandine-amphibolite facies. The facies boundary is found to cut the litho-boundary obliquely. The higher metamorphic imprint in Chhatru-Maru Sudar area led Srivastava (1979) to incorporate the metasediments below Zor diamictite within Salkhala, while the strike mapping revealed it to being to stratigraphically younger Ramsu Formation i.e. its Dhadpeth and Pogul Members.

DISCUSSION

The present geological studies in Banihal-Ramban-Desa-Chhatur region of Doda district has established the strike continuity of rock formations, especially those belonging to Precambrians, between Digdaul-Banihal along National Highway in the west and Chhatru-Maru Sudar in the north-east. This belt, constituting the south-eastern part of the NW-SE trending Kashmir Synclinorium, exposes a huge rock pile of Precambrian to Triassic age. While the Upper Palaeozoic-Triassic succession is better worked out which compares well with other parts of Kashmir basin, the Precambrian-Lower Palaeozoic sequence are least understood and required proper mapping and classification.

Sharma, Verma and Sharma (1979) classified the entire area into Precambrian Salkhala, Cambro-Silurian Bhadarwah, Devonian Muth Quartzite and Lower Carboniferous Chamalwas Slate *Syringothyris* Limestone, besides the other Upper Palaeozoic-Triassic formations. They conceived tight, overtuned, NW-SE trending folds in Ramban-Banihal sector, involving frequent repetitions of formation. The present studies, however, reveal a right-side up succession between 'Panjal Thrust' in the south and Pir Panjal range in the north. The Bhadarwah Formation of Sharma *et al.* (1973), supposed to form the core of a north-westerly plunging anticline here, has been classified into Salkhala, Dumgali and Batrau and lower Pogul members of Ramsu Formation, and all assigned a Precambrian age because of their unfossiliferous character and stratigraphic position below Late Precambrian-Early Cambrian fossili-ferous Machhal Formation. Sharma (1976) recognises the oldest Salkhala only in Doda-Thatri belt, further southeast. Srikantia and Bhargava (1974) opine that the Bhadarwah Formation of Sharma is the less metamorphosed variant of Salkhala. The term 'Bhadarwah Slate' may, however, be restricted to Bhadarwah basin proper further southeast, where its stratigraphic position is limited between Salkhala and 'Sunbain Quartzite' (Table I).

Sharma *et al.* (1979) considered the quartzite, occuring in stratigraphically different formations like the present Dumgali and Batrau Member and middle unit of Pogul Member of Ramsu, to be 'Muth Quartzite', repeated due to folding. However, the sedimentary characters including current bedding, as revealed by most of these quartzites, suggest right-side up beds without any large-scale folding.

Sharma *et al* (1979) do not agree with pebble-bearing 'Ramsu Formation' of Vohra (1966) near Ramsu as a separate formation, and instead refer it along with associated lithologies to 'Chamalwas Slates', forming the basal part of Lower Carboniferous *Syringothyris* Limestone. They combine the lower slate and upper slate-quartzite unit of present Pogul Member of Ramsu into 'Chamalwas', shown as

Table 1. Generalised Stratigraphic succession of Southeast Kashmir basin in Banihal Ramban Desa Chhatru Belt, Doda District, Jammu and Kashmir, and their equivalents in Bhadarwah-Chamba basin.

Formation	Member	Lithology	Thickness m	Equivalents in Bhadarwah-Chamba Basin	Age
		Scree, hill-wash, moraine, terrace material etc.			Sub-Recent
Khunamuh-Khreuh-Wuyan		Limestone, argillaceous limestone, shale, arenite. *Fossiliferous.*	-	Dalmon (Lr. Trias), Kalhel	Triassic
Zewan		Shale, sandy shale, calc-shale, limestone. *Richly fossiliferous.*	30-150	Gamgul, Salooni	Upper Permian
Panjal Volcanic		Green, amygdaloidal and vesicular andesites and basalts.	-	Panjal Volcanic	Lower Permian
		Unconformity			
Agglomeratic Slate		Diamictite, shale-slate, arenite, conglomerate.	0-300	Agglomeratic Slate	Lower Permian to Upper Carb.
Fenestella Shale		Shale, siltstone, quartz arenite conglomerate. *Fossiliferous.*	150-900	—	Lower Carb. (?)
Syringothyris Limestone		Limestone, arenite, shale, calc-shale, conglomerate. *Fossiliferous.*	20-350	—	Lower Carb.
		Unconformity with Lolab			
Muth Quartzite		White, milky white, orthoquartzite.	50-60	—	Middle Devonian
		Unconformity with Karihul			
Margan		Purplish siltstone-arenite, whitish quartz arenite, shale, conglomerate.	0-30	—	Lower Devonian to Silurian
		Unconformity with Lolab			
Karihul		Shale-slate, greenish micaceous arenite, limestone. *Rare fossils.*	300	—	Middle Cambrian
Lolab		Grey-greenish, thinly-bedded quartzite bearing worm burrows, argillite intrcalations; upper part argillite with occasional quartzite.	0-500	—	Lower Cambrian
Machhal	Zilant Gali	Slate, phyllite, laminated slate, occasional quartzite bands.	500-1500	Katari Gali, Brahmaur	Lower Cambrian (?) to (?) Upper Precambrian
		Disconformity			
	Brarsul	(ii) Ash grey tuff, agglomerate, argillite.	0-200		
		(i) Slate, limestone, chert. *Microfossils.*	5-200		
		Unconformity			
R	Zor	Grey, bluish tosteel grey diamictite.	0-800	Langera, Manjir	*P*
		Unconformity			
a		*Upper*: Slate, phyllite, schistose phyllite, quartzite interbands, pebbly and gritty lenses.	150-1000	Sunbain Quartzite	*r*
	Pogul	*Middle*: Grey, greenish, whitish quartzite with gritty lenses; slate, phyllite intercalations and bands.	100-600	*C h a m b a*	*e*
m					*c*
		Lower: Slate, phylite occasional quartzite. *Dhadpeth Member*: Garnet schist with quartzite, calcsilicate and marble lenses in Jowartha-Maru Sudar section towards northeast.	300-1500		
s				Bhadarwah Slate	*a*
	Batrau	Phyllite, arenaceous phyllite, quartzite, diamictite, crystalline limestone	500-1500	*F m.*	*m*
u					*b*

Table 1 (Contd.)

Formation	Member	Lithology	Thick-ness m.	Equivalents in Bhada-rwah-Chamba Basin	Age
	Khaura	Slate, phyllite, schistose quartzite, diamictite, limestone, dolomite.	0-300		*r*
		——— Unconformity ———			
Dumgali Quartzite		Grey, greenish, buff, whitish, flaggy and massive quartzite, phyllite, schist.	0-500	? Kilar (Vaikrita) Group	*i*
		——— Unconformity ———			
Salkhala		Phyllite, schist, carbonaceous and graphitic, garnet and kyanite schist, paragneiss, limestone, crystalline limestone, quartzite, gypsum lenses. (Base not exposed)	-	Salkhala, Khokhan	*a* *n*
		——— Panjal Thrust ———			
		Rocks o 'parautochthonous Zone'			
		Intrusives			
		Basic intrusives: Doleritic, metadoleritic, amphibolitic sills and dykes occurring in all the formations from Salkhala to Agglomeratic Slate.	-		Upper Palaeozoic (?)
Piparan Granite		Leucocratic, medium to coarse, porphyritic, foliated, gneissose, biotite granite; intrusive into Salkhala, Dumgali and Ramsu formations. Gabbroid-leuco-/mesogranitic differentiates occurring locally.	-	Kaplas Granite, Dalhousie Granite	Cambrian (?)

forming two limbs of a fold with the middle quartzite unit of Pogul ('Muth Quartzite') as the core, which is erroneous. As dicussed elsewhere, the present work enlarges the scope of 'Ramsu' as a formation, wherein the 'Ramsu Formation' of Vohra (1966) near Ramsu form its basal 'Khaura Member', while his 'Ramsu Formation' of Paristan Gad represent its top 'Zor Member'. These units have neither any physical strike continuity nor can they be explained by folding and thus do not belong to the same stratigraphic horizon.

A stratigraphic break is recognised between Salkhala and the next succeeding Dumgali Quartzite or Ramsu Formation in the west. However, towards northeast in Piparan-Maru Sudar section, the intervening Dumgali Quartzite is absent, and the unconformable contact between Salkhala and Dhadpeth Member of Ramsu Formation here is obliterated due to high metamorphic imprint. Similar unconformity is also envisaged in Doda-Bhadarwah section, where Dumgali Quartzite between Salkhala and Bhadarwah Slate is again absent.

The other stratigraphically less understood formation is that of 'Chamalwas'. Vohra (1964, unpublished) recognises this formation below 'Ramsu' in Paristan area and assigns it to? Cambro-Silurian or older, Bhatia and Bhatia (1973) in Chamalwas-Shahbanbas sector equivalent to Precambrian Ramban Formation, Sharma *et al.* (1979) in Ramsu-Banihal between 'Muth' and Syringothyris Limestone and of Lower Carboniferous age, while Srivastava (1979) recognises it below basal 'pebbly phyllite' of 'Ramsu Formation' in Chhatru area and equates it with Precambrian 'Dogra Slates'. The present work, however, reveals the 'Chamalwas' of above workers to represent either the lower or upper units of Pogul Member of Ramsu, or the Machhal Formation, or even combinations of the two. In Chamalwas-Shahbanbas sector, for example, the E-W Shalagaddi Fault has juxtaposed the argillites of the lower units of Pogul with those of Machhal Formation, and the two together are referred to as 'Chamalwas' which is erroneous. Thus in terms of lithological association, stratigraphical position and age connotation, this formation is much misunderstood and would serve best if its usage is discontinued.

In the Duligam area near Banihal, Sharma *et al.* (1979) did not map the prominent E-W Chhankut Fault, along which the upthrown Lolab-*Syringothyris* Limestone-*Fenestella* Shale succession abuts against the downthrown Ramsu-Machhal block. Thus the 'pebbly slate' and the overlying limestone-bearing sequence, *i.e* Zor and Brarsul members of Ramsu and Machhal formations respectively of present workers, is considered by Sharma *et al.* (1973) to be the lateral variant of '*Syringothyris* Limestone' in

Nil-Pogul-Paristan section in the southeast.

The Machhal Formation, occuring between Ramsu and Lolab formations, has assumed significance because of the occurrence of Latest Precambrian microfossils from its lower Brarsul Member, thereby indicating a possible age range of Late Precambrian to Early Cambrian for the whole of this formation. Tiwari (1988) record conodonts *Protohertzina* and ? *Taliella* from a greyish black slate from 'lower part of Lolab Formation' in Lolab valley of Northwest Kashmir and expect the Precambrian-Cambrian boundary to lie around this horizon. However, based on the studies by first author in association with Gopendra Kumar during IGCP Project 29 (demarcation of Precambrian-Cambrian boundary) assignment in the same area, this horizon and location fall well within the 'Machhal Formation', and occurs stratigraphically below the trace-fossil bearing basal Lolab Formation. In the same area, Raina *et al.* (1983), Kumar *et al.* (1984) and Maithy *et al.* (1988) assign a Late Precambrian age for Machhal based on trace-fossil and acritarch studies from upper Machhal and Lolab formations.

A relatively younger age, as indicated for Machhal Formation of Southeast Kashmir in the present area, could be explained by its being a time-transgressive facies of Early Cambrian Lolab Formation of Northwest Kashmir. However, in both these areas, the dominantly argillaceous suite of Machhal is succeeded by the characteristic trace-fossil bearing rhythmites of basal Lolab. The typical members of latter, namely Razdain and Vel, too are distinguished in both. The diamictite-bearing Ramsu Formation is found to underly Machhal in parts of Northwest Kashmir (Raina & Sehgal, 1983-84, unpublished) and even limestone and chert is recognised in basal Machhal in some sections here. All these factors negate the possible time-transgressive equivalence of Machhal of Southeast Kashmir with that of Lolab of Northwest Kashmir.

In the Chhatru-Singpor section to the northwest, Wakhaloo and Dhar (1971) erroneously refer the entire succession between present Zor diamictite of Ramsu and the Agglomeratic Slate proper below Panjal Volcanic as 'Agglomeratic Slate' as also pointed out by Fuchs (1975), Srivastava (1979) and Gupta *et al.* (1979). The present work also discounts the existence of the 'thrust' between their Precambrian metamorphites and the so-called 'Agglomeratic Slate'. The 'Ramsu Formation' of Srivastava (1979) and 'Chingam Formation' of Gupta *et al.* (1979) in the same area, both referred to as Cambro-Silurian in age, stand resolved into Ramsu, Zilant, Lolab and Karihul formation of Precambrian — Middlecambrian age. The silurian — Devonian Margan Formation is absent in the present section Gupta *et al.* (1983) define a new 'Sinthan Formation' of Lower-Middle Carboniferous age in Singpor area and classify it into three members namely *Syringothyris* Limestone, Passage Bed and *Fenestella Shale*. Since *Syringothyris* Limestone and *Fenestella* Shale are well known formational names in Kashmir, the use of 'Sinthan' becomes redundant. Similarly, the 'Passage Bed Member' can form the basal unit of *Fenestella Shale*.

A major stratigraphical break is reflected above Late Precambrian-Early Cambrian Machhal or Lolab formations in Banihal-Desa area. The succeeding formations here are either Lower Carboniferous *Syringothyris* Limestone or Lower Permian Panjal Volcanic respectively. This vindicates Wadia's (1934) contention of 'Mid-Palaeozoic unconformity' in the Kashmir basin, which is of far greater magnitude in this part of the basin. Sharma (1976), however, did not recognise this important break. A similar break between Late Precambrian-Early Cambrian Katari Gali Formation (= Machhal) and Upper Carboniferous-Lower Permian Agglomeratic Slate-Panjal Volcanic (Table 1) was recognised in the nearby Bhadarwah-Bhallesh basin to the southeast by the first two authors during recent studies there.

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