
The Vale of Kashmir: Landform Evolution and Processes

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Abstract

The Vale of Kashmir is one of the most popular tourist destinations in India. Nestled between the imposing Pir Panjal Range and the towering Karakoram Ranges, the bowl-shaped intermontane valley is studded with numerous freshwater lakes and green meadows. The Jhelum River meanders through the 135 km long valley and exits the oval-shaped basin through a deep gorge near Baramula. The valley preserves a unique landscape known as Karewa. These thick lacustrine and fluvial deposits, capped by loess, form high terrace-like features and cover nearly half the valley. The floodplain of the Jhelum River and the multiple lakes constitute the remaining part of the valley. It is generally agreed that the Kashmir Valley originated from the draining of a huge lake (the *Karewa Lake*), which was formed as a result of tectonic upheaval and subsequent tectonic uplift of the Pir Panjal and Zaskar Ranges. None of the Karewa deposits provide evidence of glaciers having existed during their deposition within the valley. The uplift of Pir Panjal at ~ 4.5 Ma not only triggered the deposition of Karewa sediments in the valley, but the elevated ranges formed an orographic barrier to the incoming southwest monsoon winds and enhanced the dependence of the valley on winter precipitation.

Keywords

Intermontane basins • Tectonic geomorphology • Kashmir Valley • Pir Panjal • Jhelum River • Karewa Lake • Karewa deposits

1 Introduction

The Vale of Kashmir or the Kashmir Valley, famous for its captivating and exhilarating scenic beauty, is one of the most popular tourist destinations in India. Snow-clad mountains, sparkling lakes with *shikaras* (long wooden boats) and houseboats, lush green meadows, pine forests, silver-white streams, sprawling apple orchards and lush

green rice fields attract more than a million Indian and foreign tourists every year. The bowl-shaped valley, nestled within the imposing Pir Panjal Range in the south and west, the towering Karakoram Ranges in the north, and the Zaskar Range in the east (Fig. 1), is drained by the Jhelum River, a tributary of the Indus River.

The picturesque Kashmir Valley is studded with lakes, such as Wular, Mansbal and Dal (Fig. 2). The first, a Ramsar site, is a remnant of a former bigger lake, and other two are of riverine origin and/or remnants of old beds of the river system. The Jhelum River originates from the eastern mountain girdle of the valley and flows through the Wular Lake. It exits the enclosed basin west of Baramula (Fig. 1) via a narrow gorge, cut across the Pir Panjal Ranges. The Liddar, Sind and Kishan Ganga are the main tributaries

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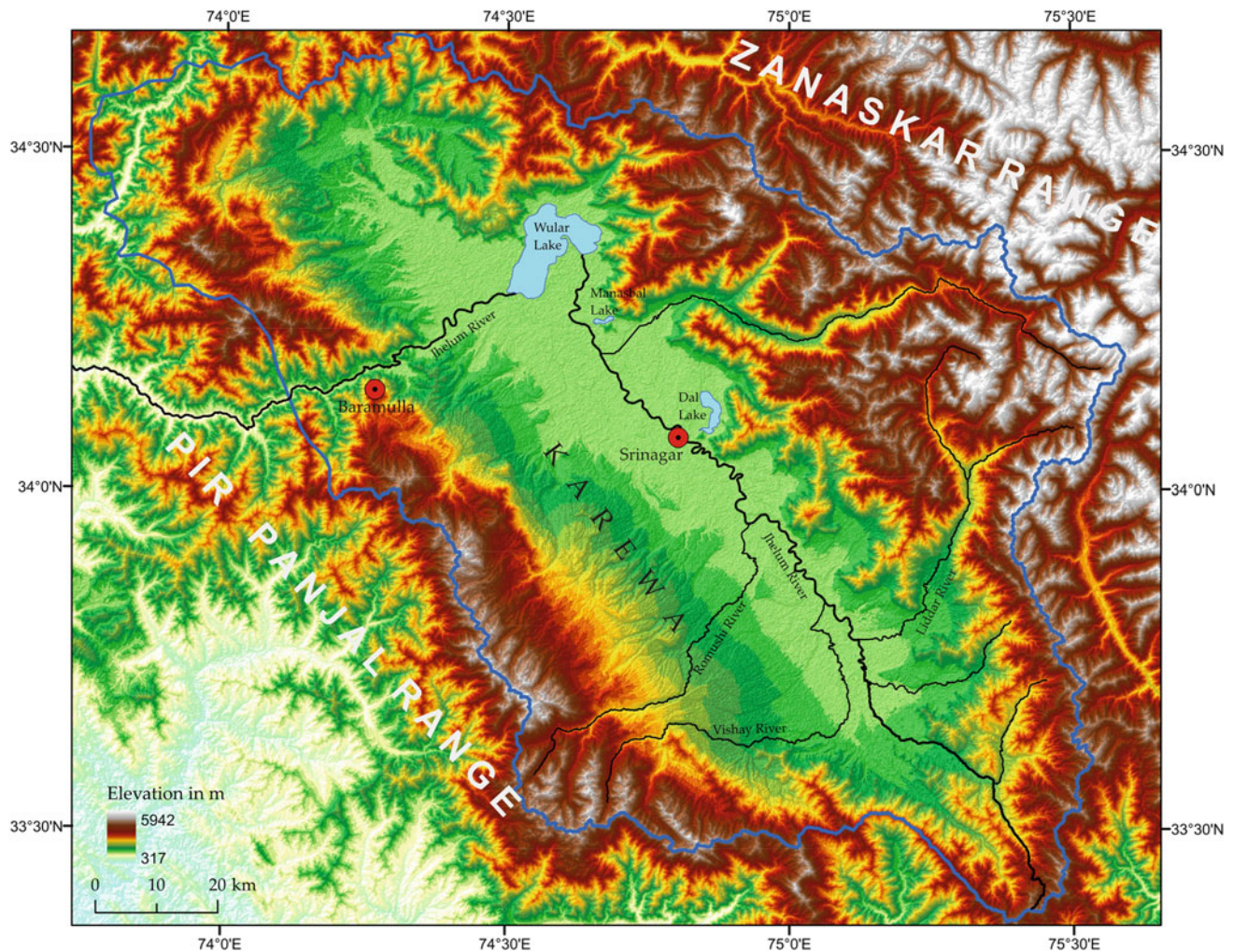


Fig. 1 The oval-shaped intermontane Kashmir Valley. The continuous *blue line* demarcates the watershed of the Kashmir Valley

from the north. The Romushi and Vishay Rivers are the main tributaries from the south.

The altitude of the valley at Srinagar is $\sim 1,600$ m a.s.l. As a result, the climate of the valley is generally cool in spring and autumn, mild in summer and cold in winter. Summer has little rain with cool nights. Emperor Jahangir (1569–1627 CE) of the Moghul dynasty, appreciating the scenic beauty and cool salubrious climate of the Kashmir Valley, called it as the “Paradise on Earth”. The moderate climate inspired Muslim rulers to lay down beautiful gardens, namely Shalimar, Nishat and Chashm-e-Shahi along the periphery of the Dal Lake and at the foot of Zabarwan Hills, near Srinagar. Elsewhere, the valley is punctuated with green meadows namely Gulmarg (Fig. 3), Pahalgam, Sonmarg, etc. that are world known tourist resorts. In winter, Gulmarg is skiers’ paradise (Fig. 4).

2 Geology of the Kashmir Valley

The oval-shaped Kashmir Valley is about 40 km wide and stretches approximately 135 km from NNW to SSE. The Jhelum River, which is closer to the northern side, divides the basin into two parts. The bowl-shaped Kashmir Valley is an intermontane fault basin that could be an “extensional rift basin” oriented parallel to the main orogenic belt with a tendency to sink with respect to the general rise of Himalaya (Agarwal and Agrawal 2005) (Figs. 5 and 6). The rocks, extending from southwest to northeast of the Kashmir Valley, comprise progressively complicated structures, whereas towards the plains of India there is a progressive uplift and folding. The bowl-shaped basin, part of the Kashmir Nappe (Fig. 6), consists of Precambrian basement overlain by a thick succession of fossiliferous Palaeozoic



Fig. 2 Picturesque Dal Lake with floating house boats and *shikaras*. The historical (18th century) Hari Parbhat Fort is seen in the background (Photo courtesy of Rakesh Chandra)

and Triassic rocks with thrust contacts in the north (Zaskar Thrust) with Great Himalayan Range and in the south (Panjal Thrust) with Pir Panjal Range.

Almost 1.3 km thick succession of sand, mud and gravels belonging to Neogene to Quaternary age, fill the Kashmir Basin. The thick fill-deposits, locally known as Karewa or *Udra*, form elevated benches, hill-tops and plateaus (Figs. 5 and 7).

3 Major Landforms

The valley is an alluvium filled oval-shaped depression ($\sim 4,865 \text{ km}^2$) that was once occupied by a vast lake, known as the “*Karewa Lake*”. The lake was gradually drained out, leaving flat-topped valley-fill Karewa (*Udra*) deposits (Fig. 7). The recent alluvium filling the bottom of the valley varies from 3 to 25 km in width along the Jhelum River. The valley can be divided into three sub-divisions: (i)

the Jhelum Plain, (ii) the Karewas, and (iii) the Rimlands (Singh 1971).

The Jhelum Plain includes the floodplain extending from Khanabal to Baramula. The Jhelum River meanders sluggishly through the Jhelum Plain and overflows its banks in spring and autumn due to heavy rainfall and/or melt waters from the glaciers. The floods add fresh alluvium to the advantage of farmers and swamps beyond the Wular Lake. Flanking the floodplain is the Bahil tract that stretches between Kulgam and Shopiyan and forms the ‘rice bowl of Kashmir’.

Flat-topped terrace-like features are prominently seen in the southern part of the vale. These distinct upland valley-fill deposits (Karewas) of lacustrine origin occur above the modern floodplain of the Jhelum River and its tributaries and are contrastingly infertile. Modern techniques of irrigation and acute shortage of cultivable land has compelled the local farmers to grow maize and fruits (apples, plums and almonds) on these uplands.



Fig. 3 Lush green meadows in foreground and snow covered mountain tops at Gulmarg in summer (Photo courtesy of Rakesh Chandra)

The mountains surrounding the valley that are blanketed with thick cover of conifer in the north and deciduous trees on the Pir Panjal, form the Rimland. The lush green meadows (Gulmarg, Pahalgam, Sonmarg, Yousmarg, etc.) are situated in these rimlands that are visited by shepherds along with their livestock for grass and clean water during summer. The Rimland rises above 3,500 m a.s.l. and is covered with snow till late April.

Triassic limestones of south Kashmir reveal some karstic features such as karren, springs, few caves and small conduits. Most of the springs are the places of worship by Hindus and termed as ‘nag’ such as Anantnag, Kokernag, Tulmul nag, etc.

4 The Karewa Deposits

The Karewa deposits in the Kashmir Valley cover about half the basin (Figs. 1, 5). The Karewa deposits on the Pir Panjal side have a much wider spread (12–15 km). These sediments

were laid down in the tectonically created depression not only in response to the change in climate but also to various tectonic events that commenced in the Pliocene. The first phase is reflected in the Lower Karewa (=Hirpur Formation), followed by the deposits of the Nagum Formation (Upper Karewa), associated with the second phase. The entire Karewa Group is divided into Hirpur, Nagum, and Dilpur Formations (Fig. 5). The Hirpur Formation consists of gray to bluish-gray clay, light-gray sandy clay, fine to coarse-grained green to purple sand, conglomerate, lignite, and lignitic clay (Singh 1982). The Nagum Formation comprises of fine to coarse-grained greenish to purplish sand, gray and ochre sandy clay, ochre and cream colored marl and gravel. The lithologies of the Karewa do not support glacial origin for any of the deposits. The Upper Karewa deposits are exposed in the central and northeastern part of the Kashmir Valley and are capped by loess-palaeosol sequence termed as Dilpur Member. Loess exposed on the SW or Pir Panjal flank and on the NE or Himalayan flank is termed as ‘older loess’ and ‘younger loess’, respectively (Bhatt 1975, 1979).

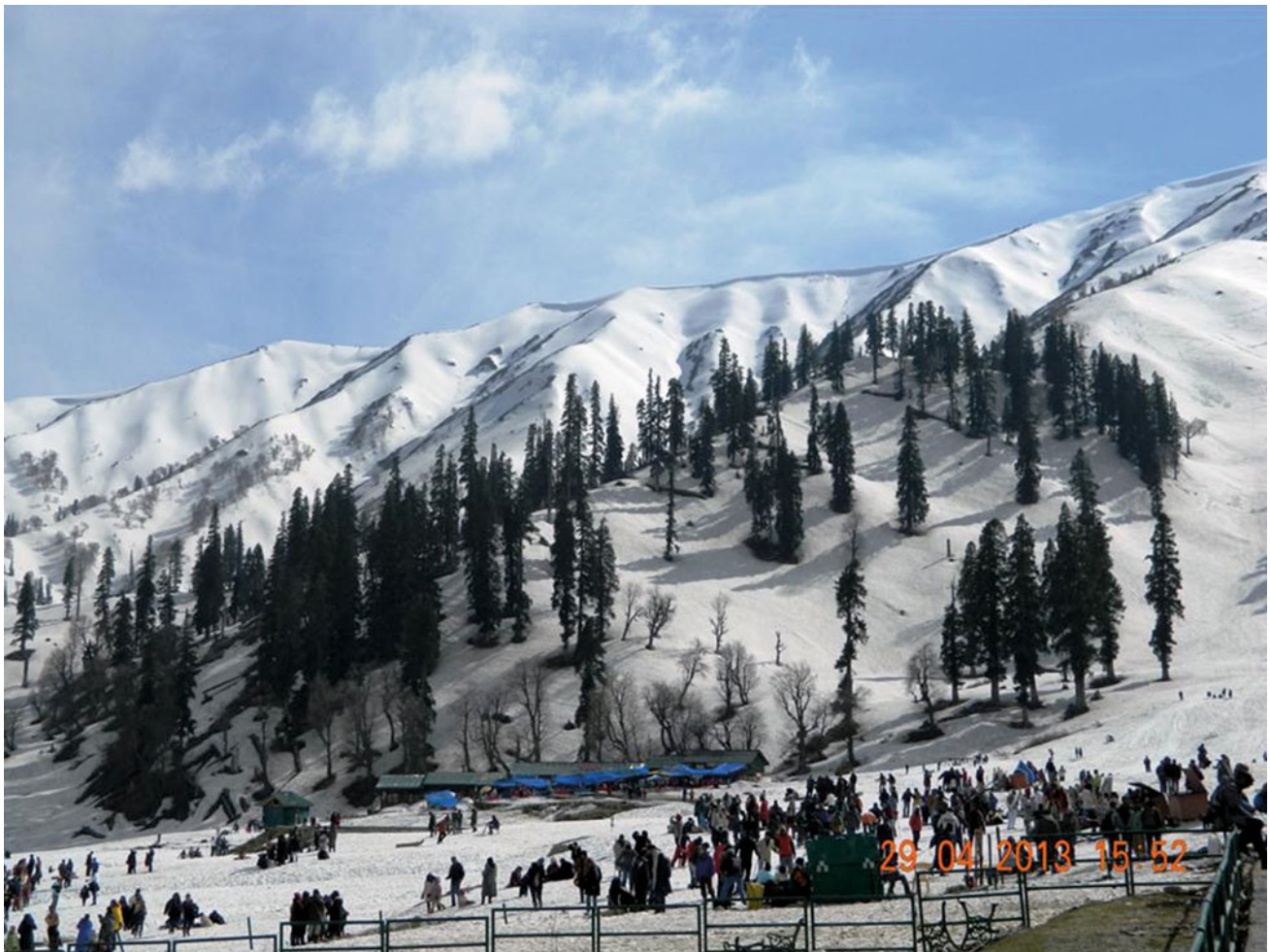


Fig. 4 Snow-clad Gulmarg and waiting tourists/skiers in winter (Photo courtesy of B.S. Bali)

The age of Karewa Group has been a matter of debate. Opinions about the onset of its deposition vary from the Miocene—on the basis of diatom and ostracode analysis, through the Pliocene—on the basis of vertebrate fauna and cross-relationships with the stratigraphy of Siwaliks, to the late Pliocene—on the basis of correlation with glacial stage elsewhere. Termination of Karewa deposition may have occurred in the late Pleistocene or at the beginning of the Holocene. The 440 m thick section on Romushi River (Fig. 1) identifies Plio-Pleistocene magneto-stratigraphic sequence of Karewa Group from ~ 4.40 to 0.77 Ma (Basavaiah et al. 2010), supported by fission track dates (~ 2.6 and 2.12 Ma) of tephra layers (Fig. 8) from Pakharpura and Baramula. It is now thought that the emergence of Pir Panjal Range at ~ 4.5 Ma triggered the deposition.

Buried soils or palaeosols occur within the loess. The loess-palaeosol sequence (Dilpur Member) forms an important part of the Upper Karewa (Nagum Formation) that coincided with the deglaciation (~ 15 ka) and

continued till ~ 10 ka, when the early Holocene humid phase set in. Neolithic habitational debris occurring above loess deposits has been reported from Burzahom and Puthkhah, indicating that the loess pre-dates the Neolithic settlement (Kusumgar et al. 1980).

5 Evolutionary History and Palaeoclimate

It is now generally agreed that the present-day topography of the Kashmir Valley originated from draining of a huge lake similar to those of the Kathmandu and Pokhara Valleys. The lake was most likely drained through an outlet west of Baramula, giving rise to the present gorge (De Terra and Paterson 1939). The resultant depression was gradually filled by sediments derived from the surrounding mountain ranges, particularly Pir Panjal. The former lake was created by the rise of Pir Panjal, which impounded the then existing drainage.

Fig. 5 Geological map of Karewas showing the geographical distribution of each member (after Bhatt 1982; Ahmad 2012)

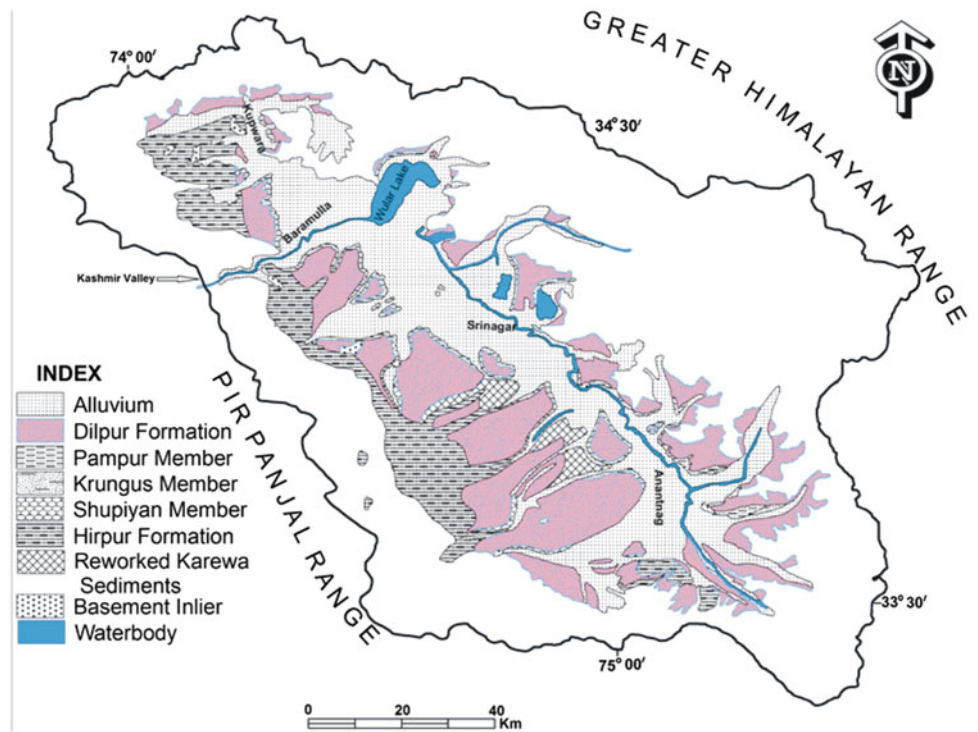
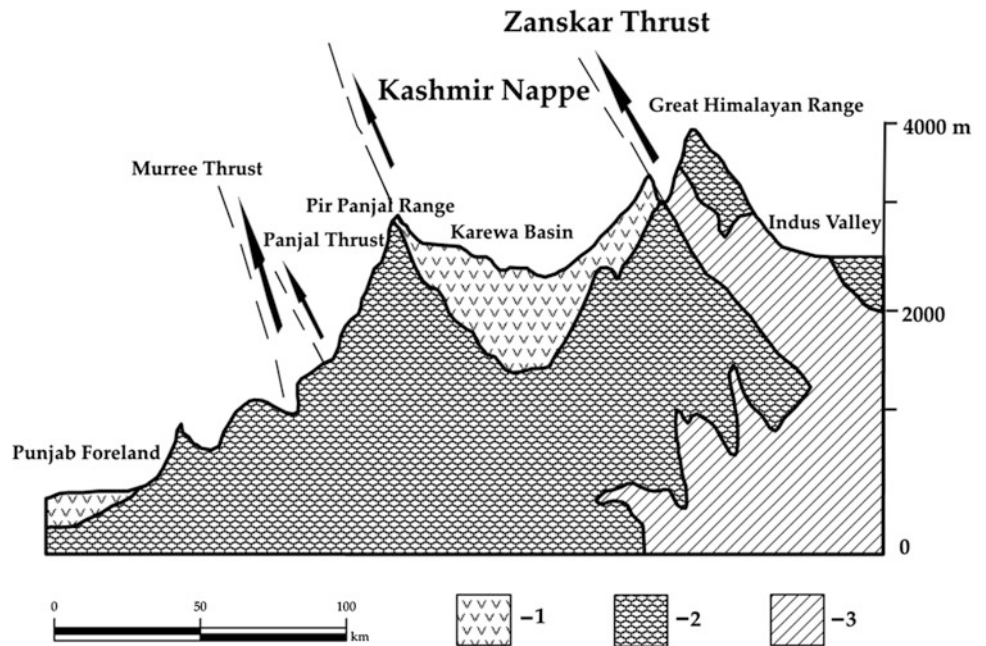


Fig. 6 Diagrammatic section across the Kashmir Himalaya, showing broad tectonic features (after Agarwal and Agrawal 2005). 1 Neogene-Quaternary deposits, 2 Palaeozoic and Mesozoic sequences, 3 Proterozoic basement



The sedimentation of Karewas was in a lake that was shallow, ~5–10 m deep and in some areas up to ~30 m, known as Hirpur Lake. The lake had marginal swamps, which are indicated by the presence of lignite and lignite mud deposits. The grey shales represent the deeper parts of the lake having fine grained carbonates. The extensive drainage

system with subaqueous channels producing bar finger sand (elongated lenticular sand body) fed the Hirpur Lake. The progradation in the lake during the Upper Karewa (Nagum Formation) is represented by the development of alluvial fans grading laterally into braided river system (Singh 1982). The Shupiyan Member represents a major phase of lake regression

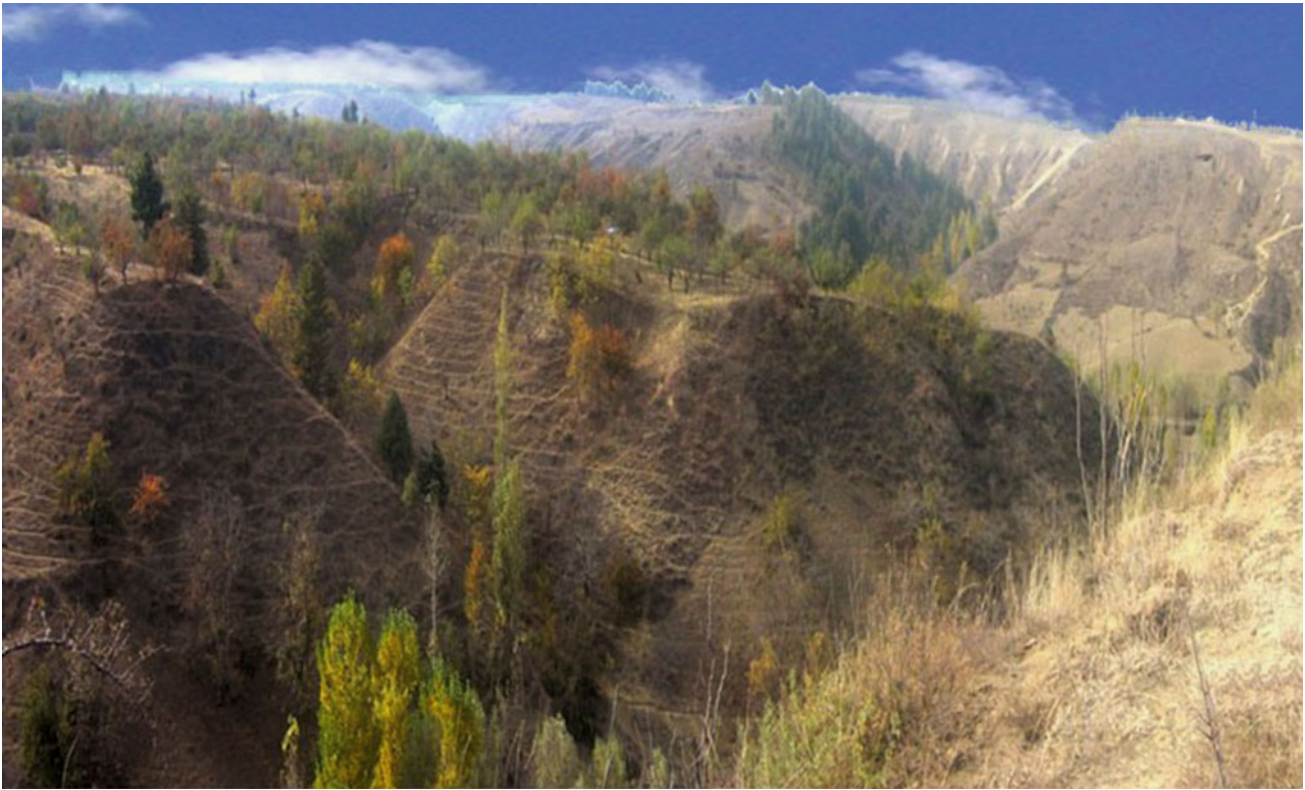


Fig. 7 General landscape of Karewas. The Karewas have been dissected into a multitude of steep sided ravines ranging in depth from 50–150 m (Photo courtesy of Rakesh Chandra)

from the southwestern part of the valley resulting in the development of braided river system, dominated by gravelly/conglomeratic facies. The thick conglomeratic deposits at the base of Karewa were laid by high energy stream flows, succeeded by fluvio-lacustrine deposits. The conglomeratic deposits are believed to have formed ~ 3.15 Ma. The Hirpur Lake was thus reduced to half the size and became shallower (~ 2 – 10 m). The reduced lake, known as Pampur Lake, supported extensive aquatic vegetation with no marginal swamps. The drainage system produced mostly Gilbert-type delta and delta sheet sand due to wave activity. The muddy facies thus formed are termed as Pampur Member (Fig. 9) of the Upper Karewa (Singh 1982). Thus, the erstwhile Karewa Lake after the initial deposition of the Lower Karewa (Hirpur Formation) started receding gradually from the SW side and shifted the basin more to the north and northeast where the Upper Karewa (Nagum Formation) was deposited.

The supply to the lake was mostly from the surrounding mountains and therefore the fossil record from Karewas represents a mixed community of mountainous and plain areas adjacent to the lake. Nevertheless, the presence of aquatic vegetation such as *Trapa*, *Typha*, *Nymphaea* in the Karewa sediments suggests warm climate in the valley (Vishnu-Mittre 1965, 1979).

A sudden increase in the rate of sedimentation ~ 1.95 – 1.77 Ma (the Olduvai sub-chron) is attributed to the rising Pir Panjal Range that served as an orographic barrier to the incoming southwest monsoon and making the valley dependent on winter precipitation (Basavaiah et al. 2010). The glaciers during Quaternary were therefore, restricted to the montane valleys and did not extend to the Kashmir Basin. This inference is based on the re-interpretations of Karewa conglomerates from outwash gravels to tectonic alluvial facies (Holmes et al. 1989).

Available evidence indicates that the climate between ~ 4.40 and 3.0 Ma was warm and temperate with the influence of southwest monsoon, since the orographic barrier of Pir Panjal Range in the south was low. The rate of sedimentation within the basin was also low perhaps due to vegetated landscape and consequent low rate of erosion. The event of cold, temperate and dry phase between 3.0 and 2.2 Ma is recorded on the basis of the presence of *Arvicolid* (cold loving rodent) and pollen data. The fluvial source to the erstwhile lake between 4.40 and 1.95 Ma was from Pir Panjal Range. The fluvial activity was directed to NW during upper Matuyama and lower Brunhes chron (~ 1.07 – 0.77 Ma) suggesting the onset of Jhelum River flow in the Kashmir Basin (Basavaiah et al. 2010).

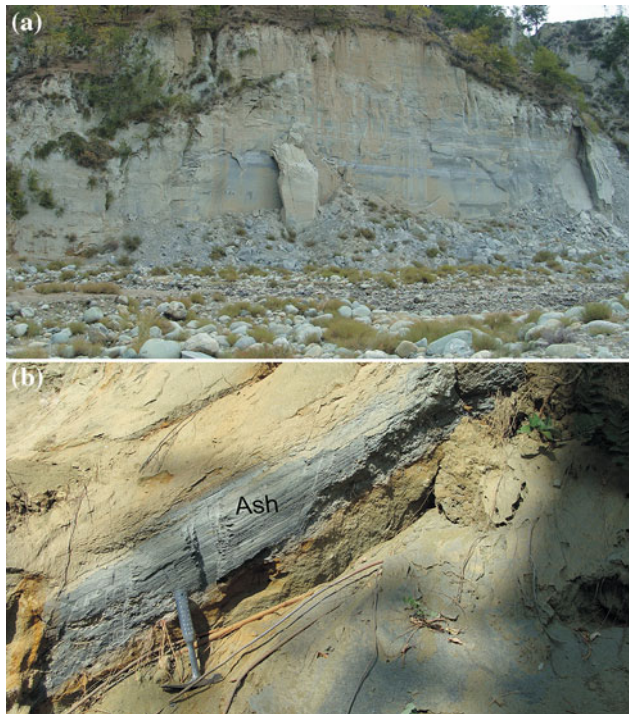


Fig. 8 **a** Karewa deposits (~ 70 m) exposed along Romushi River at Aglar. **b** A close up of the deposits showing volcanic ash (~ 2.4 Ma) horizon along the Romushi River section. The source of the ash is believed to be the Dasht-e-Nawar Volcano in Afghanistan (Photo courtesy N. Basavaiah). For more details refer to Basavaiah et al. (2010)

Abundance of oak during the early Pleistocene period of the Lower Karewa indicates moist temperate climate. The presence of mixed oak woods and the pollen studies suggest that the average annual precipitation then over the valley was much higher than the present. The cold oscillation periods, inferred from the style of the Lower Karewa deposits, were responsible for reducing the forest cover and the spread of grasslands that were dominated by *Artemisia* and *Chenopodiaceae*—an alpine meadow landscape (Vishnu-Mittre 1965, 1979; Agrawal et al. 1985). The evidence of first such cold, temperate and dry event at ~ 3.4 Ma is substantiated by the presence of *Arvicolid*. The climate in the Kashmir Valley has been in transition from sub-tropical to cool to temperate with some variation in precipitation ~ 2.2 Ma, as indicated by the pollen record. The rainfall conditions, more particularly during the winter monsoon, enhanced around 0.77 Ma (Bronger et al. 1987; Basavaiah et al. 2010).

The development of landscape in the Kashmir Valley occurred prior to, concurrently with, and after Karewa deposition (Singh 1982; Bhatt 1979). The formation of Karewa Lake is a consequence of the existence of rudimentary Pir Panjal Range that was formed sometimes in

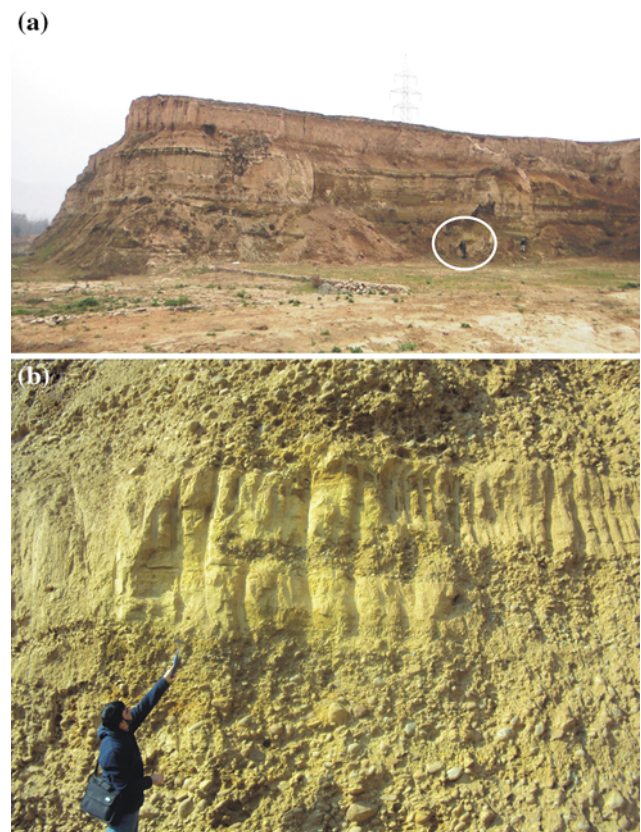


Fig. 9 **a** Upper Karewa tableland at Pampore having Pampur Member in the lower and Dilpur Member in the upper part of exposed section. Encircled is the human scale. **b** Close up of Pampur Member of Upper Karewa exposed near Pampore, Kashmir (Photo courtesy of I Ahmad)

Neogene and was responsible for blocking the south flowing drainage from already uplifted Great Himalaya Range. The uplift of the Pir Panjal Range pre-dates the initiation of sedimentation i.e. Hirpur Formation in the Karewa Lake. The transition from the structurally complex Lower Karewa (Hirpur Formation) to non-deformed Upper Karewa (Nagum Formation) indicates the occurrence of tectonic upheavals contemporary with the Karewa deposition, which are therefore, syn-Karewa. The existence of pronounced angular unconformity between the Hirpur and Nagum Formations on the Pir Panjal side of the Karewa deposits as observed in the field, substantiates it. Major change in the drainage system in some parts of the Karewa Basin subsequent to the deposition of Hirpur Formation further corroborates that the period of Karewa deposition was a key stage in the development of the landscape here. Presence of plant-fossil remains from Hirpur Formation situated at an altitude of $\sim 3,350$ m a.s.l, such as *Quercus glauca*, *Alnus*, *Cinnamomum*, fruits of *Traps patans*, and *T. bispinoas*, living species of which otherwise grow at altitudes $\sim 1,400$ – $1,800$ m a.s.l further confirm the tectonic

upheaval of Lower Karewa during the period of the sedimentation (Vishnu-Mittre 1965, 1979; Agrawal et al. 1985). The formation and gentle tilt of terraces formed subsequent to the deposition of Upper Karewa authenticate the post-Karewa tectonic upheaval in the region that resulted in the development of present-day landscape (Singh 1982).

6 Conclusions

The geomorphic, climatic and tectonic history of the bowl-shaped Kashmir Valley and its surrounding ranges is largely contained within the thick deposits within the basin, which today stand high above the floor of the valley and add to the uniqueness of the valley. Although the age and genesis of these Karewa deposits remain a contentious issue, multi-disciplinary studies strongly suggest that these deposits were laid down by fluvio-lacustrine, fluvial and aeolian processes from Neogene to Holocene, in response to the emergence of Pir Panjal. The bowl-shaped intermontane basin was created by tectonic uplift of the Pir Panjal Range around 4.5 Ma. The uplift impounded the then existing drainage and gave rise to a large lake, known as “Karewa Lake”. The present large-scale morphology of the valley was created by draining of the lake water via an outlet west of Baramula across the Pir Panjal, giving rise to the present gorge, as well as by deposition of Karewa sediments. Archaeological evidence suggests that the deposition continued till pre-Neolithic times (early Holocene).

During the period of deposition of Karewa sediments, the climatic conditions have fluctuated from sub-tropical to cool to temperate. The main source of precipitation over the valley has also shifted from southwest monsoon to the mid-latitude westerlies after ~ 2 Ma with the gradual rise of Pir Panjal. The changing climate conditions and tectonic pulsations have been instrumental in changing sediment accumulation rates in the Karewa Lake deposits from time to time. The present picturesque landscape of the Kashmir Valley owes its origin to these major tectonic and climatic events that occurred from Neogene to Quaternary.

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