



PALEOCLIMATIC RECONSTRUCTION THROUGH MORPHO- STRATIGRAPHIC ANALYSIS OF LOWER REACHES OF AJAY RIVER BASIN, WEST BENGAL, INDIA

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ABSTRACT

Alluvial stratigraphy of the lower reaches of Ajay River and its tributary system record distinct and synchronous episodes of regional fluvial adjustment with active tectonics during late Tertiary to Quaternary period. Evolution of drainage system during the Quaternary took place due to changes in sedimentation process, the dynamics of basin morphology and the active tectonic deformation of some typical marginal faults. Changes in the facies and depositional style through time can be analyzed through modern analogue and sedimentological model. Alternate episodes of flood and overbank sedimentation and the burial of paleosoils under the newly formed layers in sandy overbank facies is the major problem for exploring the spatial structure of paleoclimate and their related fluvial environment. However, progressive marine aggradation and recession leaves the imprints in the sedimentological facies of the deltaic and paradelatic tract of Bengal basin.

KEYWORDS: Alluvial Stratigraphy, Morphostratigraphy, Paleoclimate, Quaternary Geomorphology.

1. Introduction

The stratigraphic records preserve the evolutionary imprints, and studying the sedimentological and lithological architecture is the key to unveil pre-existing climatic conditions. Climate change is a nature and human induced dynamicity which effects the fluvial landscape by altering the fluvial system on hydrological, sedimentological and topographical scales. The assessment of paleoclimate is based on proxies and one of the most prominent proxies is morphostratigraphic analysis because soils form at the Earth's surface, in direct contact with the atmospheric and climatic conditions at the time of their formation [1]. The physical landscape response leads to change the system of erosion, resultant features and consequences such as land degradation, desertification, and submergence. According to the concept of quaternary geomorphology, the geomorphic processes puts their distinctive imprint upon landforms they encounter and each geomorphic process develops its own characteristic assemblage of landforms. Alluvial stratigraphy of the lower Ajay River and its tributary system record distinct and synchronous episodes of regional fluvial adjustment to the active tectonics and geological framework. Changes in the facies and depositional style through time can be analyzed through modern analogue and sedimentological model. Alternate sequence of flood and overbank sedimentation and the burial of paleosoils in sandy overbank facies is the major problem for exploring the spatial structure of paleoclimate and their related fluvial environment. However, progressive marine aggradation and recession leaves their imprints on the sedimentological facies of the deltaic and paradeltaic tract of Bengal basin. Quaternary floodplain landforms and sediments bear the imprints of past and present active environment, which affect the components and functions of fluvial system since late Pleistocene. So, to understand the fluvial response to climate change in Pleistocene or later Quaternary times and to assess human intervention on it, this study has been taken up to examine the dependent relationships between morphostratigraphic characteristics, sedimentological architecture and climatic parameters of the morphostratigraphic units of the lower Ajay River basin.

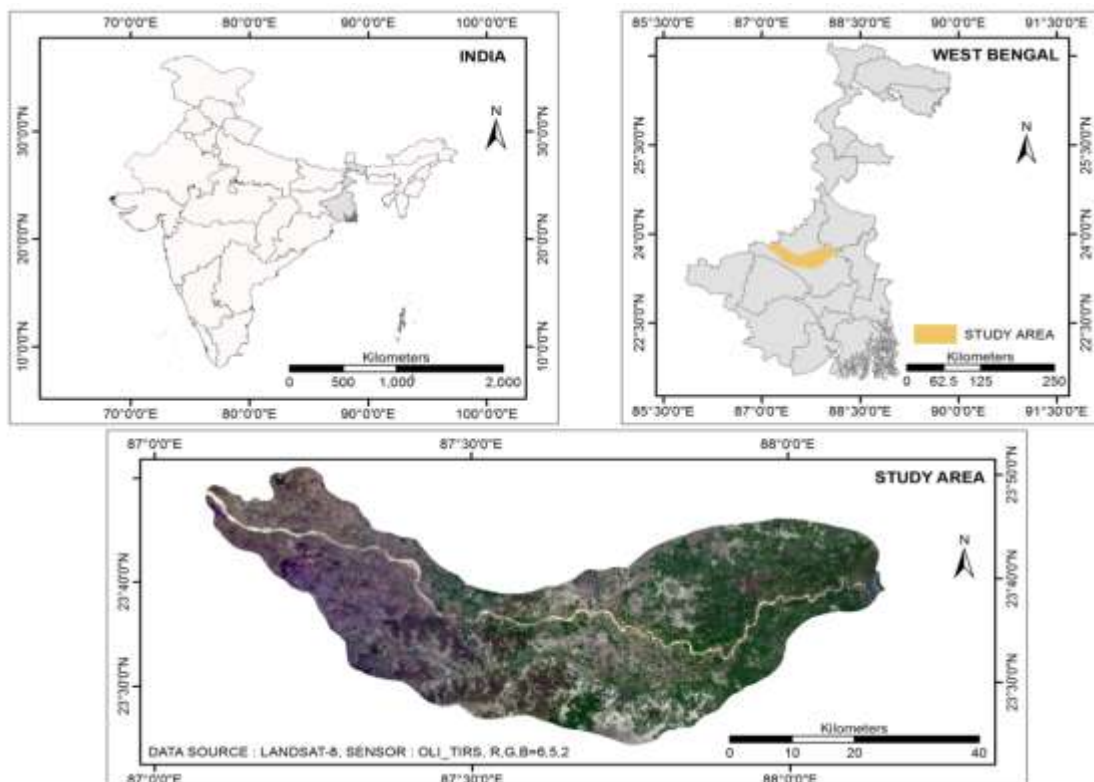
2. Objectives

The present work mainly deals with the following objectives, these are

- i) To identify the morphostratigraphic structure of the study area.
- ii) To find out the relationship between sedimentological architecture and the regional morphostratigraphic history for paleoclimatic reconstruction in lower Ajay River Basin.

3. Study Area

Ajay river is a right bank tributary of Bhagirathi River which originates from eastern fringe of the Chhotanagpur plateau at 346.3 meters above mean sea level and flows through about 299 Km crossing three states(Bihar, Jharkhand and West Bengal) finally to meet Bhagirathi River near Katwa in Purba Bardhaman district of West Bengal. The funnel shaped basin covers an area of $\sim 6221 \text{ Km}^2$ ($23^\circ 25' \text{ N}$ to $24^\circ 35' \text{ N}$ and $86^\circ 15' \text{ E}$ to $88^\circ 15' \text{ E}$) and its lower reaches covers an area of $\sim 2816 \text{ Km}^2$ engulfing $23^\circ 25' \text{ N}$ – $23^\circ 45' \text{ N}$ latitude and $87^\circ 15' \text{ E}$ – $88^\circ 15' \text{ E}$ longitude (Map 1). It is bordered by Mayurakshi River basin in the north and Damodar River basin in south. The Ajay River in its lower reaches flows over the semi-consolidated formation of Gondwana sedimentary rocks in the western part to unconsolidated formation of Quaternary sequences divided into older Pleistocene alluvium and recent alluvium [2]. Incised by a number of lineaments and faults, the study area is subjected to neotectonic activities and the flow and form of the river and its associated landscapes has portrayed a varied change in the morphostratigraphy of the basin area. Climatically the basin is characterized by subtropical monsoon climate with spectacular reversal of monsoon circulation of wind between summer and winter. On an average, the Ajay basin receives 1272mm annual rainfall. The summer temperature sometimes goes up to 40° c whereas; the winter temperature sometimes comes down to below 10° c .



Map1: Location of the Study Area

4. Database and Methodology

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The present investigation highly rest upon the integrated use of Remote Sensing and GIS techniques along with field investigation.

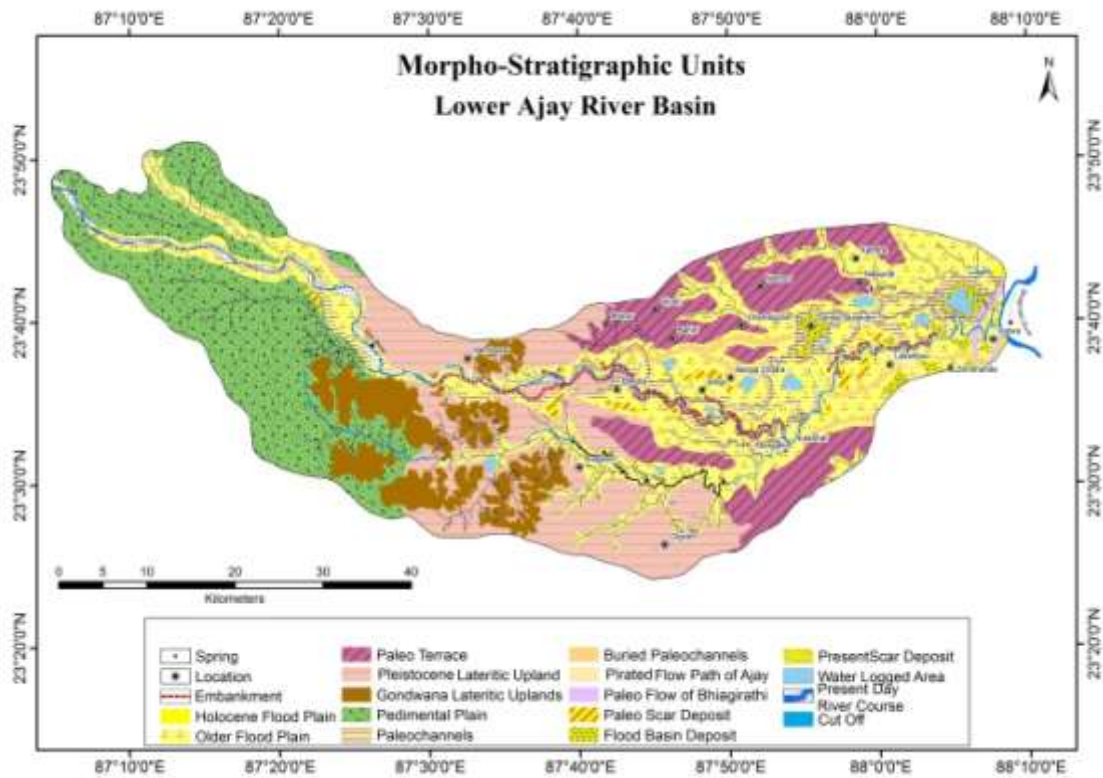
- i.** Basic topographic and drainage details were gathered from Survey of India (SOI) topographical sheets of 2011 on 1:50,000 scale and satellite imageries were consulted. IRS-P6-LISS-III false color composite of band 2, 3, 4 was consulted on 1:50,000 scale for revealing the morphostratigraphic character of the Ajay River.
- ii.** Published and unpublished reports of Geological Survey of India were consulted for conceptual frame work.
- iii.** Borehole data from PWD was collected for reconstructing the morphostratigraphic set up. Lithologs were made from the borehole samples and additional information was gathered for understanding the stratigraphy.
- iv.** The data obtained and processed were systematically interpreted on the light of taken objectives to display the morphostratigraphic evolution of the lower Ajay River basin for paleoclimatic reconstruction.

5. Results and Discussion

The geomorphic history of the lower Ajay River basin dates back to the formation of the Bengal basin. Inland delta building process and transitional environmental changes from fluvial to marine are the morphostratigraphic character of this part of the basin. Due to the re-activation of some basement faults of Bengal basin and episodic uplifts, the courses of the Ajay River got modified since early Pleistocene [3]. A critical study of the morphostratigraphical section of the study area along with the lithology of some borehole samples in the area has been brought to enlighten the sedimentological architecture and morphostratigraphic history of lower part of Ajay River basin.

The reconstruction of prehistoric landforms and paleoclimate largely depends on morphostratigraphic character. Lower Ajay River basin is floored by the alluvial sediments of Quaternary age along with unconsolidated formation of Gondwana.

Modern technologies coupled up with the age-old identification technique has evolved as a popular method for morphostratigraphic feature identification and its identification gives strong proof of climatic variability and tectonic instability in the region.



Map 2: Morphostratigraphic Units of Lower Ajay River Basin

5.1 Morphostratigraphic Characteristics:

The first step involved in evaluating the morphostratigraphy of the area is building up the relative chronology of the morphostratigraphic units followed by the study and analysis of the soil and parent material content of each stratigraphic unit and structuring them in sequential order. The fossil imprints found in the parent material add new dimension towards their dating and in understanding the geological history of the area. There is sequence of estuarine-marine fluvial depositions of post Miocene to recent age. This litho-stratigraphic architecture has developed a complex morphostratigraphic set up in this paradeltaic tract of Bengal basin. The formation of the basin was initiated during late Cretaceous to early Miocene due to differential morphotectonic movements in the marginal shelf zone of Bengal basin. Different morphostratigraphic surface in the area descend in step from the western part to the eastern part. Thus based on multi-parametric approach, four morphostratigraphic units have been identified in lower Ajay River basin (Map 2), which possesses a morphostratigraphic linkage for reconstruction of the paleoclimate that persisted over the study area long ago before the present time. These are discussed below-

5.1.1. Morphostratigraphic Units of the Lower Ajay River Basin:

a) **Gondwana Lateritic Upland:** This morphostratigraphic unit occupies the central as well as western part of the lower Ajay River basin. It is characterized by nearly flat topped, broad hummocks with deep valley fills having sub parallel and occasional radial drainage pattern. The succeeding clay-silt-sand sequence with lateral facies variation is compact and ferruginised is represented by lateritic pebble to gritty sand layer at the base (Plate 1). The lateritic sandstone sequential layer possibly marks the episodic change from shallow marine to estuarine environment and finally to the fluviotile environment of sedimentation.



Plate 1: Lateritic Upland Forms over Gondwana surface

The presence of duricrust in the top most layers is an important feature of this morphostratigraphic unit. The thickness of this duricrust generally varies from 30-50 cm (Plate. 2). In some places this morphostratigraphic unit has got eroded by rills and gullies. Sometimes this morphostratigraphic features reveals topographic discordance which is an indicator of neotectonic activity operating in this region. Evidence of multiple cycle of laterization can be traced from presence of hard crust lateritic duricrust lying 2m. to 3m. below the present day surface(Plate 2). This kind of formation covers the south-central part of the basin.



Plate 2: Laterite profile developed over Gondwana Surface near Illambazar

- b) **Pleistocene Lateritic Upland:** This morphostratigraphic feature constitutes south central and northern part of the basin. The lateritic formation is the manifestation of the Plio-Pleistocene depositional sequence and a change over from the shallow marine estuarine to the fluvioatile environment which persisted throughout the remaining part of the Quaternary period. This morphostratigraphic unit terminates into a lateritic hardpan or latosols (Plate 3). It has developed as a result of wide spread laterization and associated valley trenching activities dating back to pre-middle Pleistocene age.



Plate 3: lateritic profile developed over Pleistocene Sediments

This lateritic upland is dissected by different tributaries of Ajay River and sometimes is overlain by grey to ash coloured loamy sediments which represents the older alluvial deposits. Terminal parts of this morphostratigraphic features are sometimes adorned with bulff like formation at its convergence with the alluvium formation.

c) **Pleistocene Upland:** This morphostratigraphic feature is characterized by oxidized sand, silt and clay with proximal turn up in pedocal soil unit (Plate 4.a,b) dating back to Pleistocene to early Holocene period assessed on the basis of the vertebrate fossil found in the sedimentary layers. This morphostratigraphic unit is the result of wide spread regression of Pliocene to early Pleistocene sea resulted from the regional upliftment of this part of the Bengal basin. This was succeeded by a phase of erosion and valley trenching due to eustatic base level change and that had led to new phase of deposition of fluvial elastics in the middle Pleistocene period.

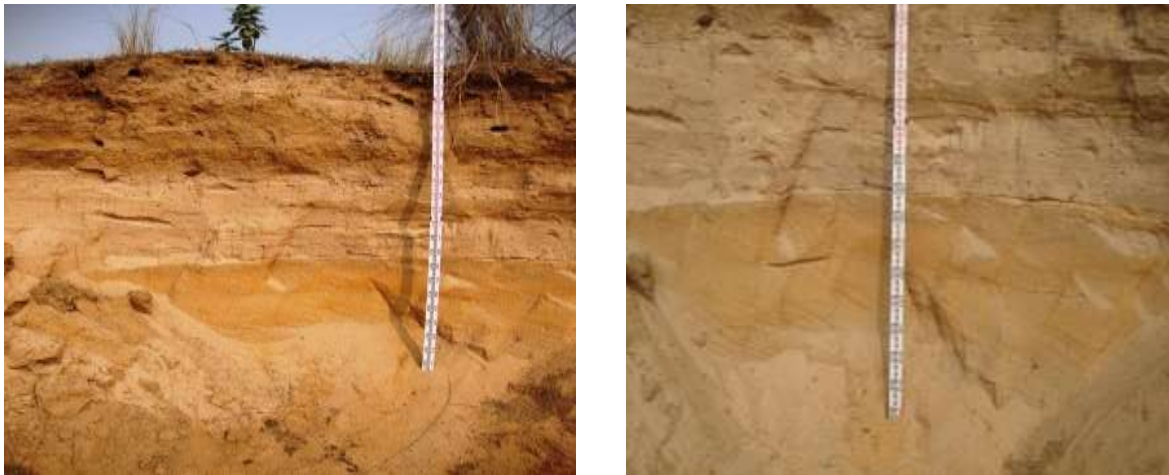


Plate 4.a,b: Profile of Fluvial Facies Along the Stretch of Ajay River near Bhedia

Morphotectonically it is the pedimental surface covered with thick sequence of Tertiary, Pleistocene and Quaternary sediments. It is divided into Buried Pedimental Plain Shallow (BPS) and Buried Pedimental Plain Moderate (BPM).

d) **Quaternary Alluvial Plain:** This morphostratigraphic unit has developed approximately in late Pleistocene and Holocene during active sedimentation in the Bengal basin. During the end of Pleistocene, the basal sand and gravel beds deposited in Bengal basin in a relatively colder and drier climatic condition than that of the present time. Between 15,000 to 10,000 years before present, the relative warmer climatic conditions and phenomena were related with sea level rise and marine transgression. After that fluvial sedimentation started over marine deposits. These fluvial sediments consist of unconsolidated medium to fine grain yellow sands with light brown silt and grey to black clay, which are identified in some of the point bar and channel bar deposits along the tract of Ajay River. Stratigraphic sequence of this unit is made up of alternate layers of marine and fluvial deposits. In the stage of the rising sea level, the sea transgressed inland and the previously deposited geomaterials of the earlier phase were redistributed by the action of sea waves and ocean currents. During

stationary stage the sedimentation took place under flood plain environment and comparatively finer material was deposited over the pre-existing sedimentary layers. However, each glaciation and sea level fall incorporated entrenching of the river and formation of topographic discordance. This morphostratigraphic unit is characterized by landforms comprising of paleochannels, paleobars, levees and back swamps.

The lithologs of different sample units have been analysed to assess their inherent stratigraphic character (Figure 1.a, b).

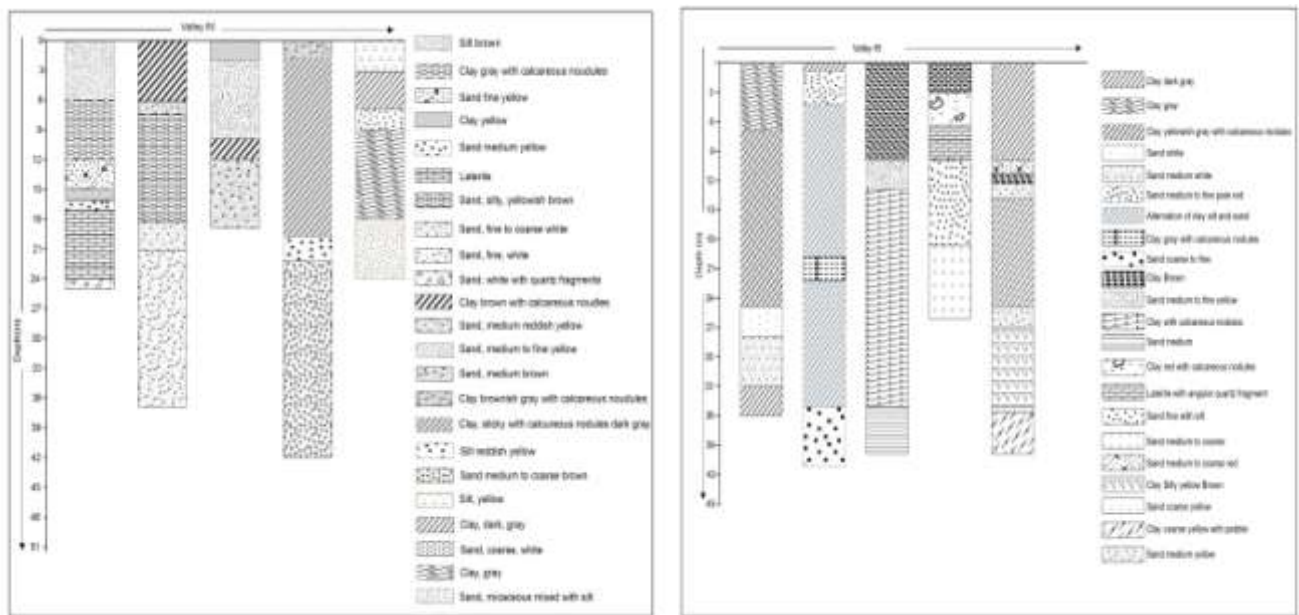


Figure 1.a, b: Lithologs of Some Sample Locations

5.2 Paleo-Climatic Reconstruction from Morphostratigraphy:

When the causes behind the past climatic fluctuations are understood, forecasts of climatic variations in the future will be more accurate [4]. The geomorphostratigraphic analysis throws much light on the paleoclimatic reconstruction [5]. Analysing the morphostratigraphic characteristics, a strong fluctuation in the sea level is noticed. The morphostratigraphic features and sedimentological architecture points towards the fact that five to six cycles of climate change has occurred in the study area and its surroundings in between ~14 thousand to 6 thousand years before present. The proofs from floodplain of Ajay River signifies that the consecutive phase of aggradation and incision is linked with the alternate wet and dry periodic pattern of south west monsoon variability during late Quaternary period. All the stratigraphic proxy records of climate contain a climatic signal, but that signal may be relatively weak, interrupted with a great deal of extraneous noise arising from the effects of other (non-climatic) influences[6]; so the cause-effect relationship between the

morphostratigraphic units and the the-then actively operated morphological processes have been done to reconstruct the paleoclimate of the study area. The paleoclimate interlinks with the morphostratigraphy have been established in the following section-

- i.* The alternate beds of sediments imply towards marine transgression and recession which is the strongest proof of past glaciations and de-glaciation.
- ii.* The onset of semi-arid climate was associated with formation of waterlogged areas and back swamp deposits of diminishing intensity of low energy floods. The relatively warm humid climate was associated with sandy bed forms, valley fills and slag water deposit and formation of ferruginous nodules.
- iii.* Lateritic constituent of ferruginous litho section is actually the weathered product of ex-situ laterization of debris flow of fluvial deposits during the Pre Tertiary and Late Pleistocene periods. These detrital lateritic sediments were deposited as valley deposits in the shelf zone of Bengal basin and were re-laterized under an alternate tropical wet and dry climatic condition. Therefore the presence of laterites in both surface and subsurface below 3 to 8 m suggests the altered episode of dry and wet climatic condition in geological past.
- iv.* The granulometric analysis reveals that the finer sediments in the litho section were formed in very low fluvial regime and channel fills condition in between the late Pleistocene and early Holocene.
- v.* Coarser materials and pebbles in the litho section indicate much stronger monsoonal regime than that of the present day and active tectonic disruption in this part of the basin.

6. Conclusion

The morphostratigraphic feature identification is a tough job due to their varied or camouflage surface expressions. But since the soil directly interacts with atmospheric elements and withstand the ongoing climatological happenings, so they archive the secrets of the prevalent climatic conditions within them. A detailed study of the morphostratigraphic and climatic relation has been carried out in spatio-temporal scale which reveals a plethora of exciting information about the paleoclimate of the Lower Ajay River Basin. The drainage pattern of lower Ajay basin is controlled by several lithological formations, tectonic activity and changing climatic parameters from Miocene onwards but eastern portion of the basin has evolved in Pleistocene onwards. The study area is an integral part of western margin of Bengal basin which is characterized by the change in drainage course particularly in Pleistocene onwards and relict drainage system is an indicator of much larger fluvial system

in the marginal basin area. It is evident from the study that the lower reaches of Ajay River basin have withstood a series of synchronous change in the morphostratigraphic framework in response to the active tectonics and varying climate of the region. The period of glaciations and de-glaciation has carved the structure of lower reaches of Ajay River to its present form. About five to six climate changes have been ascertained. This study not only provides the Paleoclimatic hint, but provides a way forward for forecasting the future climate.

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