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Indian Institute of Geomorphologists (IGI)

## **B4: Geomorphological Field Guide Book on KASHMIR HIMALAYA**

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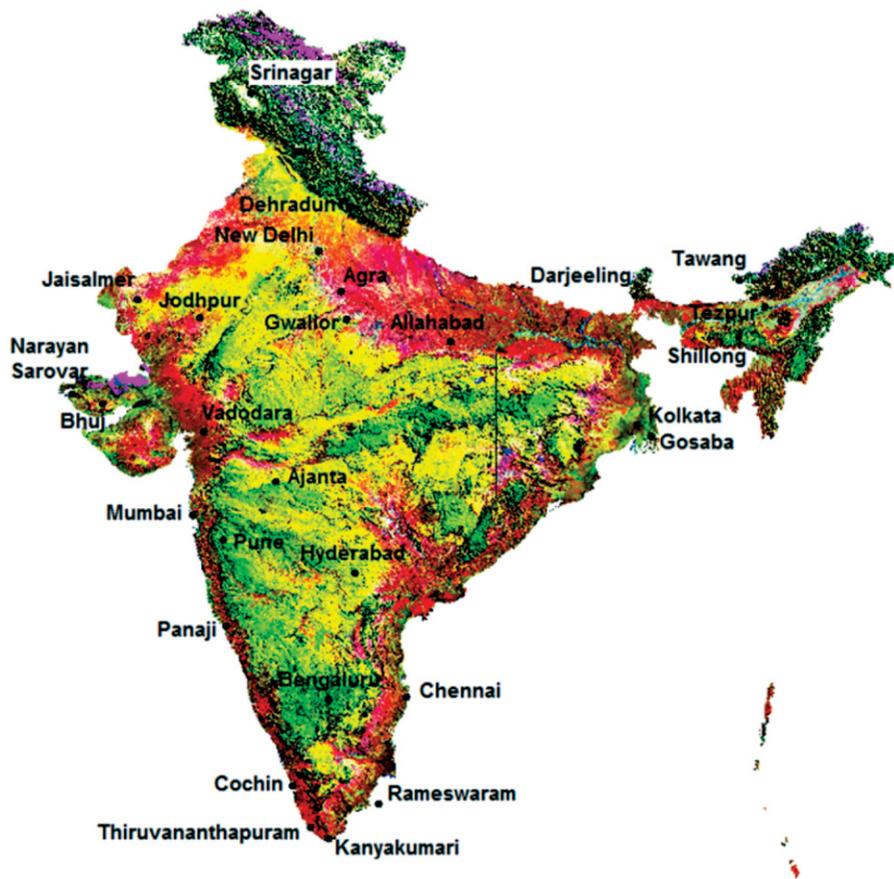


Image-map of India, showing some places of interest for the 9th International Conference on Geomorphology, 2017 (Map prepared by A. Kar through processing of relevant ETM+ FCC mosaics and SRTM 1km DEM, both sourced from the US Geological Survey site). Boundaries are approximate.

## Geomorphological Field Guide Book on Kashmir Himalaya (12-18 November, 2017)

### Itinerary

Day	Date	Travel		Driving dist. in km	Place
		From	To		
Day 1	12 November 2017	Delhi	Srinagar	600 (aerial)	Arrival in Srinagar (Stay)
Day 2	13 November 2017			–	Breakfast, Srinagar
		Srinagar	Sonamarg	87	
		–	–	–	Spot-1 Sonamarg valley
		–	–	–	Lunch, Sonamarg
		Sonamarg	Thajwas	7	
		–	–	–	Spot-2 Thajwas Glacier
Day 3	14 November 2017	Thajwas	Sonamarg	7	Sonamarg (Stay)
		–	–	–	Breakfast, Sonamarg
		Sonamarg	Machoi	30	Spot-1 Machoi Glacier
		–	–	–	Machoi Glacier
		–	–	–	Lunch, Machoi
		–	–	–	Machoi Glacier
Day 4	15 November 2017	Machoi	Srinagar	127	Srinagar (Stay)
		–	–	–	Breakfast, Srinagar
		Srinagar	Wular Lake	50	
		–	–	–	Wular Lake
		–	–	–	Lunch, Wular Lake
					Wular Lake
Day 5	16 November 2017	Wular Lake	Srinagar	50	Srinagar (Stay)
		–	–	–	Breakfast, Srinagar
		Srinagar	Hirpur	60	
		–	–	–	Spot-1 Hirpur
		–	–	–	Lunch, Hirpur
		Hirpur	Pampore	45	
		–	--	–	Spot-2 Pampore
		Pampore	Srinagar	15	
Day 6	17 November 2017	–	–	–	Spot-3 Srinagar (and stay)
		–	–	–	Breakfast, Srinagar
Day 7	18 November 2017	Srinagar	Pahalgam	90	Spot-1, Pahalgam
		–	–	–	Breakfast, Srinagar
		Srinagar	Delhi	600 (aerial)	Departure



## A. Kashmir Himalaya: An Introduction

The field guide book is a part of the 9th conference of International Association of Geomorphologists to be held at New Delhi, India, from 6-11th November 2017. The guidebook consists of brief descriptions of the geomorphic sites to be visited during the conference field trip to Kashmir Himalaya, (Fig. 1 and 2). Since the participants would be visiting various locations in Kashmir Himalaya, a brief geomorphic description is provided on the landscape evolution related to the history (geology), structural setup and to geomorphic features.

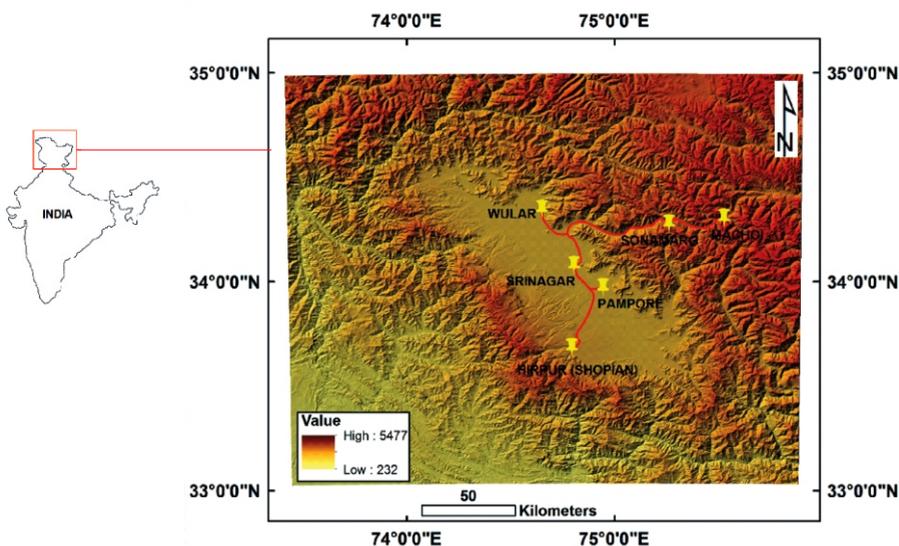


Fig. 1.  
Locations to be visited in Kashmir Himalaya.

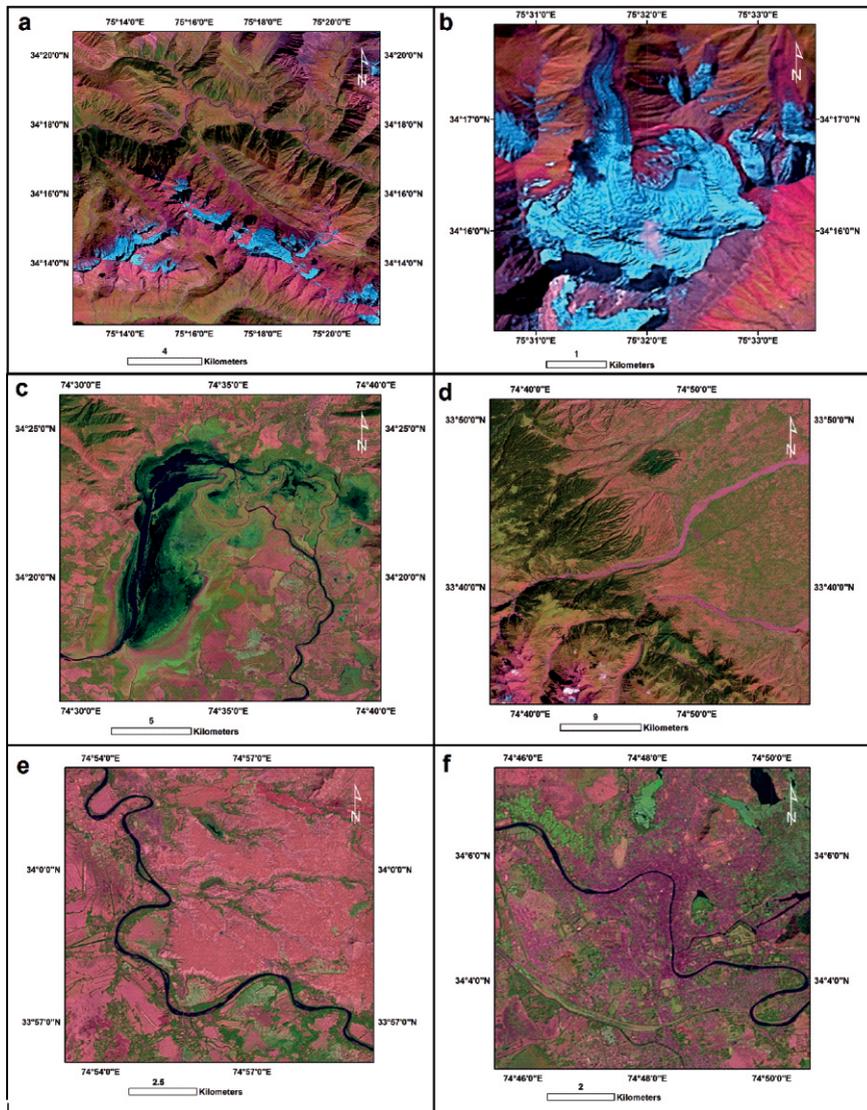


Fig. 2.

Landsat-ETM image subsets showing the major spots to be visited during the excursion (a) Sonamarg and Thajwas, (b) Machoi Glacier, (c) Wular Lake, (d) Hirpur (Shopian), (e) Pampore and (f) Srinagar.

## HIMALAYA

Mountain belts created by continental collision represent the most dominant geologic features on the surface of the Earth. The Rockies and the Appalachian belt in North America, the Andes in the South America, the Ural mountains in central Eurasia, the Alps of Europe and the Himalayas are some of the best examples, each extending for thousands of kilometers. A great deal of attention has been paid to the evolution of these mountain belts since the advent of plate tectonics. The youngest and perhaps the most impressive of all the continent-continent collisional belts on the Earth is the Himalayan orogen; its evolution has long been subject of discussions (Gansser, 1964; Molnar and Tapponnier, 1975; Bhat, 1987; Treloar and Searle, 1993). The Himalayan mountain building is the product of collision between India and Eurasian plate that began during the Eocene epoch and is considered to be one of the major tectonic events in the Cenozoic era and a live example of collision mountain belt as the process of mountain building is still active, forming the highest range and plateau in the world (Molnar and Tapponier, 1975; Molnar and Chen, 1977).

The Himalayan mountain belt extends over ~2500 Km from northwest to northeast with a variable width of 230 to 330 km, terminating at both east and west ends with syntaxial bends. Based on the works of Burrard and Hayden (1932), Wadia (1931), Bordet (1961), Gansser (1964), Le Fort (1975), Windley (1985), Hodges (2000), Steck (2003), DiPietro and Pouge (2004), the Himalayan terrain from south to north has been conventionally divided into sub parallel tectono-stratigraphic subdivisions: Sub-Himalaya or Outer Himalaya, Lower Himalaya or Lesser Himalaya, Higher Himalaya or Greater Himalaya, and Trans Himalaya or Tibetan Himalaya.

The dividing planes between these subdivisions are the thrusts of regional dimension with varying tectonic activity (Gansser, 1964; Valdiya, 2002) and each subdivision has a characteristic stratigraphy which is hardly co-relatable with adjacent zones (DiPietro and Pouge, 2004). From south to north, the classic bounding faults are: the Main Frontal Thrust (MFT) between the Indo-Gangetic alluvial plain in south to the Outer Himalaya in north, the Main Boundary Thrust (MBT) between the Outer Himalayas and the Lesser Himalayan sedimentary zone (LHSZ), the Main Central Thrust (MCT) between the Lesser Himalayas and the Higher Himalayan Crystallines (HHC); the South Tibetan detachment system (STD) between the Higher Himalayas and the Tethys Himalaya, and finally the Indus-Tsangpo suture zone (ITSZ), which marks the northern limit of exposed Indian plate rocks. Along each of these thrusts, tens to hundreds of kilometers of the displacement between India and Asia have been accommodated (Gansser, 1964; Powell and Conaghan, 1973; Seeber and Armbruster, 1981; Schelling, 1992; Treloar et al., 1992; Srivastava and Mitra, 1994). All three zones exert a major influence on the creation of the unique geomorphic architecture of the Himalaya.

## Kashmir Himalaya

Neogene–Quaternary intermontane basins occur throughout the Himalaya and southern Tibet. Of the numerous intermountain basins in the Himalaya, the Kashmir basin with distinct NW-SE asymmetric disposition, juxtaposed between Zaskar mountain range in the east-northeast and Pir Panjal range in the west-southwest (Fig. 3), forms a larger segment of the NW Himalaya with basin and range topography. The Kashmir basin is believed to have evolved in the late Miocene by shifting of the NE thrust complex from the base of the Zaskar Himalayan side to the southwest forefront of the Pir Panjal range (Burbank, 1983; Burbank and Johnson, 1983); as a result, the NE thrust complex was replaced by the existing structural system (basement complex-MBT/MCT). This was followed by accumulation of low energy fluvio-lacustrine sediments (Karewa) that constrain initial timing of valley formation to ~5–4 Ma (Burbank and Johnson, 1983; Burbank and Reynolds, 1984). Bhat (1982) proposed a rift-reactivation model to explain the formation of the Kashmir basin along two deep-seated faults, i.e., the Panjal thrust from the west and Zaskar thrust from the east. However, recent work suggests that the Kashmir basin evolved as a result of movement along basement dextral strike-slip fault (Alam et al., 2015a,b).

Several thrust faults have been delineated in southwest of the Pir Panjal range including the MCT/Panjal, MBT/Murree, Riasi, and Kotli thrusts (Thakur et al., 2010); as a result, the zone has a complex pattern of faulting (Fig. 3). The southern-most deformation front of Kashmir Himalaya is defined by an active fold belt known as Surin-Mustgarh anticline that extends from river Beas in southeast to Jhelum in the northwest. Furthermore,

several out-of-sequence faults have been identified and delineated between Himalayan Frontal thrust (HFT) and Main Boundary thrust (MBT). These include the Riasi thrust (RT), the Kotli thrust (KT) and the Bagh-Balakot fault (BBF). The latter was the source of Oct-2005 Mw 7.6 Muzaffarabad earthquake (Kaneda et al., 2008; Hussain et al., 2009; Thakur et al., 2010), which claimed more than 80,000 lives. No faulting was known north of

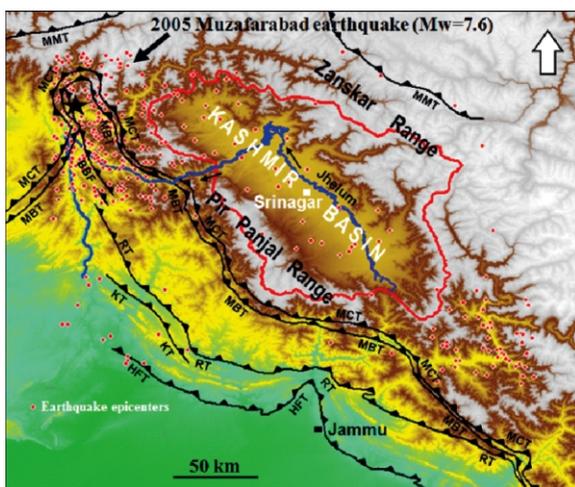


Fig. 3.  
Kashmir Himalaya and its structural setup.

the MCT/Panjal thrust or MBT/Murree thrust except a high angle thrust fault (reverse) with an average northeast 60° dip and NW-SE strike length of ~100 km (Madden et al., 2010, 2011; Ahmad and Bhat, 2012; Ahmad et al., 2013, 2015; Ahmad, 2014). The unrelenting competition between deposition, erosion and tectonic activity produced most of the geomorphic features in the Kashmir basin.

Kashmir basin is spread over an elevation ranging from the minimum of ~1560 meters to the maximum of 5550m amsl. The maximum hydrographic dimensions of the Kashmir basin are 185 km (length) and 120 km (width). Only outlet for the drainage system is Baramulla-gorge, where the Jhelum River exits the Kashmir basin. The bordering transverse tributaries flowing across the Pir Panjal and Zaskar ranges have brought enormous amount of fan deposits consisting of boulders, sand and silt over extensive areas at their confluence. The tributaries of Jhelum River are also responsible for changing the shape of the landform through degradation and aggradations processes.

The basin has diverse geological record ranging from Precambrian to Recent (Middlemiss, 1911; Wadia 1975; Raza et al., 1978; Bhatt, 1989). With Salkhala series (Precambrian) and Dogra slates (lower Cambrian) as oldest stratigraphic basement floor (Wadia, 1975; Krishnan, 1982), the basin has a more or less full sequence of fossiliferous Paleozoic such as Panjal Volcanic series (Panjal trap and Agglomeratic slate), gneissose granite, Gondwana shale, Fenestella shale, Syringothyris limestone, Permo - Triassic rocks, conglomerate beds, and varved clays in various parts of Kashmir (Lydekker, 1883, Middlemiss, 1910; Wadia, 1975; Krishnan, 1982). The exposed bedrock units of the valley consist of Panjal Volcanic series (Panjal trap and Agglomeratic slate), gneiss or gneissose granite and metamorphic schists, and Triassic limestone.

### **Geomorphological Evolution Kashmir Himalaya**

Kashmir Himalaya has youngest mountain range possessing a dramatic landscape with snow, glaciers surging river system spreading between the Pirpanjal and the Zaskar and establishment of Indus water shed (Jehlum-Suru Zaskar). The Orogen is marked by two tectonic episodes. The first episode is related to collision between India and Asia that resulted crustal shortening, thickening and initiation of metamorphic impact on sedimentary series of Indian continental margin. The second episode lead to extensional tectonic structure related to exhumation of high-grade metamorphic rock of High Himalayan Crystalline that lead to compression of beds due to ductile normal shearing, doming and normal faulting. The geological events go back to 60 Million years to attain its present elevation and since 15 Million years has lead to initiation and establishment of monsoon system in the region. Pleistocene has been the time period when pulsating uplifts resulted in pushing Himalaya further up causing precipitation in the form of snow around the year giving rise to large glaciers (Valdiya, 1993). Cold conditions were set in Kashmir Himalaya and its adjoining valleys as early as 2.5million years ago. The glaciations period was followed by time de-glaciation that resulted in formation of huge lakes, this period was followed by extreme dry condition when fierce dry wind blew Kashmir valley (Pant et al.1978). The temperature of ice plays major role in movement and morphological activity resulting in staggering geomorphological diversity, exceptionally rich field for study of glacial, fluvial and arid cold landscapes.

## B. Description of the Field Sites

During this program participants would have an overview of the general geomorphic setup of the major landforms of Kashmir and Karakorum Himalaya particularly with regard to the landform characteristics of beautiful Kashmir Valley and Drass valley (Ladakh) enclosed by Pir Panjal and Zaskar ranges. These youngest mountain ranges have dramatic landscape with snow, glaciers and surging river system of Jhelum, Sind and deposition rim land along the basin floor produced by hill slope process. The landscape presents wide range of changes in land form due to forces related geomorphic environment related to cold climate, humid climate and dry climate geomorphology related to different processes and their landforms association with Glacial, Fluvial, and Aeolian actions, that are available at every new step; however, during this program following geomorphic sites have been selected to observe them in context of process geomorphology.

### **DAY 1: FROM SRINAGAR TO MACHOI GLACIER (120 km)**

#### **Spot 1: Sonamarg**

Sonamarg meaning 'golden meadow' is an alpine valley that evolved from glacial action. Sonamarg is situated at an altitude of 2800 m, ~87 km northeast of Srinagar. Sonamarg representing one of the preferred tourist destinations remains inaccessible during winters due to heavy snowfall and is usually open for visitors in late April. The drive to Sonamarg is through the spectacular facets, deep rock-cut gorges, grassy meadows, and forested slopes along the banks of River Sind. The river originating below the lofty peaks near Zojila (3256m) and joined by number of other head streams from Amaranth (5003m), Kolahoi (5425m) and Panjtarni snow fields, flows through Sonamarg. Sonamarg also serves as a base camp for major tourist routes leading to several mountain lakes, e.g., Vishansar, Kishansar, Gadsar, Satsar and Gangabal, including holy cave of Amarnath for religious pilgrimage. It is also the take off point for a drive to Ladakh across Zojila, a major pass in the Great Himalayan Range, through which the Srinagar-Leh Road passes. Sind basin in general and Sonamarg in particular is an appropriate area to observe the last glacial remnants. Dainelli in 1922 made detailed observations on the glacial sequences in the Sind valley and recognized four glaciations:

- (a) First interglacial: the cemented conglomerate of Malshahibagh rests on the glacially molded hill slope and underlies the Karewa clays laid down as the Karewa lake began to form.

- (b) Second glacial: the fluvio-glacial deposits and glacial trough below Gund are given in evidence.
- (c) Second interglacial: it was suggested that the upper Karewa clays were laid down in the lower Sind.
- (d) Third glacial: the striations, roches moutonnees, glacially scooped floor and moraine deposits at Gund in the Sind valley.
- (e) Third interglacial: it was not discussed
- (f) Fourth glacial: the upper Sind was covered with ice and the while Sonamarg, producing moraines there. Dainelli (1922) also noted two terraces in the Sonamarg, which he correlated with fourth glaciations.

However, De Terra and Patterson (1939) have disagreed with the lower glacially molded hill of Malshahibagh interglacial unit of Dainelli (1922). De terra and Paterson (1939), on the basis of general physiography divided the whole Sind into three parts:

1. The lower Sind is a mature pre-Pleistocene form, extending from the outlet to a point near Hari and carrying the evidences of oldest glaciations only. The region has large and thick deposits of outwash and of lake clays.
2. The middle Sind extends from the Hari to the natural boundary formed by Gagangiyer gorge. The third glacial advance alone has produced moraines and evidence for earlier glaciations lies well above the present valley floor, truncated by erosion into a rising block at Hari.
3. The upper Sind carries the moraines of the fourth and later ice advances above Gagangiyer gorge, which can be divided into the Sonamarg meadow and the Baltal valley.

### **Spot 2: After breakfast whole day tour on the Thajwas glacier**

Thajwas is an ideal and easily accessible spot to understand large scale glacial retreat and preserved features. Thajwas Glacier is located about 7 Km from the Sonamarg valley. The adjoining area remains permanently covered with snow throughout the year. Several small streams are gushing out from the Thajwas Glacier to join Sind via Sonamarg. Thajwas Glacier occupied about 2.99 Km<sup>2</sup> in 1962 and has reduced to mere 1.07 Km<sup>2</sup> in 2001, which indicates that the glacier has lost 1.92 Km<sup>2</sup> (~63%) of its aerial extent within the span of 40 years. The drastic retreat of the Thajwas Glacier can be attributed to the prevailing climatic variability. During the last four decades of 20<sup>th</sup> century, mean maximum temperature has increased by 0.4°C while as the mean minimum temperature has registered an increase of 0.1°C.

## **DAY 2: FROM SONMARG TO MACHOI GLACIER (30 km)**

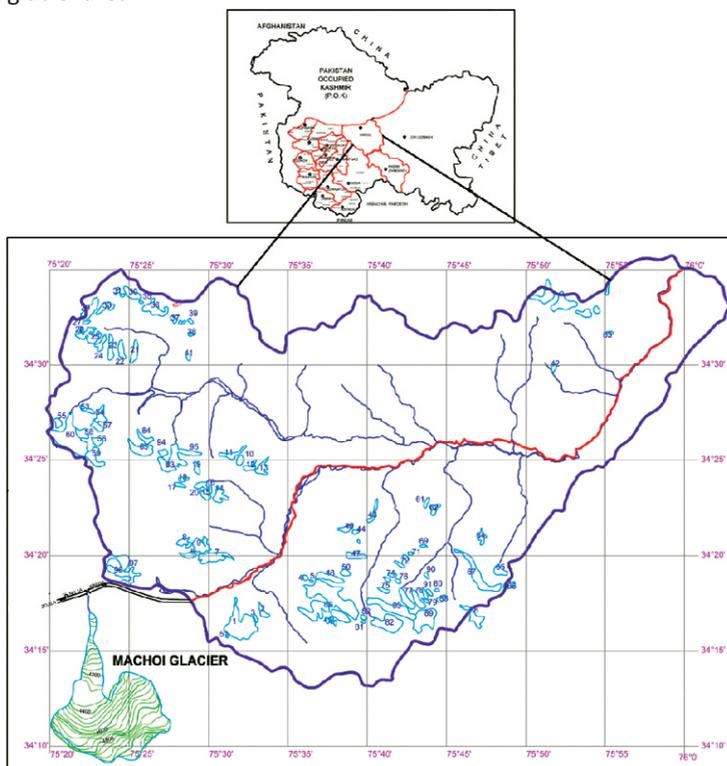
### **Spot 1: Machoi Glacier**

Machoi is a small transverse valley glacier housed in Kanipathar ranges located SE of Zojila that separates it from westerly Sind Valley. It is 4.19km long and 1.5km to 3 km wide has been named after the highest peak (Machoi Peak ~5458m amsl) that lies at the eastern end of the glacier. Baltal and Zojila are two important points on the 30 km road stretch from Sonamarg to Machoi; the former represents the base station of Hindu pilgrimage to Amarnath Cave, while as later one Zoji-La pass is a gateway to Drass-Ladakh situated on National Highway 1-a road, connecting Srinagar to Kargil and Leh. The Srinagar-Kargil road remains closed to vehicular traffic during winter season due to closure of Zojila pass as result of heavy snowfall. The valley has a distinct climatic characteristic due to its location in the shadow zone of Great Himalaya having an aerodynamic link with the air mass of westerly air flow and westerly disturbances (originating from Mediterranean and Caspian ocean) moving aloft the Pamir Range giving rise to cold anticyclone leading to production of thermal gradient during winter season (October to May) that is responsible for anchoring southerly jet. The study region has cold sub arid type of climate. The winters are long chilly (mean minimum temperature  $-15^{\circ}\text{C}$  to  $-25^{\circ}\text{C}$ ), lasting November to May. Summers are short (June to September) mild (temperature varies between  $-8^{\circ}\text{C}$  to  $25^{\circ}\text{C}$ ). Nearly 72% of its annual precipitation is received by Western Disturbances that is confined to November to May which sometimes prolongs to summers as well otherwise summers get scanty rains

Machoi glacier is selected as benchmark glacier in Drass basin, Kargil, Ladakh Himalaya (Karakorum) been monitored and studied by many geologists/glaciologists in the past 130 years (Lawrence 1895 ; Oldham 1895 ; La Touche 1910; Raina 1975; Koul et al 2016). The glacier has experienced a marginal change in glacier extension and volume. The glacier is about one kilometer from the road head, has evidently extended almost down to where road now runs and is shown by heaps of moraines material. The research team of university of Jammu extensively monitored the glacier from the snout (4350m) to the altitude of 4800 m (accumulation zone) by GPS survey and carried continuous field mass balance measurements during 2011 to 2014. The glacier has a positive net balance with cumulative specific balance of 0.16 m w.e./km/yr. This has resulted in shifting ELA from 4540 m asl in the year 2011-2012 to 4509 m asl 2013-2014 (Table 5) and the glacier snout to advance 4 meters in central part (3656 m to 3652 m), but along the sides there has been deformation squeezing and retreat (0.56 m).

The climatic data of Drass reveals that there has been a small increase in annual mean temperature at Drass of  $-0.426^{\circ}\text{C}$  per decade prior to year 1995. However, since 1996

the rate of increase has accelerated to 0.375°C per decade. The analysis of mean monthly temperature (Maximum and Minimum) trend line for period 28 years was lack of fit of lower portion of data (1988-2000) to upper portion of data (2001-2013); hence it is attributed to phase transition threshold. It indicates that winter is cooler, late winter warm humid, and summer cool and wet during time series 2001-2013 in comparison to cold winters (November-March), mild late winter (March-May) and warm and dry summer during 1988-2000. Further, the decrease in mean maximum as well mean minimum temperature during 2004-2013 is associated with change with inter-decadently of Pacific Oscillation and with increase in El Nino/southern Oscillation events that resulted in lower ablation season temperature particularly during summers of 2004-2014 (Yasunari, 1987). These trends in weather conditions have undoubtedly led a favorable environment for decelerated retreat to the extent of no change in glacier area to slow retreat of glacier snout and marginal loss in Machoi glacier area



**Fig. 4.**  
 Location map of Drass glacier sub-basin and Machoi Glacier,  
 Kargil Ladakh (after Koul et al., 2016).

### DAY 3: FROM SRINAGAR TO WULAR LAKE (50 km)

#### Spot 1: Wular Lake

Wular Lake is located in northeastern corner of Kashmir basin at a distance of ~50Km from Srinagar. Wular is the largest freshwater lake in India spread over an area of 189 km<sup>2</sup> with extensive marshes of emergent and floating vegetation. In view of tremendous ecological and economic importance, the lake has been declared as Ramsar site in the year 1990 (no. 461). The area around Wular lake comprises of a range of geological Formations such as Permian, Panjal trap, Agglomeratic slate, gneiss or gneissose granite and metamorphic schists, upper and lower Triassic limestone and Slate with scanty intercalations of black Shale as hard rock units and recent Alluvium and; however, the area is dominated by the upper Palaeozoic and Triassic rocks (Middlemiss and Bion, 1910; Thakur and Rawat, 1992). The upper Palaeozoic rocks (Agglomeratic slates, Panjal Traps, slates and granites), overlain by Triassic limestone series (blue and dolomitic limestone), cover the maximum area from NE side of Wular lake. At some places the Triassic rocks are overlain by recent sediments. Compared to hard rock terrain, Recent Alluvium covers a small portion of the Wular lake surroundings, which comprises of pebbles, sand silt and clay.

Wular acts as a storage sump for whole drainage of the Kashmir basin; however, with continuing inflow of the sediment load and solid waste the maximum depth of lake has reduced to 7 meters from 20 meters in 18th century. Moreover, state of human interference, in the form of settlement expansion around the lake, farming practices and encroachment has resulted in degradation of the ecologically sensitive aquatic ecosystem (Fig. 5). This site provides an opportunity to witness transformation of natural landscape and alteration of aquatic system because of natural and anthropogenic reasons over time.



*Fig. 5.*

*East to west view of the Wular Lake.*

**DAY 4: FROM SRINAGAR TO HIRPUR (SHOPIAN) (60 km)****Spot 1: Hirpur (Shopian)**

The site has been selected to observe one of the most remarkable geomorphic features of Kashmir valley, i.e., Karewa (Plio-Pleistocene) deposits. Karewa is fluvio-glacial and lacustrine sediments, which has been assigned Group status (De terra and Paterson, 1939; Farooqi and Desai 1974; Bhatt 1989) (Fig. 6; Table 1). These deposits spread in the form of mounds, terraces, flat lands, dissected plateaus, and pop-ups from Shopian-Kulgam in the south Kashmir through Badgam in the middle and extending to Handwara for a stretch of about 120-130km with varying width from 13-15km (Wadia, 1975). Dominant in SW of the Kashmir basin, the Karewa deposits occupy nearly an area of 2500 km<sup>2</sup>. These deposits consist of 1300m thick sequence of unconsolidated clays, sands, and conglomerates with lignite beds unconformably lying on the bedrock and are overlain by the recent river alluvium (Bhatt 1975, 1976; Wadia 1975; Burbank and Johnson 1982; Singh 1982). The Karewa deposits preserve the record of past four million years in which the sedimentation is controlled by the tectonic events (Burbank and Johnson 1982). The Karewa deposits also containing volcanic ash horizons where some of the ashes from Pir Panjal side were found to be  $2.4 \pm 0.3$  Ma old (Burbank and Johnson, 1982). Based on unconformity (a boulder bed) the Karewa Group has been subdivided into Hirpur and Nagum Formations by Singh (1982); whereas, Bhatt (1989) divided them further into younger Hirpur, Nagum, and Dilpur Formations (Fig. 7). The Hirpur Formation broadly consists of gray to bluish-gray clays, light-gray sandy clays, fine to coarse-grained green to purple sands, conglomerates, lignite, and lignitic clays. The Nagum Formation is made up of fine to coarse-grained greenish to purplish sands, gray and ochre sandy clays, ochre and cream colored marls and gravels, while as the upper Dilpur Formation mostly consists of brown silts.

The southwest Kashmir (Pir Panjal range) hosts significant Karewa deposits, descending through long gentle slope towards the valley floor as compared to short and moderately steep slopes on the northeast Kashmir (Zanskar range). The Karewa deposits are mostly capped by the loess sediments, which is the youngest unit of the Karewa group and are aeolian in origin (Pant et al., 1978; Bronger et al., 1987). These loess sediments are characterized by the presence of inter-bedded profiles of paleosols. The maximum thickness of loess is  $\sim 22$  m on the southwestern side compared to only  $\sim 4$  m on the northeastern part of the Kashmir basin. The loess sequence on SW (Pir Panjal) side is superimposed on the gravel bed of the Shopian Member of the upper Karewa. However, from NE (Zanskar) side, these loessic sediments cap the upper Karewa laminated silt of the Pampore Member. The loess deposits along northeastern part are younger than 85 ka years. However, along the southwestern part entire loess sequence is at least  $\sim 300$  ka old (Singhvi et al., 1987).

The whole lower Karewa unit is exposed along the northeast flowing Pir Panjal tributaries on the southwestern side (Fig. 6).

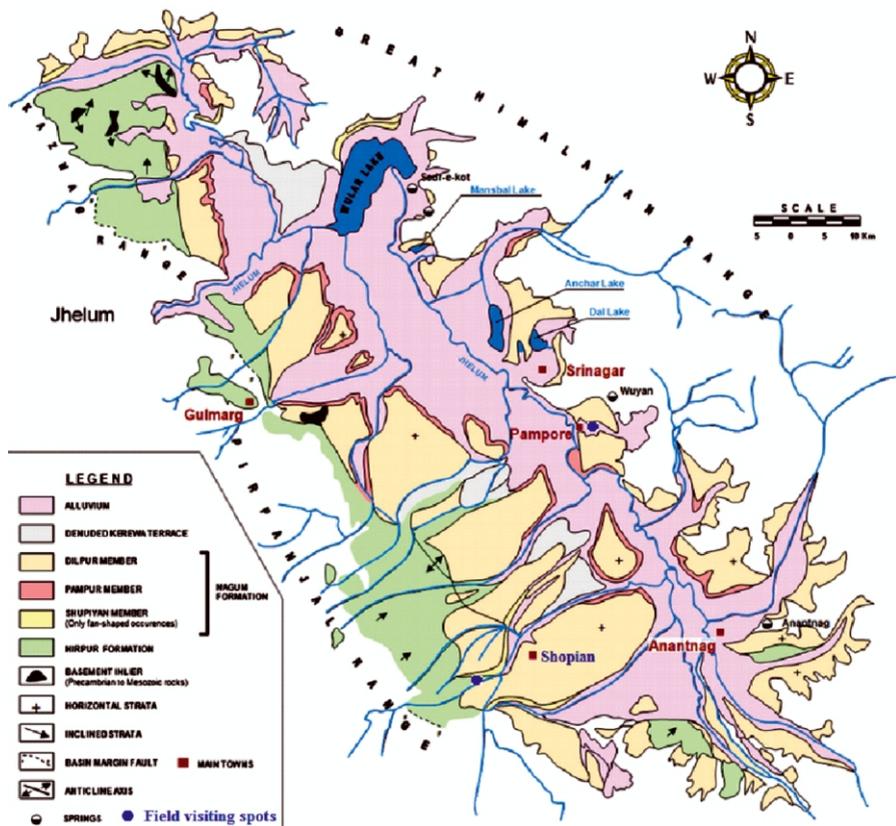


Fig. 6. Karewa Formation of Kashmir basin (after Bhatt, 1989).

Table 1: Stratigraphic succession of Karewa Formation (after Wadia, 1975; Bhatt, 1976, 1989).

Formation/Group		Lithology	Age
Alluvial deposits		Clay, sandy clay, silt with infrequent gravel	Recent to Sub-recent
Loess-paleosol succession of Dilpur Formation	Dilpur Formation	<b>K A R E W A</b>	Layers of brown silt vary from calcareous to non-calcareous types
Shopian Member	Nagum Formation		Gravels, sand, sandy clay, marl and silt
<b>Angular unconformity</b>		<b>Angular unconformity</b>	
Methawoin Member	<b>H i r p u r F o r m a t i o n</b>	<b>G R O U P</b>	Clay, sandy clay, conglomerate, varve sediment, lignite and sand
Rambiara Member			
Er.Unconformity			
Dubjan Member			
<b>Unconformity</b>			
Triassic Formation		Limestones, shales etc.	Lower, Middle and Upper Triassic
Panjal Trap	<b>P a n j a l v o l c a n i c s e r i e s</b>	Andesite, Basalts etc.	Permian
Agglomeratic slate		Slates	Upper carboniferous

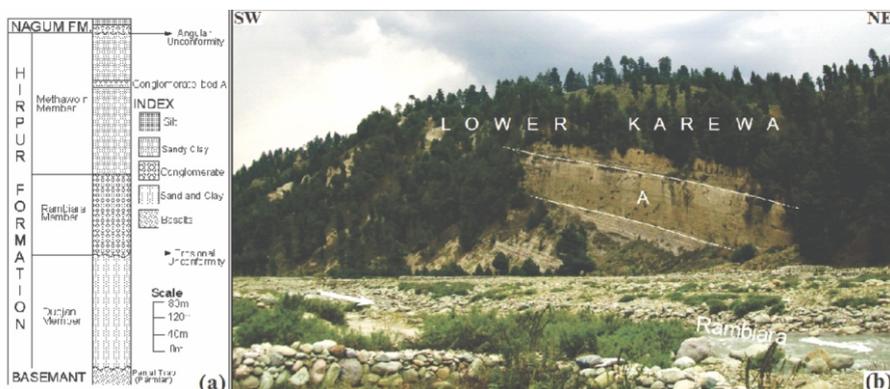


Fig. 7.

(a) Litho-column of Lower Karewa (Hirpur Formation) (after Bhatt, 1989), (b) showing exposure of tilted (NE) lower Karewa at Hirpur village in upper Rambiara valley. Letter A is younger conglomerate marker horizon in Methawoin Member.

### Spot 2: Pampore (45 Km)

While returning back from Hirpur the next spot would be the upper Karewa deposits (Pampore Member) named after nearby town Pampore. Although, Pampore Member is invariably and abundantly exposed at different locations in the cliff walls of the numerous Karewa plateau from Anantnag area in the southeast, through Bijbiara, Tral to Pattan and Baramulla area in the northwest Kashmir; however, the Member is best developed and easily accessible in Pampore town, where it is ~ 41m thick (Bhatt, 1989). The Member extends from Pampore in the north to Sambur in the south (Bhatt, 1989). Pampore Member consists of light grey and orange-coloured sandy clay and coarse to fine greenish and purple sand, with thin layers of bluish-grey to cream color clay and marlekor band (Bhatt, 1989). The base of the Pampore Member is not exposed in the type section, whereas the Triassic limestone is exposed in the adjacent parts of the section at Sambur. A characteristic lithological feature of Pampore Member is the sequential occurrence of finely laminated sand-sandy clay alterations, sand and light gray structure-less muds in vertical successions. The sand to sandy-clay alterations often show ripple structures; the sands are usually cross-bedded. The Pampore Member was deposited in a 1-2m deep lake; as a result, the lake bottom was always within the reach of waves and received enough sunlight and supported dense subaqueous vegetation. The deeper facies lack sand layers and mottling by rootlets, suggesting the maximum depth of the lake basin between 5 and 10 m. De terra and Paterson (1939) has recorded an assemblage of Mammalian vertebrate fossils including *Elephas hysudricus* from the basal part of Pampore Member. Moreover, there is a record of fresh water Ostracodes and Molluscs from the strata of Pampore Member (Bhatia, 1968).

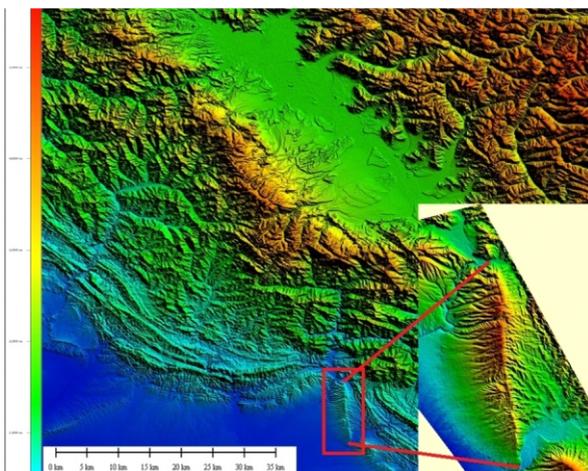
### Spot 3: Srinagar

Apart from the longitudinal tectonic belts, existence of transverse lineaments/faults is characteristic feature of Himalayan tectonics. These transverse faults trend oblique to the NW-SE grain of the Himalaya and extend northwards from the alluvial plains through the pediment zone south of foothills of the Tertiary belt into the Lesser Himalaya (Valdiya, 1979). Many of them confirm to the known deep seated ridges beneath the accretionary wedge of Indo gigantic plain (Virdi, 1979; Valdiya, 2002); and behave as wrench or tear faults. Yet little is known about their role in accommodating N-S shortening between India and Eurasia, and in most cases slip rates are only estimated from satellite geodesy and GPS. These transverse lineaments/faults show four prominent trends viz, NNW-SEE, N-S, NNE-SSW, and NE-SW.

Here, we present one of these transverse structural lineaments known as Srinagar-Pathankot Fault 'SPF' (suspected). The journey will be devoted to interpretation of geomorphic features associated with Srinagar-Pathankot Fault 'SPF'. We will explore the different landform assemblages linked to the northern segment of the 'SPF'.

Srinagar-Pathankot Fault 'SPF'-one of the transverse lineaments of NW Himalaya which runs N-S across Pir Panjal Range (PPR). This right lateral strike slip starts from Pathankot cutting across Pir Panjal Range (PPR) running through Kashmir basin for a distance of more >150 Km.

We name this fault as Srinagar-Pathankot (SPF) Fault, after the two prominent cities at its northern and southern ends respectively. The 'SPF' consists of two principal fault strands-the Southern strand runs from Pathankot up to Riasi along Sidhra ridge, the axis along which the Chenab River flows. The anticlinal ridge in fact forms a part of the NW-SE Upper Siwalik mountain belt which has shifted from its original position to N-S orientation (Fig. 8).



*Fig. 8.  
Upper Siwalik mountain belt in Jammu,  
indicating N-S orientation instead of NW-SE,  
against general trend of mountains in  
NW Himalayas.*

Here we focus on the northern strand of SPF known as Shopian-Srinagar strand. This right lateral strike slip fault starts from Rambiar wind gap running across the Kashmir basin in N-S direction. Its strike varies and is northerly in the northern segment, north of Kashmir Basin, forcing the axial River Jhelum to make a hairpin bend in its course at Srinagar and dies out up to at least mouth of Sind River.

The Shopian-Srinagar (SS) fault is characterized by geomorphic expression including river offset, shutter ridges, sag ponds, and linear, strike-parallel valleys. The obvious imprint of this S-S strike-slip fault include the first-order, near-fault tectonic landforms at the southern end of Pir Panjal range where mountain ridges initially oriented in NW-SE direction, migrate laterally in conjunction with fault motion in a meridional direction due N-S. Continued slip along S-S fault leads to stream capture of Dodhganga and Shaliganga rivers which route across the Pir Panjal range forcing them to flow in northerly direction along the fault instead of northeast. Further down, the great bend of Srinagar is an excellent offset marker where axial river Jhelum crosses S-S fault thereby, giving rise to platted structural anomaly. East of this S-S fault above the great bend of Srinagar (in the upstream direction) the river Jhelum shows anomalous compressed meanders with high sinuosity index; while as, west of this N-S fault, the river Jhelum is disposed with deflated meanders with relatively low sinuosity index.

This is further corroborated by considering the extension of the fault further north where it marks the elevated part of Srinagar city, which according to archival scribes has been devastated many times by earthquakes. This strip of elevated upper Karewa (Pleistocene deposits) sediments lies between the Dal lake on the east and the Anchar lake on the west, a tectonic situation analogous to separation of Lake Patron from Lake Vegoritis by a narrow strip of land elevated along Vegoritis fault in Ptolemais-Florina basin in NW Macedonia (Diamantopoulos et al., 2014).

### **Day 5 - Pahalgam**

Located 95 km from Srinagar at a height of 7200 ft, Pahalgam, known as the “Valley of Shepherds”, is a famous hill station in Jammu & Kashmir. Pahalgam is surrounded by thickly wooded pine forests, breathtaking vistas of meadows and snow-clad Himalayan mountains

### **Day 6 - Departure from Srinagar to Delhi**

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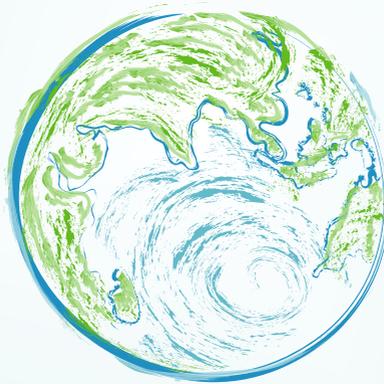
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