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Abstract Volume

IQC-2022

FOCAL THEME

Integrative Quaternary Sciences for Societal Service

ASSOCIATION OF QUATERNARY RESEARCHERS

Preface

About IQC

IQC is is an initiative by the Association of Quaternary Researchers (AOQR), India. It is designed as a biennial meeting to be hosted by AOQR during February of every second year 2022 onwards. The venue/host for future congress will move to different regions of India and will be decided by AOQR on a successful bidding basis. This three-day congress will have a conference (online mode for 2022); business meetings; exhibition and training programs. IQC-2022 is the start of this venture.

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From the Conveners Desk

India experiences a variety of climates; having distinct physiographic regions; varied topography- truly a unique land of infinite diversity. It also has a large pool of educational institutes/ organizations/ universities dedicated to scientific research and teaching which are actively involving all aspects of the Quaternary sciences. The state-of-the-art scientific techniques has allowed us to explore intricate relationship of climate, tectonics, and landscape evolution on which the societies flourished in this slice of earth's history. The current generation Quaternary scientists in India is blessed in a way that it already has a much more that what can be called as first order picture on

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how the subcontinent's deserts, rivers, mountains, basins, lakes, and coasts responded to past climatic variability and how they registered local and regional geodynamic history. The INQUA-2019 at Dublin saw the largest Indian contingent ever participating in Quaternary union and where a very decisive call was made of having Indian counterpart of this global platform. The collective efforts and guidance from seniors lead to an organized body that we termed an Association of Quaternary Researchers (AOQR). There are several plans and a road map prepared by a committed team of founder members, our patrons, and our members. Organizing a biennial meeting as Indian Quaternary Congress (IQC) is a result of one such decision. IQC aims to provide a unified platform where Quaternary community of India can present and discuss its newer findings and build a wider interdisciplinary collaborative program. The congress will encompass all aspects of Quaternary from both the terrestrial and marine domains. IQC is recognized by INSA committee on IUGS & INQUA as its flagship Quaternary congress building international linkages with Global Quaternary community and INQUA. IQC is designed as a biennial meeting to be hosted by AOQR during January-March of every second year 2022 onwards. The first edition in this sequence, due to COVID pandemic, is being organized in a virtual mode, but we are hopeful that the hard times will leave the globe soon and the IQC-2024 will be an offline congress.

This first Indian Quaternary Congress (IQC) brings forth contributions from 266 researchers working across India in different aspects of the Quaternary sciences. With the Focal theme of- Integrative Quaternary Sciences for Societal Services, papers are classified into sessions on Climate: Past, Present and Future; Earth Surface Processes in Quaternary; Oceans in Quaternary; Humans in Quaternary; Fossil records from Quaternary and Quaternary landscape evolution. The congress spanning three days (19-21 January 2022) provides opportunity for listening to 3 keynote talks, 42 oral and 49 poster presentations. The abstracts of all the presentations have been compiled in form of a souvenir for you.

We sincerely hope that IQC-2022 will be an experience benefitting the established and upcoming Quaternary enthusiasts and the society at large. The efforts leading to this are collective from mentors, office bearers and all members of AOQR and all session moderators.

With Kind Regards
Binita Phartiyal & Pradeep Srivastava
Conveners, IQC-2022

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Climate: Past, Present and Future

Boron Isotope based pH record of last three decades from the Arabian Sea coral

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Increasing anthropogenic CO_2 caused lowering of ocean pH called "ocean acidification (OA)" which becomes a threat to calcifying marine organisms. Boron isotope ratio in corals has been employed to reconstruct pH records from Pacific and Atlantic Ocean. Here, we report the first sub-annually resolved pH record (1990–2013) from the Arabian Sea based on $\delta^{11}B$ measurements on *Porites* corals from Lakshadweep coral reefs. Our pH record is characterizedbylarge variability ranging from 7.93 to 8.65 with no long-term discernable trend. The long-term declining trend expected from the ~50 ppm increase in atmospheric CO_2 during the coral growth interval appears to be obscured by large surface pH variability in the Arabian Sea. Our investigation reveals that physical oceanographic processes e.g. upwelling, downwelling and convective mixing modulated by El Niño–Southern Oscillation (ENSO) largely control surface pH variability and masked expected long-term OA trend resulting from anthropogenic CO_2 rise. Based on our observation and model-based simulation showing increase in ENSO frequency and amplitude for future scenarios, we expect that pH extremes are likely to increase which is critical for resilience and adaptability of calcifying marine organisms.

Mean monsoon climate shift at the edge of Roman Warm Period

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Paleoclimatic archives showed linkages between monsoon fluctuations and cultural enrichment/societal demise during the Holocene. Since the early Holocene, monsoon strength appears to follow the precision-based solar insolation. This close relationship has been weakened in the last two millennia (Annapureddy et al. 2021). Abrupt climate transitions for shorter time scales have been recorded (Cheng 2004), and other unusual monsoon climate transitions often coincided with global climatic shifts (Deplazes et al. 2014). However, change in monsoon's mean state

in the last three millennia has not been reported. Indian summer monsoon rainfall (ISMR) variations for the last ~3.2 thousand years (kyr) B.P. (Before Present; relative to AD 1950), derived from the oxygen isotopic data of two stalagmites collected from the peninsular Indian cave, are presented here (Figure 1).

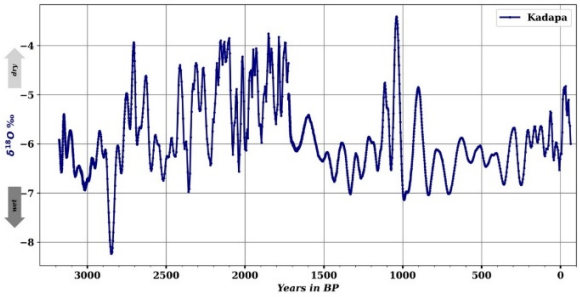

Figure 1: ISMR reconstruction for the last ~3.2 kyr using composite of two Kadapa cave stalagmites.

The 3.2 kyr record of ISMR shows the mean state of monsoon climate shifted around the edge of the Roman Warm Period (RWP), i.e., ~1.7-1.8 kyr BP (see Figure). Signature of such climate shift is available in the different proxy records from the sub-continent, yet this monsoon climate shift remains overlooked. This monsoon climate shift was rapid and took a few decades to a century and was a departure from the solar insolation-driven drying trend, continuing since the mid-to-late Holocene. Our analyses suggest that the monsoon climate shift is related to a dramatic increase in El Niño/Southern Oscillation (ENSO) variability and intensification of El Niño and La Niña events around 1.75-2 kyr BP (Thompson et al. 2017) would have forced the monsoon climate's mean state to departure from the solar insolation driven drying trend which was continuing since the mid Holocene to last 2000 years. Based on the close correlation between the global climate drivers and monsoon strength, authors proposed that the internal climate drivers (ENSO) dominated over the Solar forcing and caused a shift in mean state of monsoon climate around the edge of RWP.

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Decoding the dynamics of soil erosion and hydroclimatic signals using End Member Modelling Analysis on southwest Indian lakes

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The present study documents the sedimentation history and hydrodynamic operators of deposition in two southwest India lakes during the last two millennia. The Grain Size Data (GSD) was decomposed by End Member Modelling Analysis (EMMA) into geologically meaningful subpopulation termed as End Members (EM). Four EMs in the Vagamon and three EMs in Vellayani Lake attribute different detrital processes associated with overland runoff during seasonal rainfall. EM1 and EM2 in the Vellayani Lake are associated with interrill and rill erosion respectively and their relative abundances

(EM scores) are indicative of intensity of rainfall. EM3 is attributed to the pluvial flooding events in Vellayani Lake basin. EM1 to EM4 in Vagamon Lake are solely associated with the slope erosion during the rainfall. The EM scores from these lakes demonstrate the mixing proportion of individual EM in sample space and indicate towards the most active mode of soil erosion and hydrodynamic conditions in the lake catchments. Relative abundance of coarser and finer EMs in these lakes describes the efficiency of overland runoff and the energy involved in the hydrodynamic processes of the sediment deposition and sorting. The sensitivity of the detrital processes and hydrodynamics thus reveal the changing hydroclimatic conditions (such as monsoonal rainfall intensity) in the lake catchments and surrounding regions. EMMA, GS parameters and the reconstructed rainfall signals are exclusively compared with other paleomonsoon records during global cold/warm events. Mean grain size variation and EM scores from Vellayani Lake indicate episode of intense rainfall and pluvial flooding events during ~ 560 to 960 AD and the strengthening of Indian Summer Monsoon (ISM) in the study area during Medieval Warm Period (MWP). Regional rainfall intensity reconstructed from EM and sediment textural data is comparable to the ISM reconstruction from Central India, North-East India and Arabian Sea.

Variability of Indian summer monsoon strength in northeastern India in the past three millennia

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The Indian Summer Monsoon (ISM) is a complex ocean-climate coupled phenomenon which is crucial for the habitation in the Indian subcontinent. However, its date of onset, intensity and duration varies significantly in space and time as a response to various forcing factors. To understand the natural forcing mechanisms to the ISM at various time scale, we have generated an oxygen isotope time series from a 23cm long stalagmite from the Mawmluh cave, northeastern India spanning from ~ 3.95 cal. kyr BP to the ~1.07 cal. kyr BP. The region receives the world's highest amount of rainfall with distinct seasonality, ISM contributing 75-80% of rainfall in the wet season while the dry season faces water shortage. Depleted $\delta^{18}O$ ratio between 3.9-3.8 cal. kyr BP, 3.2-2.9 cal. kyr BP and 1.5-1.07 cal. kyr BP, suggest wetter phases and strengthened ISM conditions. In between these strong ISM phases, intervals of weak ISM and fluctuatingrainfall conditions. A sharp enrichment in oxygen isotopes ratio at ~3.6 cal. kyr BP indicates towards a weak ISM

phase around that time. The strong ISM interval of 3.2-2.9 cal. kyr BP corresponds to Minoan Warm Period and also the time when the Vedic civilization flourished in India. The strong ISM intervals of 3.947-3.9 cal. kyr BP and 1.5-1.07 cal. kyr BP, however do not correspond to any known warm or wet period historically. Instead, the 1.5-1.07 cal. kyr BP lies within the Dark Ages Cold Period and possibly because of a regional variability in ISM conditions, directed by different operating factors. A trend in $\delta^{13}C$ similar to $\delta^{18}O$ signals indicates flourishing vegetation under stronger monsoon. We have not found any signature of the 4.2ka arid event from our sample.

Late Holocene lake-level fluctuations and hydrodynamics of larger lakes from Trans Himalaya since 3 ka

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Development of large number of lakes in the Trans-Himalaya and Tibetan Plateauis crucially influenced by the climate change and tectonics. Understanding the lake-level fluctuations and their hydrological imbalance may provide relationship of climate-tectonic interplay in the high reaches of the Himalaya. Pangong Tso a ~140 km long, transboundary and a hypersaline lake basin is developed in the Pangong strand of Karakoram fault. The lake is highly sensitive to the changes in the physical condition of the lake periphery and the regional climate such as temperature, precipitation and snow glacial melt. The Present-day landscape of the Pangong Tso periphery shows the classical Gilbert-type deltaic sequences which are exposed by the incised rivulets. The deltaic deposits are clearly identifiable into topset, foreset and bottomset. To determine the hydrological changes of this lake, sedimentological, chronological, sclerochoronology and diatom concentration studies were conducted. We identified two primary facies using first field sedimentological investigation: (i) deltaic deposits, and (ii) channel deposits. Mollusk shells were collected from several portions and identified as Radix brevicauda, Radix lagotis, Valvatapiscinalis, and Gyraulus species. All these species are freshwater species that live in the littoral zone. In this study, we used OSL chronology and geomorphic mapping to identify three periods of lake level fluctuations over the last 3 ka. The higher lake level stand at 2.6 ka is supported by the elevation of the gastropod shell bearing layers from the present-day lake level and their stable isotope research. A steep reduction is observed up to 1.7 ka, followed by a rise in lake level between 1.6 and 1.1 ka, when the salinity was reduced to 4.03 ppt, allowing freshwater-loving diatoms to flourish in the lake. The rapid fall in lake level (~8m) is classified as the third phase, as evidenced by the incision of deltaic sequences in the last 1 ka. According to a review of the region's

palaeoclimate record, late Holocene Lake level fluctuations could be the result of the interplay between the Indian Summer Monsoon and westerlies. As a result, we infer that an abrupt increase in aridity in this region is one of the key causes of rapid lake-level decline.

High resolution climatic changes in the Kumaun Himalaya in the last 4,000 years using speleothems

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A high-resolution climatic record from 4 ka onwards from Kumaun Himalaya, the region influenced primarily by the Indian Summer Monsoon (ISM) and supplemented by the Indian Winter Monsoon (IWM) is presented here. The chronology of 41.5 cm long DH-1 stalagmite was constructed using StalAge model on six ^{230}Th/U dates. However, some samples have higher ^{232}Th concentrations, leading to an increase in the final age uncertainties, hence the chronology supports only the possible climatic boundaries. However, the significance of this work lies in its being one of the rare studies on the speleothem inferred high resolution climatic changes in the NW India for the Upper Holocene. The $\delta^{18}O$ values, ranging between -5.3‰ to -10‰, clarify a large variation, compared to the areas dominated by a single monsoon, and this can be ascribed to the two sources of moisture (e.g., ISM and IWM) in the study area during the Upper Holocene. The sample consists of aragonite except for two sections of calcite growth from 0-7.3 cm and 8.5-13.5 cm from the top. The climatic reconstruction, within the age uncertainties, indicates strengthened precipitation from 4.0 ka BP with sharp drop (>-2‰) in $\delta^{18}O$ values, attaining peak at ~3.7 ka BP. A gradual decline in precipitation is observed from ~3.7- 3.0 ka BP with incursion of three likely drought spikes, centered at ~3.4, ~3.2 and ~3.0 ka BP. Subsequently, climatic amelioration took place between ~3.0-2.9 ka BP, showing fluctuating trend in $\delta^{18}O$ values with comparatively more rainfall, possibly generated by the IWM in form of thunderstorms and hailstorms from ~2.9-2.7 ka BP. The reduced precipitation is witnessed from ~2.7 to 2.4 ka BP with a decadal scale major drought event, strongest in the present data set, at ~ 2.5-2.4 ka BP, whereas an abrupt drop in stalagmite $\delta^{18}O$ values from ~2.4-2.3 ka BP points to comparatively improved precipitation intensity. Thereafter, the precipitation gradually decreased until ca. 2.1 ka BP with one of the driest events at ~2.1 ka BP. A century scale increasing trend in the precipitation intensity is observed from ~2.1-2.0 ka BP, following which the precipitation again declined. Accordingly, five sudden drought events are documented, centering at ~3.4, ~3.2, ~3.0, ~2.5-2.4 and ~2.1 ka BP. A gradual reduction in precipitation from ~3.7-3.0 ka BP coincides with reduction and deurbanisation and stepwise disintegration of the Harappan civilization along the Indus-Ghaggar-Sarasvati valleys in the foreland areas of NW India. Variations in petrography, stable isotopes, reflectance, and luminescence along the central growth axis of another 14.5 cm stalagmite from Kumaun Himalaya indicate cooler and slightly wetter conditions in the

Himalayan foothills of northern India during the Little Ice Age (LIA), which lasted from ~AD 1489-1889 based on deposition of calcite, and AD 1450-1820 based on rapid changes in $\delta^{18}O$ values. Conditions were warmer and drier during the preceding Medieval Climate Anomaly (MCA) and also in the post-LIA periods, as evidenced by deposition of aragonite. A review of currently existing stalagmite and other proxy data from south and east Asia reveals a broad spatial pattern in precipitation over south and east Asia during the LIA, with northern areas showing generally increased precipitation and southern areas reduced precipitation. During the MCA and after the LIA, the records suggest this pattern was reversed. Weaker ISM during the LIA brought drought conditions to the core ISM area but triggered more monsoon 'breaks' that brought higher precipitation to the Himalayas. At the same time, the weaker ISM may also have pushed more depressions along the path of the southern winter jet which brought more winter precipitaton to the Himalayas and therefore a LIA wetter in our study area.

Climate variability during Holocene at the Dokriani glacier valley, western Himalaya

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The sub-alpine and alpine vegetation zones capture the climate change signals by distinct changes in biodiversity. Climate reconstructions from these areas can provide better understanding of the long-term climate variability, necessary for predictive climate modeling and a sustainable ecosystem-management. The vegetation-climate relationship was developed by analyzing palynology and stable carbon isotope ($\delta^{13}C$) datasets of subsurface peat from the sub-alpine altitude (3,500 masl) in the Dokriani glacier valley, western Himalaya. The 1.25 m deep peat sequence covered the Holocene time (11.6 ka BP till recent) based on radiocarbon dated chronology. The frequency changes in the proxy datasets recorded ecological shifts at the study site. Pollen frequency of steppe taxa (Liguliflorae, Tubuliflorae and Amaranthaceae) was high (25%) between 11 ka and 10 ka indicating the extension of Younger Dryas event. Subsequent moist conditions was inferred by an increase in *Quercus* pollen and $\delta^{13}C$ values (-27‰). Arboreal pollen of *Quercus* and *Alnus* dominated since 8.5 ka suggesting advancement of arboreal taxa to higher elevation during mid-Holocene. The pollen of moisture-loving non-arboreals (Apiaceae and Polygonaceae) increased in percentage since 6.5 ka indicating moist conditions. Gradual increase in *Pinus* pollen since 6.4 ka showeda continued upslope advancement of this taxon into the sub-alpine forest. Slight increase in $\delta^{13}C$ values (-26‰) was observed between 4.3 and 3.4 ka BP correlating to the globally dry 4.2 ka event. Moist-loving pollen taxa increased in percentage (~45%) between 1.2 and 0.8 ka BP also corroborated by the decrease in $\delta^{13}C$ values (-27‰). This moist event correlates to the globally documented medieval warm period. Pollen

of moisture-loving non-arboreal taxa declined (15%) and $\delta^{13}C$ values increased slightly (-26.5‰) since 0.8 ka BP indicating commencement of drier climate which brackets the dry Little Ice Age. Comparing the past pollen assemblage with the present pollen-vegetation relationships, the present vegetation is observed to prevail for the last 400 years.

A high-resolution record of nitrous oxide variation from the South Pole during the Holocene

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Nitrous Oxide (N_2O) is an important greenhouse gas which causes strong ozone destruction. The major sources of atmospheric N_2O are nitrification and denitrification processes occurring in terrestrial soils and the ocean whereas its main sink is the photolysis in the stratosphere. Here we present a high-resolution N_2O record obtained from South Pole Ice (SPICE) core during the Holocene. The N_2O analysis is performed in specialized wet extraction facility installed at Seoul National University that used minimum size of ice (<20 gm per measurement) to yield a high precision (~1.5 ppb average standard deviation). The obtained N_2O mixing ratios agree well with the existing records on the multi-centennial to millennial scale. We prepared a new N_2O composite by combining our results from SPICE core with the N_2O records of other ice core sites. The N_2O composite shows four important periods of N_2O variation during 11.5-10.0 ka, 10.0-6.2 ka, 6.2-2.2 ka and 2.2-1.4 ka which include two local N_2O maxima at ~11-10 ka and 3.0-2.3 ka followed by local N_2O minima at 8.8-6.2 ka and 1.4 ka, respectively. Comparison with paleo-proxy records suggest that the maximum N_2O change occurred between 11.5-10.0 ka (around Pre-Boreal or PB) which might be related to increased emission from monsoon regions as well as from Arabian Sea and Chile Margin oxygen minimum zone (OMZ). Subsequently, the N_2O decrease between 10.0-6.2 ka may be linked to the decreased precipitation around South American monsoon region and weakened Arabian Sea and Eastern Tropical South Pacific (ETSP) OMZ. The N_2O increase between 6.2-2.2 ka might be due to the increased precipitation around S. American and Australian-Indonesian monsoon regions and intensified OMZ around Arabian Sea and ETSP. Afterwards, the sharp decrease in N_2O between 2.2-1.4 ka might be related to the weakened Asian and Australian-Indonesian monsoons and weakened OMZ around the ETSP.

Evolution of the Indian summer monsoon in the Bengal region during the past ~ 10 ka and coupled shifts in a lacustrine ecosystem

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A multiproxy study from a tropical lacustrine sedimentary archive provides record of the Holocene monsoonal history and coupled shifts in lake ecosystem from the Bengal region. The study infers that the region experienced an overall high Indian summer monsoon (ISM) rainfall during the early to mid-Holocene (between 10.2 and 5.6 ka) which corresponds to the Holocene Climatic Optima (HCO) when lake stand was also high. Following this, the ISM weakened around c. 4.3 ka with aconsequent decline in lake level and an increase in dry-loving plants. The ISM was also strong between c. 3.7 and 2.1 ka following which shifted towards a drier mode however, punctuated by a stable phase between c. 1–0.8 ka and a comparatively stronger phase between c.0.2–0.1 ka corresponding to the Medieval Warm Period (MWP) and Little Ice Age (LIA) respectively. Following the changes in regional rainfall patterns, the lake started becoming shallow and completely dried up between 1700 and 1800 CE. Our results infer that millennial-scale variations in the ISM strength in the Bengal region may be due tochanges in orbital insolation and the dynamics of the Inter Tropical Convergence Zone (ITCZ) however, centennial scale variationsperhaps triggered by a variety of forcings which worked collectively.

Sediments in man-made 'lakes' in semi-arid climate hotspots of western India preserve high-resolution records of regional rainfall variability

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Over the last decade, there has been an increase in the demand for exploration of natural archives that allow for a complete understanding of the response of human-environment systems (e.g. watersheds) to climate pressures on longer timescales of human interest (i.e. century scale), especially in regions emerging as climate hotspots. Researchers are increasingly exploring novel natural archives that up until now were not considered appropriate for paleoclimate/paleoecological studies. These archives were excluded, in part, because the idea of human-environment systems is a new concept in climate sciences and also in part because of the logistics involved in conducting the in-depth integrative multi-disciplinary investigations required to unravel the climate, environment, and human impact information encoded in these non-conventional natural archives. Here, we present sedimentary records from an ubiquitous, but relatively unexplored, natural archive -- man-made 'lakes' or 'tanks', ('talav' in the local language) created by the century old practice of damming seasonal rain-fed distributaries to conserve rainwater for the purposes of agriculture. These 'lakes' are some of the most common forms of surface water bodies in the water-stressed climate hotspots of the Indian sub-continent, especially in peninsular India.

Using a novel, robust and integrative approach combining remote sensing, lake geophysics, sedimentological and geochemical investigations from ~1 m cores extracted from two man-made 'lake' sites in the west Indian state of Maharashtra, we demonstrate that the sedimentation rate at these 'man-made lake sites' are high enough to preserve a high-resolution (inter-annual) record of local erosional patterns governed by regional expressions of the Indian summer monsoon. We conclude that such 'man-made lakes', which are numerous in semi-arid regions of peninsular India, could be an important archive to explore in relation to historical (century scale) climatic and ecological research in the region. We also demonstrate the critical value of using integrative approaches, rather than traditional paleoclimate techniques of using single proxy measurements, to extract meaningful sedimentary, climatic and environmental information from these unique archives. These man-made lake sites not only fill paleoclimate data gaps, especially on the scale of centuries, but also, perhaps more importantly, address critical questions around climate impacts on coupled human-environment systems, which are important for developing sustainable and equitable policies around natural resource management.

Last 20 ka Indian Summer Monsoon Record from the Baspa Valley, Northwest Himalaya, India

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The Indian Summer Monsoon (I.S.M.) is a crucial component of the tropical climate system coupled with the global atmospheric circulation driven mainly by the land-sea thermal contrast. The lakes, wetland and peat deposits from Northwest (NW) Himalaya is climatically more significant and is the best place to study the I.S.M. and Westerly Disturbances (W.D.'s). To know the possible connection between I.S.M. and W.D.'s, we present centennial to millennial-scale Late-Pleistocene to Holocene climatic records, using multi-proxy data. We used Environmental Magnetism, Diatoms, ^{14}C Dating, Total Organic Carbon (T.O.C.) and Stable Carbon Isotope($\delta^{13}C$) as proxies from peat deposits of the Baspa Valley that are located on the Southern fringe of the Tibetan Plateau. The peat profile's low-frequency magnetic susceptibility (χlf) varies from 0.41 to 0.72 ($10^{-8}m^3kg^{-1}$), and the average χlf is 0.55 x $10^{-8}m^3kg^{-1}$. χlf shows the variation in magnetic mineral concentrations due to the freezing and thawing conditions under cold and dry climatic conditions or chemical weathering under warm and wet climatic conditions. T.O.C. values lie between 0.32 to 22.87, and the average value of T.O.C. is 3.97 (wt. %) shows the area's productivity. The Carbon Isotope ($\delta^{13}C$) value varies from -27.34 to -25.32‰ indicating the dominance of C_3plants.Diatoms are very sensitive to climate change, and the identified diatoms genus are *Pinnularia, Diploneis, Rhopalodia*, and *Epithemia,* living in freshwater conditions. Five climatic phases of alternating strengthened and weekend I.S.M. are recognised for the last 20 ka using the above data. Periods of strengthened I.S.M. are dated to ~15 to ~14cal ka B.P., ~10 to ~7 cal ka B.P., and ~2.4 to ~1.3 cal ka B.P. which is ascribed to the post older dryas increase in insolation. Whereas the phases of weakened I.S.M. are bracketed between ~20 to ~15cal ka B.P., ~14 to ~10 cal ka B.P., ~7 to ~2.4 cal ka B.P.and ~1300 to ~243calyr B.P. The above attributed to cooling associated with the Last Glacial Maximum, Younger Dryas and the mid to late Holocene decrease in solar insolation, respectively, as well as ~2.4 to ~1.3 cal ka B.P. indicates the warm and wet phase during the Roman Warm Period (R.W.P.) shows the strengthening in the I.S.M. precipitation from the NW Himalaya.

Change of Biota and fixation of Neogene/Quarternary Boundary in the Siwalik of Jammu - An overview

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Neogene and Quarternary sedimentary rocks are well preserved in the Jammu province of Jammu and Kashmir. The age of Siwalik Group is middle Miocene to middle Pleistocene. Seven formation of Siwalik Group viz. Kamlial and Chinji (Lower Siwalik Subgroup), Nagri and Dhokpathan (Middle Siwalik Subgroup) and Tatrot, Pinjor and Boulder Conglomerate (Upper Siwalik Subgroup) are well exposed in Jammu region. All these seven formations contain rich assemblages of vertebrate, invertebrates, and microfossils. In the middle of Pinjor Formation, a volcanic ash layer occurring

as detached outcrops which separated Pliocene fauna from Pleistocene fauna. Most of the workers revealed that the Pliocene/Pleistocene boundary occurring 60 meters below the volcanic ash layers based on vertebrate fauna and radiometric dating. Some authors based on vertebrate fauna, magnetostratigraphy, and satellite imaginaries concluded that the volcanic ash layer strand across the Gauss/Matuyama boundary at 2.5Ma. The author carrying out work on the Siwalik of Jammu for the last twenty years and recovered a good assemblage of fossils from the mudstone horizons underlying and overlying geochrologically dated volcanic ash layer. Based on the change in fauna, flora and lithology overlying and underlying ash beds suggested that volcanic ash layer act as transition phase between Pliocene and Pleistocene in the Siwalik of Jammu or straddle across the Pliocene/Pleistocene boundary.

Ensemble modelling approach to predict the past and future climate suitability for two mangrove species along the coastal wetlands of India

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Mangroves support numerous ecosystem services and help in reducing coastal ecological risks, yet theyare declining rapidly due to climate change, sea level fluctuations and human activities. It is important to understand their responses to climate and sea level changes and identify conservation target areas at spatio-temporalscales, specifically in regions of rich mangrove biodiversity. In this study, we predicted the potential impact of past (Middle Holocene, ~6000 years), current and future (2050s, 2070s) environmental changes on the two dominant species in the coastal mangrove forest wetlands of India, i.e., *Rhizophora mucronata* (Asiatic mangrove) and *Avicennia officinalis* (Indian mangrove) through an ensemble species distribution modelling approach. The internal evaluation metrics of the resulting Species distribution models (SDMs) tested its robustness with all true skill statistics (TSS) values being> 0.98. Surface elevationwas the most important variable (54-67%) for the distribution of both the mangrove species. Additionally, mean diurnal range (Bio2) and minimum temperature of coldest month (Bio6) contributed for *R. mucronata* distribution whereas precipitation of the coldest quarter (Bio19) and maximum temperature of warmest month (Bio5) impacted the distribution of *A. officinalis*.

High precipitation and high sea-level stand during middle Holocene led to the maximum range expansion of suitable habitat for the mangrove species which is also validated in the present study by the fossil pollen datasets. Total mangrove habitat in current and future climatic scenarios decreased in 2.6 and 8.5 Representative Concentration Pathways (RCPs) for 2050 and 2070 whichindicates the vulnerability of thespecies toclimate change impacts. Mangrove species are projected to shift their ranges in future experiencing a decrease in the amount of

suitable coastal area available to them throughout Indian coastline. Pichavaram, Muthupet, Coringa, Krishna mangroves as well as Konkan-Kerala coast mangroves are forecasted to see severe decline with a complete loss of stable habitats. However, Sundarbans, Bhitarkanika and Mahanadi mangroves along with Chilika would be conserving both the mangrove species in a low-moderately suitable habitat along the east coast of India. Dwarka coast in Gujarat along the west coast will also be the target area for mangrove biodiversity conservation during the anticipated future climate change scenarios. Our findings will assist in formulating species-specific restoration plans for mangroves in context of climate change in the Indian Subcontinent.

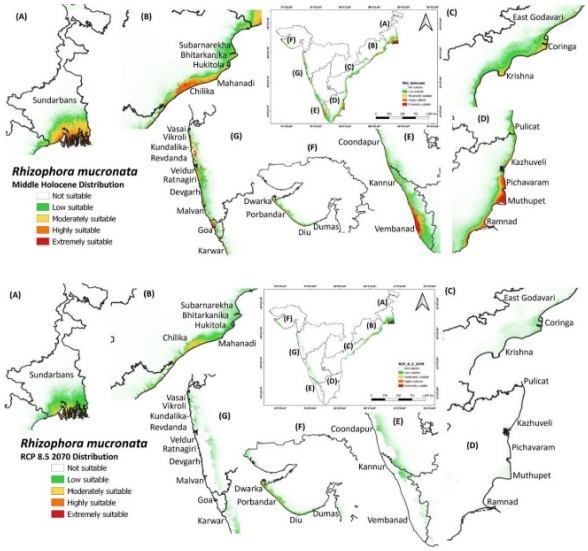

Figure 2: Middle Holocene and future (RCP 8.5 2070) potential distribution of Rhizophora mucronata along (A) Sundarbans, (B) Mahanadi Delta, (C) Godavari and Krishna Delta, (D) Cauvery Delta, (E) Kerala coast, (F) Gujarat coast and (G) Maharashtra coast in India

The impact of atmospheric CO_2 on $\delta^{13}C$ values and stomatal index: observation from industrial and non–industrial plants

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Anthropogenic CO2 emission has been dramatically increases after the industrial revolution, posing critical changes in earth's biosphere and atmosphere. Plants are highly sensitive to atmospheric CO2 concentration as well as environmental conditions because they fix inorganic carbon into organic carbon through photosynthesis. Therefore, it is crucial to understand how plants isotopic values (δ13C values) responses as well as physiological adjustment occur in the elevated CO2 levels. To see the variation in δ13C values and stomata density of C3 plants, we have sampled mature leaves of *Azadirachta indica, Eucalyptus globulus, Cascabelathevetia, Mangifera indica,* and *Tectona grandis* from five natural habitat including a location having intense industrial population, from a transect between Pilibhit and Haldwani, India. Our results exhibit that the variation in $\delta^{13}C$ values of every plant leaf has a similar trend which ranges from –34.3‰ to –27.4‰ throughout the transect. The variation in $\delta^{13}C$ values of intra-plant leaves have a minor difference (~1‰), implying that the plant leaf $\delta^{13}C$ values are homogenised and may be used for overall vegetation and climatic interpretation. The $\delta^{13}C$ values of all plants leaf collected from the industrial region are significantly lowered (average –32.1‰) compared to

the leaf samples collected from rural area (–28.3‰). It implies that rise of anthropogenic CO_2 due to fossil fuel burning, contributes a majority of lighter carbon isotope (^{12}C) in the atmosphere which is recognised by a lower $\delta^{13}C$ values in that regions plants. We also calculating the stomatal index (SI) of industrial and rural plants and observed a 25% lowering in SI values in industrial plants. It suggests that, plant changes its physiology to maintain high photosynthetic rate and minimum water loss, resulting lower stomatal index at greater ambient CO_2 concentrations. These findings suggest that rising of anthropogenic CO_2 directly affecting plants isotopic value and also structure and function of leaves. Our study shows that the$\delta^{13}C$ values of leaf and SI values can be used as a valid proxy for future mapping of the sequestration of fossil fuel derived CO_2 in the industrial belts.

Tree-ring width data from four agricultural drought-prone districts of central India

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For many decades, Bundelkhand and Vidarbha regions are taken as the type examples of agricultural drought, often under media focus for farmer suicides due to crop failure (Gupta et al., 2014; Dongre and Deshmukh, 2012). Both transit from basaltic black soil to red soil derived from granite, gneisses, and schists and are in the central Indian monsoon trough area away from any rain shadows. The probability of meteorological droughts for the years 1901-2003 (Pai et al., 2011) shows us that although rain deficit is likelier in Bundelkhand than in Vidarbha, both these regions are superseded by many regions in the nation (e.g. Telengana). In contrast, they are more significantly represented in the Drought-Prone Areas Programme in terms of agricultural droughts (Venkateswarlu et al., 2014). In looking for the cause behind the frequency of droughts in the subcontinent; we are hindered by the lack of long-term soil moisture data. Modelled soil moisture data (1948-2004) from the NOAA (Fan and van den Dool, 2004) is the only such data available but has no long-term validation. Plants primarily source water from the soil, hence its signatures are preserved in tree-ring cellulose isotopic values which can be used to reconstruct soil moisture evaporation (Bose et al., 2016). Application of this method to cellulose isotope datasets of rural trees in Bundelkhand and Vidarbha would lead to reconstructions of long-term agricultural soil evaporation variability. Moreover, comparison with reconstructions from nearby forests should indicate the causes of these regions being repeatedly affected by agricultural droughts.

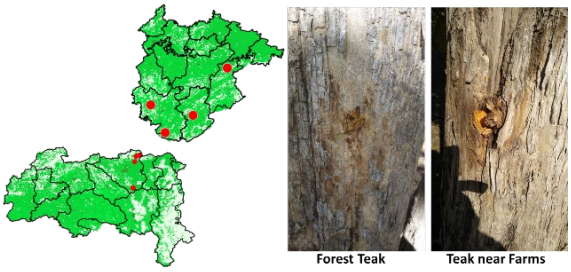

Figure 3: left: sample locations and right: wetter tree bark in forest specimen

With the above goal in mind, tree-ring samples were taken from teak trees

(*Tectona grandis*) from forests and agricultural sites in four districts in these regions at the end of 2019. These districts were, Nagpur, Sagar, and Panna covering significant stretches of the Deccan plateau. The tree ring widths were cross dated and a chronology developed using a standard dendrochronological technique. The timeline spans the years 1896 to 2019 C.E., (124 years). According to a preliminary study covering all districts, the most significant declines in growth happened between 1945- 1970, as well as between 1980 and 2019 CE.

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Understanding the isotopic record of secondary cave carbonate deposit used for palaeoclimate reconstruction

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Secondary cave carbonates, speleothem are used in palaeoclimate community for climate reconstruction by conventionally analyzing the stable isotopic composition. In the tropical settings such variability in the composition is explained with the variation in the amount of convective rainfall or precipitation. Much debate surrounds the credibility of such record to repeat in other specimens from the nearby cave featuring similar climatic control. Here, we studied a speleothem stable isotopic composition from North East India which receives high rainfall, and the isotopic ratios in speleothem carbonate exhibit the pattern of rainfall amount, which varies temporally. We examined inter-cave dynamics which exhibited unexpected deviation in the isotopic composition and observed pattern. However, the erroneous absolute value showed a large similarity with the trends recorded in the other archives denoting warm time interval known for the time of Roman Warm Medieval Period. We proposed here a multi-proxy approach to establish accurate conclusion, especially in the case of paleoclimate reconstruction using speleothem based isotopic studies.

Mid-Late Holocene Climate reconstruction from coastal dunes of western Kachchh and implications for Sea level change, Kachchh, Western India

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Coastal Dunes are integral land forms associated with sea-level fluctuations and varying climates. Climatic changes directly affect dune development by modifying the wind regime or indirectly by influencing vegetation cover and sediment supply (Neuman et al., 1997). The present study focuses on the mechanism, climate, and sea-level implications of the coastal dune building activity in the eastern coast of Kori Creek (Gulf of Kachchh, western India). Coastal dune sediments having a deposition of ~10m thickness are investigated using various proxies like sedimentology, geochemistry, and optical chronology. The study suggests that the dune sediments overlying the Tertiary Oyster Bed is dated to ~4ka. The grain size analysis and correlation of the inland dunes and coastal dunes textural parameters show no stark difference, revealing they were deposited during the same time. Further, the geochemical data generated from the samples of the coastal dune site represent semi-arid to semi-humid climate with increasing chemical maturity and weakening monsoon during the time of deposition. Based on the current erosion of the dune face and optical ages of the samples, it can be inferred that the Kachchh coastline was exposed due to the lowering of the sea level at the time of the deposition of coastal dunes. The sea must be at a lower level to attain a preferable condition for the deposition of dunal landforms. The lowering of the sea exposed the beach with sandy material, providing accommodation space for dune formation. The dry phase at ~4.2ka became the most conducive environment of coastal dune formation. The time of dune deposition is coeval with the Harappan civilization existing in the Kachchh region. While the weak monsoon might have played a role in the disintegration and collapse of the civilization, lowering of the sea level during ~4.2 ka does not appear to be of significant influence.

Neuman, C.M., Lancaster, N., Nickling, W.G., 1997. Sedimentology44 (6), 1103–1111.

High resolution precipitation variability over Northwest Himalaya from 4.0 to 1.9 ka BP: Impact of Indian Summer Monsoon (ISM) and Indian Winter Monsoon (IWM)

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A stalagmite based high resolution climatic record between 4.0 and 1.9 ka BP from Dharamjali Cave (29°31′27.8″N: 80°12′40.3″E; altitude, 2200 m) in Pithoragarh (Kumaun Himalaya). The area is influenced primarily by the Indian Summer Monsoon (ISM) and supplemented by the Indian Winter Monsoon (IWM) or Westerlies. The chronology of DH-1 (41.5 cm) was constructed using StalAge model on six 230Th/U dates. The $\delta^{18}O$ values areranging between –5.3‰ and –10‰. The composition of sample is mainly aragonite except for two sections of calcite growth from 0–7.3 cm and 8.5–13.5 cm from the top.

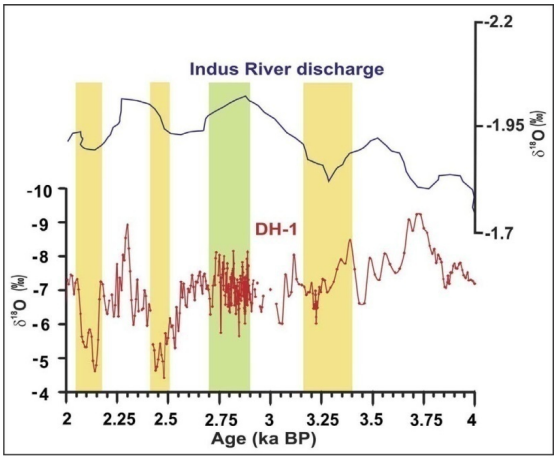

Figure 4: Comparison of DH-1 δ18O record with palaeo-discharge of the Indus River. Green and yellow panels indicate wetter and drier periods respectively.

A gradual decline in precipitation is observed from 3.7 to 3.0 ka BP with major droughts, centered at 3.4, 3.2 and 3.0 ka BP. Subsequently, climatic amelioration took place between 3.0 and 2.9 ka BP, showing fluctuating trend in $\delta^{18}O$ values with comparatively more rainfall, possibly generated by the westerlies in the form of thunderstorms and hailstorms from 2.9 to 2.7 ka BP. Precipitation declined from 2.7 to 2.4 ka BP with a decadal scale major drought events, strongest in the present data set, at 2.5–2.4 ka BP. The dry event from 3.7 to 3.0 ka BP coincides with reduction and deurbanization and step-wise disintegration of the Harappan civilization along the Indus-Ghaggar-Sarasvati valleys in the foreland areas of northwestern India.

A 1600-Year Environmental Magnetic Record of Palaeo-monsoon Variability from a Coastal Lake in Karnataka

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There have been many extreme climatic events reported from southern India during the past few years. However, the high-resolution palaeorainfall records in the region are limited. In the present study, the palaeomonsoonal variability in the region is investigated based on the environmental magnetic propertiesof a 154-cm long sediment core fromLake Ramasamudra, a small lake in coastal Karnataka, southern India. The recordspans the past 1586-years (2037-451 calyr BP) based on five AMS ^{14}C dates. The

environmental magnetic study reveals the strength of the monsoon during the past in terms of fluctuating magnetic mineral concentration. The magnetic mineralogy of the lake is mainly composed of magnetite, as indicated by the high values of the S-ratio (Figure 5).

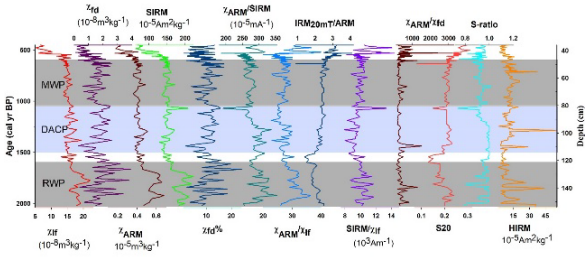

Figure 5: Down core variations of environmental magnetic parameters of Lake Ramasamudra

The magnetic grains present in the sediments are mostly Stable Single Domain (SSD) and Superparamagnetic (SP), indicating a relatively stronger intensity of pedogenesis in the catchment in response to the enhanced monsoonal conditions. The reconstructed paleoclimatic record describes three different climatic zones, i) 2040-1600 calyr BP corresponding to the Roman Warm Period (RWP), ii) 1500-1050 calyr BP corresponding to the Dark Ages Cold Period (DACP), and iii) 1050-600 calyr BP, contemporaneous to the Medieval Warm Period (MWP). High values of concentration-dependent magnetic parameters (χ_{lf}, χ_{fd}, χ_{ARM}, and SIRM) during RWP suggest a high influx of terrestrial sediments into the lake, which delivers ultrafine Stable Single Domain (SD) and Superparamagnetic (SP) magnetite. It is an implication of strong monsoon and pedogenesis in the lake catchment during this period. During DACP, a steady decrease in the concentration-dependant magnetic parameters in response to a weakening monsoon is observed. The monsoonal intensity was the weakest during MWP, as indicated by low χ_{lf} values and other parameters. Spectral analysis of the magnetic susceptibility data reveal periodicities of 526, 226, 102, 90, 81 and 67 years, most of which are of solar origin. This indicates the influence of the solar forcing on the Indian summer monsoon.

Vegetation and climate changes based on pollen record from Garhwal Himalaya (India) and its implications on ENSO influences during the past ~2000 years

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Interannual to interdecadal variability of Indian Summer Monsoon (ISM) is closely associated with the El Niño-Southern Oscillation (ENSO). The El Niño (La Niña) events are associated with deficit (excess) ISM rainfall. However, the ISM-ENSO relationship has weakened since the 1980s. The ISM-ENSO link has also not been well established on a centennial to millennial scale. We present a pollen record of vegetation and ISM variations for the past ~2000 years from Bednikund lake, Pindar basin, Garhwal Himalaya. ISM weakening is indicated by an overall decline in vegetation during ~1860-1050 calyr BP (Dark Ages Cold Period), which corresponds with a period of high ENSO variability. Vegetation restoration during ~1050-790 calyr BP (Medieval Climate Anomaly, MCA) suggests enhanced ISM rainfall, whereas less diverse vegetation indicates weak ISM during ~500-335 cal yr BP (Little Ice Age, LIA). In contrast to the inverse relationship between ISM rainfall

and ENSO, our record suggests that strengthened (weakened) ISM during the MCA (LIA) was associated with an El Niño–like (La Niña–like) state as reconstructed from tropical Pacific hydroclimate records. Such inconsistency in ISM behaviour can be attributed to tropical Pacific Sea surface temperature anomalies, which indicate contrasting ENSO patterns during Holocene, thereby highlighting the role of solar insolation and the position of the ITCZ in ISM variability.

Modern pollen representation of the vegetation from the Meghalayan Cave of India: A comparative assessment of bat guano from conventional soil and moss substrates

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The present study examines the pattern of preservation of pollen and non-pollen palynomorphs on bat guano samples inEraaning Cave in relation to the current vegetation of the surrounding Garo hills of Meghalaya. It is observed that, the recorded pollen data does reflect the tropical mixed deciduous forest with an admixture of riparian and evergreenplant taxa from the local and regional vegetation. The presence of evergreen and riparian taxa namely, *Mesua, Schima, Duabanga*, and *Syzygium* in the pollen assemblage is strongly indicative of the high rainfall inthe region. The recovery of fern and fungal spores in the pollen assemblage also reflects thewarmand humid climaticcondition in this region. The forest-land and open-land samples fromthe vicinity of the cavewere also studiedto understand the nature of pollen preservation in relation to the bat guano samples. The presence of cereal, *Areca*, *Psidium*, and *Citrus* along with *Melastoma* pollen in both bat guano and open-land samples is indicative ofthe anthropogenic activities in and around the study area. Multivariate principal component analysis (PCA) andbox plot were applied to the quantified data obtained from pollen frequency analyses which clearly revealed asignificant variation and similarity in vegetation types among the surface samples collected in and aroundEraaning Cave. The generated pollen data from the bat guano, forestland, and open-land samples reveals that, bat guano in cave sediments provides a reliable substrate to understand the modern pollen and vegetation relationshipand can fruitfully be utilized as a baseline for the reconstruction of the palaeoecology in the Garo hills ofMeghalaya. The study also suggested that the bat species utilized the mixed vegetation composition and differentlandforms as their preferred habitats as demonstrated by the pollen data from the bat guano samples.

Late Holocene climate changes reconstructed from the lacustrine sedimentary record in the southern Yemen

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GayalelBazal lake is karstic paleolake situated on southern margin of Arabian Desert, a climatic sensitive zone that responds to small-scale hydrological changes. High-resolution biomarker and ostracods assemblage data obtained on 3.25 m composite core from the lake can provide insight into paleoenvironmental changes in the region. Variations in sediment lithology and sedimentology from the lake core suggests fluctuation in the precipitation regime during the late Holocene. Two major events are recorded from the composite sediment core in the past 1200 years (i) Medieval Climate Anomaly (MCA) and (ii) Little Ice Age (LIA). The climate reconstruction based on the *n*-alkane distribution suggests higher abundance of longer chain length carbons (C_{27}-C_{35}) derived from higher plants of the watershed during the MCA indicating wetter condition in the region. Furthermore, ostracods assemblage data also revealed *Paracyprettaamati* abundance increases during the MCA and decreases during the LIA. The arid phase of LIA is also marked by gypsum formation and dust deposition and is consistent with evidence and theory for weakened boreal summer monsoons during intervals of northern hemisphere cooling. Overall, this study will provide a better insight of the monsoon variability and to help to understand the role of northwards migrations of the Intertropical Convergence Zone (ITCZ) vis-à-vis monsoonal dynamics in the region.

The Late Holocene culture and climate dynamics in the Indian summer monsoon realm

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The understanding of long-term adaptation by communities to climate variability may provide valuable perspective on possible response of human societies to modern climate changes. In this study, geochemical and sedimentological analyses has been conducted on the fluvial deposits exposed near river Sina, Maharashtra, central India to investigate the complex interplay between climate and cultural dynamics during the Late Holocene. Asystematic catchment analysis has been carried out to understand the richness and availability of natural resources, agriculture pattern, flora, fauna and the geomorphology. The cultural objects available at the site include

pot sherds, shell bangles, glass bangles and copperartefacts. The radiocarbon dates of the organic residues from the pot sherds represents the Medieval period (ca.1600 cal yr BP–950 cal yr BP). The OSL sample obtained from the bottom unit indicates the studied sequence with lower age value of 7.5± 0.4 ka. The grain-size as well as the geochemical parameters shows a marked variation in the past hydrological regime. The temporal changes reflected in the richness of the cultural materials suggest that the human population attempted to adapt against the fluctuating climate conditions. Similar observations are also available from the Lake Lonar (central India) record indicating the significance of the natural climate variability and mega-droughts as major environmental factors affecting human settlements. The regional comparison of geo-archaeological datasets shows that the pronounced weakening of the Indian summer monsoonal rainfall during the Late Holocene epoch coincides with the disruption, migration and resettlement of the indigenous societies, deciphering the possible impact of climate on human settlement.

Organo-molecular records of warm periods from Late Quaternary loess-palaeosols from Dilpur Formation, Kashmir

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Previous isotopic composition-basedstudies inferred cold climatic incidences, low pCO_2 and water stressed conditions experienced by theDilpur loess-palaeosols. Layer-wise clay mineralogical investigations unveiled three stadials with each followed by three interstadials.Cold periods are well defined by clay mineralogical changes along with radiocarbon dating however, inadequate information is available on warm transitional periods (e.g., MIS-1, MIS-3 and MIS-5). Elemental geochemistry and organo-molecular proxies have been attempted to comprehend climate during transitional warm periods. Positive Europium anomaly shows reducing conditions during these periods. GC-MS analysis of n-alkanes, fatty acids and polycyclic aromatic hydrocarbon (PAH) compounds revealed dominance of long chain C_{27}, C_{29} and C_{31} n-alkanes, infer their derivation from tree, shrub and grass dominated flora, respectively. Further, dominance of n-C16 fatty acid, together with the naphthalene and fluoranthrene represent their derivation from the algal and bacterial, and mosses as the source, respectively. Obtained C_{31}/C_{27} n-alkane values bearing palaeosol suggest that the trees grown in the warm (MIS-3, MIS-1) and grasses in the cold periods (MIS-5, MIS-2). Palaeosol layers deposited prior and later to glaciations show abundance of n-alkanes, suggestive of grass type of palaeo-flora that existed during advancing and waning periods of glaciation. Moreover, n-alkanes together with the fatty acids revealed progression of shrubs and trees in the inter-stadials. Mixed type of palaeofloral signatures recorded from the glacial-interglacial transitions reflect bimodal climate, although, glaciation persisted dominantly throughout the transitional periods. Moreover, organo-

molecular records for pale-brown eleventh palaeosol layer of 109 ka suggest temperate climate, endorsing for a longest stadial period of 127-94 ka. These incidences when considered in conjunction with the clay compositional records, resolve three major stadials of 127 - 94, 78 - 58 and 42 - 10 ka durations, interceded by three inter-stadials of 94 - 78, 58 - 42 and 10 - 0 ka within the span of 127 ka.

Diatom-based water-table reconstruction during Middle to Late Holocene in the High-Altitude Himalayan Peatland, India

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The Kedarnath peat sequence is demonstrated with a total of 127 samples from a 5.22 m long sequence to reconstruct the palaeoenvironmental conditions over the mid-late Holocene (last 8,000 years to present). Diatoms were extracted by chemical cleaning and studied under light and scanning electron microscopy and a total of 122 diatom taxa were recorded. Several successional changes in the total and relative abundances of diatom species were noted in the peat section. Principal Component Analysis and Cluster Analysis were applied to the diatom data to identify the statistical relationships of diatom assemblages. Our results show high diatom productivity during ~5700-5350 calyr BP, ~4350-4250 calyr BP, ~3850-3000 calyr BP, and ~1700-950 calyr BP, and therefore indicate higher water-table. Contrarily, diatoms were low to absent during ~8000-5700 calyr BP, ~5350-4350 calyr BP, ~4250-3850 calyr BP, ~3000-1700 calyr BP, and ~950-300 calyr BP, and therefore indicate lower water-table. The reconstructed water-table variations during the mid-late Holocene in the Indian Himalayan region could be attributable to changes in the rain fall intensity. Our data correlate with the solar insolation and Northern Hemisphere climate changes, which may have played a significant role for high-altitude Indian Himalayan natural ecosystems. The poor preservation of diatoms in peatland during ~950-300 calyr BP invokes the need for in-situ data monitoring for the Indian peatlands.

A non-linear palaeohydrology time series analytic study – an attempt to delineate the predominant influence of Western Disturbance over Indian Summer Monsoon in Higher Central Himalaya since Post LGM

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Palaeohydrology was reconstructed from a proglacial relict lake situated above tree line (~4000 m msl) in the Higher Central Himalaya. The palaeohydrological proxies used are mineral magnetism and sediment organic matter carbon stable isotope values. The lake is in transition zone influenced by periodic Indian Summer Monsoon (ISM; summer) and non-periodic Western Disturbance (WD; winter), and receives annual rainfall of 700 mm. For delineating and reconstructing the

contribution of ISM and WD, we sampled every cm of sediments from a 4 m pit. Bayesian age-depth model used nine luminescence ages after discarding three ages. A non-equidistant time series data was possible from 40 a to 15,650 a, with a median resolution of 35 a.

Mineral magnetism and inter-parametric ratios were used to represent the changes in bulk magnetic mineral concentration (χ_{lf}, SIRM), its mineralogy (sIRM, hIRM and S-ratio), and its grain size (ARM, χARM/SIRM, χARM/χ_{lf}, SIRM/χ_{lf}). Variation in these values depends on the hydrological conditions around and diagenetic processes in the lake. Hence each magnetic proxy can be a state variable of the lake. Using appropriately chosen time delay (τ) and embedding dimension (m), complete information about the state could be extracted from each proxy time series via recurrence plot (RP). Recurrent network analysis (RNA) was done on the adjacency matrix constructed from the network that was converted from the respective time series using visibility graph algorithm. Determinism, laminarity, transitivity, ratio of recurrence rate and determinism and average path length are used as complexity quantifiers to infer predictability, intermittency, regularity, dynamical transitions and abrupt dynamical transitions, respectively.

There were two prominent abrupt climate transitions at 8 ka (χ_{lf}) and at 4 ka (all). The lake system was predictable during 8 – 4 ka, and 11.8 – 6.2 ka, and unpredictable till 12 ka and since 4 ka. Assuming predictability represents ISM, the system was predominantly influenced by WD till 12 ka (from 16 ka, at the latest) and since 4 ka.

The $\delta^{13}C$ values from bulk sediment organic carbon were measured on representative samples. PCA scores based on all magnetic data are 46.9 % PCA 1 and 32.7 % PCA 2. Trend of PCA 1 scores and χ_{lf}matches with the published data of precipitation trend while PCA 2 and $\delta^{13}C$ trend following published temperature graph. It seems that hydrological condition is controlled by the interplay of ISM and MLW. PCA scores, its correlation or anti correlation with $\delta^{13}C$, $\chi_{lf}$and its associated parameters like temperature and precipitation support the results of RQA and RNA. These set of non-linear time series analyses are shown to have potential to delineate the contribution of ISM and MLW, and reconstruct the palaeohydrological conditions in a climatic transition zone.

A lacustrine geochemical record of the chemical weathering intensity and rainfall during the Holocene from tropical southern India

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The geochemical data obtained from lake sediments can not only provide valuable insights into chemical weathering

intensity within lake catchment, but also information on changes in the past rainfall and the provenance. The present study aims to determine variations in the intensity of chemical weathering and provenance of Shantisagara lake sediments in southern India for the past 11,000 years based on various geochemical proxies. The different metal/Al ratios like K/Al, Fe/Al, Ti/Al and Zn/Al exhibits significant down-core variations indicating the changes in the detrital influx to the lake. The Principal Component Analysis (PCA) of metal/Al ratios extracted three components which represents fine detrital fraction, fine grained pedogenic component and coarse-grained detrital fraction. The Chemical Index of Alteration (CIA) values do not exhibit much variations because of the highly weathered nature of sediments, but Rb/Sr values exhibit significant fluctuations downcore. The similar LREE-enriched chondrite normalised REE patterns indicate that there was no significant change in the provenance of sediments during the Holocene. The data indicate high detrital influx around 10,500 cal. years B.P. pointing towards high rainfall conditions. Overall, the region experienced moderate to strong monsoon during Early Holocene period (~ 11,000 to 8000 cal. years B.P.). A fluctuating trend of terrigenous influx and chemical weathering intensity is documented during Mid-Holocene (~ 8000 to 4000 cal. years B.P.) period in response to variable rainfall. During the Late-Holocene (4000 cal. years B.P. to Present) period, decreasing rainfall trends are observed, albeit with a slight increase from 2000 cal. years B.P. to Present.

Phytoliths in modern plants from dry and moist deciduous forests of the western margin of Bengal Basin and its implications in palaeovegetation reconstructions

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Phytolith assemblages of 244 modern plant specimens (including 76 grass and 168 non grass taxa) and 50 surface samples collected from the dry and moist deciduous forests along the mean annual temperature (c.21.1–26.3ºC) and precipitation gradient (c. 1180–4663 mm) of the western margin of Bengal Basin have been studied to understand the relationship between modern vegetation and climate variables which is an essential pre-requisite for past palaeoecological reconstructions. The present study aims to understand how reliably the phytolith morphs can depict a standing vegetation cover and whether the open and closed forests and grassland habitats can be discriminated. This study further aims to identify the principal climatic factor(s) governing the distribution of phytolith morphs in different vegetation types. In order to do so

the phytolith assemblages diagnostic for the above-mentioned habitats are identified and their relationship with the climatic variables such as mean annual temperature (MAT), mean annualprecipitation (MAP), actual evapotranspiration (AET), potential evapotranspiration (PET) and moisture index (MI) is assessed. We infer that in the Bengal Basin distribution of the phytolith assemblages from different habitats within the above-mentioned vegetation zones are primarily influenced by mean annual precipitation. The results of the present study could be utilized as a baseline while reconstructing past vegetation and the climate of the Bengal region.

Vegetation, Climate Change and Human Impact in Central Ganga Plain During Late Holocene Period

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The Ganga Plain abounds with a large number of potential lakes and sedimentary deposits of different shapes and dimensions for the Quaternary palaeoclimatic studies. Most of the lakes are situated in the interfluves of the Ganga and its tributaries and formed as abandon channels in the past. These lakes serves as the natural archives, which enunciate the chronicle of the changing vegetation scenario and concurrent climatic oscillations of the past, based on pollen and other proxies retrieved in the sediments. The study of 300 cm core accomplished from BilandKhera Lake, situated in the proximity of Gupta- Kushan cultural mound in Sitapur District, Uttar Pradesh has deduced the vegetation succession, climate periods and lake level fluctuations. Since ~4000 to 2600 yrs BP open grassland interspersed with stretches of herbaceous vegetation comprising grasses, sedges, Asteraceae, Cheno/Am, etc., occurred in the region under a regime of dry climate. Few trees of *Madhuca indica*, *Holoptelea*, *Shorearobusta*, etc. were also sparingly dispersed therein. Around 2,600 to 1,260 yr BP theopengrasslandwere thrived by the open mixed deciduous forests as supported from the enhancement in *Madhucaindica*, Sapotaceae, *Holoptelea*, *Shorearobusta* as well as sporadic invasion of *Mitragyna*, *Terminalia*, *Flacourtia*, *Grewia* etc. This enhancement in the forest floristic reflects the initiation of a warm and humid climate in response to enhanced monsoon precipitation. Since 1,260 yr BP onwards the depletion in the prominent forest ingredients viz., *Madhuca indica*, Sapotaceae, *Shorearobusta*, *Holoptelea* and other associated trees suggests that the forests turned more sparse and less varied due to the beginning of a warm and less humid climate, due to the impact of reduced monsoon precipitation. The Cerealia pollen and other concomitant cultural taxa presence in complete length of the core suggests the study area was under of cereal-based agricultural practice.

Using proxy data and vegetation modelling to predict past, current, and futuredistributional shift of *Butea monosperma*, a therapist for land degradation in India

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Extensive deviations in spatio-temporal social and environmental processes are stressing the world's arable lands essential for the provision of food, water, and quality air. Detecting the causes that contribute to the distribution of a natural forest species capable of restoring the lost ecosystem function and productivity will aid in determining better food security, livelihoods and provision of ecosystem goods and services. We modelled the spatial range of *Butea monosperma*under past i.e., Last Glacial Maximum (LGM), MiddleHolocene (MH), current and future (2070) climaticscenarios with MAXENT. Area of suitable habitats are identified for which the species presence is inferred in all the models for different time projections. In order to validate the inferred suitable habitat, we tested the model by the current occurrence and fossil pollen data of *Butea monosperma*. Our distribution models agree with the fossil pollen records for the middle Holocene (4500-7000 yrs. BP) and predicts prevalence of *B. monosperma* covering 74.27% of the Indian Subcontinent with maximum habitat stability in western and southwestern India (12.47%). Widespread distribution of the plant species during LGM supports the presence of the last remnants of tropical dry deciduous forest in the region. However, a decline in habitat suitability (55.42%) is predicted for current and future climatic scenarios with maximum stability (0.42% - 5.14%) along the Southwestern Ghats in the Southern, Gir Range in the Western, foothills of Siwaliks in the Northern and Khasi-Jaintia hills in the Eastern part of India. Temperature seasonality (39.2%) ranging from 5-30˚C significantly affected the distribution shift of *B. monosperma*along with annual precipitation (15.9%) and annual mean temperature (11.5%). Model results provide evidence of habitat fragmentation and depletion and identifies the stability hotspots for *Butea monosperma* for its conservation and establishment of land management policies mainly for the dry tropics.

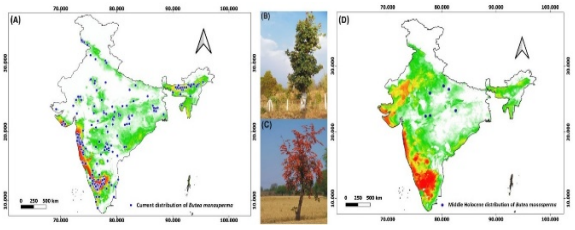

Figure 6: (A) Current distribution data of Butea monosperma in the Indian Subcontinent based on occurrence records and Species distribution modelling, (B) Surviving B. monosperma on road verges, (C) B. monosperma during spring season, (D) Middle Holocene distribution map of B. monosperma with available fossil pollen data from different localities.

Hurdles and breakthroughs of integrated paleoclimate reconstruction: a case study from western India

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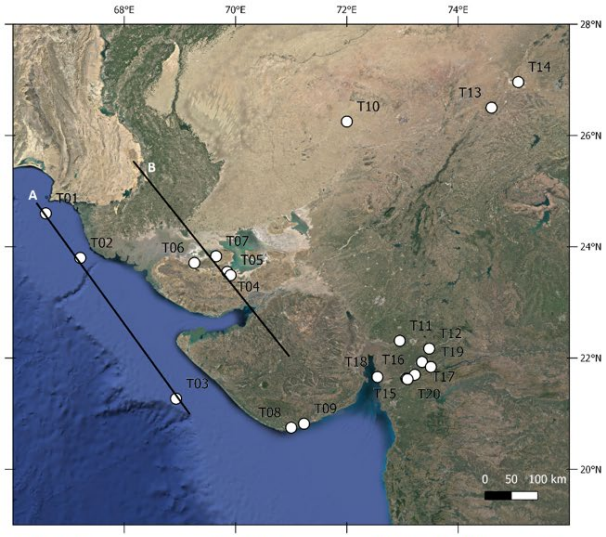
The spatial density of paleo datasets is generally low due to problems inherent in sampling and analysis. Further, data even if existing is rarely compiled for integrated research. The existing databases have data compiled based on the compiler's proxy/archive of interest (CRU-Paleoclimatic Data, 2012; The Paleobiology Database, 2019) or voluntary contributions sorted according to location and proxy (NOAA-NCDC Paleoclimate, 2019; PANGAEA, 2019). However, even in large compilations, much data remain missing due to multiple reasons. Further, to the best of our knowledge, there is no Geographic Information System (GIS) compilation of paleoclimate data sets enabling their comparative calibration, integrated assessment, and interpretation. This lack of multi-dimensional compilation leads to limited use of paleoclimate data in prominent geosciences applications in modern times; e.g., Basin analysis and Climate modelling due to the requirement of x-y-z or x-y-t arrangement of data. This work attempts to integrate all available paleoclimate datasets in the western Indian region to identify the hurdles which need to be solved before such compilations may lead to coherent regional paleoclimate reconstructions.

CRU-Paleoclimatic Data, 2012. Climatic research unit.

The Paleobiology Database, 2019. The paleobiology database.

NOAA-NCDC Paleoclimate, 2019. Paleoclimatology data, national climatic data center, national oceanic and atmospheric administration.

PANGAEA, 2019. Data publisher for earth & environmental science.



Code	Reference	Name of site	Longitude	Latitude	Age yrs BP (Approx) Base	Top
T01	Limmer et al. 2013	Core Indus-10, Indus Shelf	66.59	24.60	12000	0
T02		Core Indus-23, Indus Shelf	67.21	23.80	13000	0
T03	Azharuddin et al. 2017	Core SK240/485	68.93	21.27	12750	1500
T04A	Basu et al. 2019	Luna, Banni Grassland	69.26	23.71	995	0
T04B	Pillai et al. 2018				1000	0
T04C	Pillai et al. 2017				995	0
T05	Khonde et al. 2017	Dhordo, Kuchh	69.65	23.83	17700	850
T06A	Basu et al. 2019	Chachi, Banni Grassland	69.85	23.55	4582	0
T06B	Pillai et al. 2018				4500	0
T06C	Pillai et al. 2017				4582	0
T07	Khonde et al. 2017	Berada, Kuchh	69.91	23.49	17700	4700
T08A	Banerji et al. 2017	Diu Island	71.00	20.75	4105	0
T08B	Banerji et al. 2015	Vasoj village			4710	2000
T09	Banerji et al. 2019	Rohisa, Gujarat	71.23	20.82	2000	-13
T10	Prasad et al. 1997	Nal Sarovar	72.00	26.25	6750	0
T11	Laskar et al. 2013	Lohara	72.55	21.66	4280	0
T12	Prasad et al. 2007	Kothiyakhad	72.95	22.31	3660	2950
T13	Laskar et al. 2013	Dadhal	73.07	21.63	2200	0
T14		Sengpur	73.09	21.62	1960	0
T15		Dhamlai	73.22	21.70	1900	0
T16A		Kanjeta cliff section	73.35	21.93	2900	0
T16B	Laskar et al. 2010				15300	101
T17	Prasad et al. 2014	Wadhavana	73.48	22.17	7500	1297
T18	Laskar et al. 2013	Motalimatawada forest	73.51	21.84	630	0
T19	Krishnamurthy et al. 1981	Budha Pushkar	74.60	26.50	6490	2490
T20	Sinha et al. 2006	Sambhar Lake	75.08	26.96	35000	0
	*64PE300, RVPelagiaon, northern Arabian Sea					

Figure 7: Publications used in this study with their respective locations and ages of interpretations

Earth Surface Processes in Quaternary

Characterization of sedimentary organic matter and depositional processes in the Mandovi estuary, western India: An integrated lipid biomarker, sedimentological and stable isotope approach

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A multiproxy study involving bulk (TOC, $\delta^{13}C_{org}$, grain size) and molecular (*n*-alkane biomarkers) analyses is used to investigate surface sediments from the Mandovi estuary in Goa, west coast of India to determine the origin, distribution and composition of organic matter (OM). The $\delta^{13}C_{org}$ and *n*-alkane based indices (terrigenous/aquatic ratio (TAR) and P_{aq}) indicate higher terrigenous OM accumulation in the river dominated upper reaches of the estuary. The presence of unresolved complex mixture (UCM), *n*-alkane indices (carbon preference index (CPI), average chain length (ACL), natural *n*-alkanes ratio (NAR)) and diagnostic isoprenoid ratios (pristane/phytane (Pr/Ph), Pr/*n*-C_{17}, Ph/*n*-C_{18}) helped to characterise intense human activity in the lower estuary. This conclusion is further supported by relatively high concentration of hopanes indicating petroleum contamination in the lower estuary. Furthermore, the study also highlights the important role of grain size on the distribution of OM along coastal margins, and provides detailed understanding of the variations in OM distribution/accumulation forced by natural processes and anthropogenic activities. The results of this study have significant implications for identifying natural and anthropogenic OM sources in estuarine systems especially in the context of increasing anthropogenic activities.

End member contribution and sediment exchange in the beach-dune system, East Coast of India: Implications to coastal resilience and hazard mitigation

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Beach-dune complex isa continuumin relation to exchange of sediments between onshore and offshore throughout the year. This induces textural changes of the sediments through its fluctuating hydrodynamic conditions. The present study analysed sediment texture of beach-dune comple ofBakkhali and Talsari region; East Coast of India. Multivariate statistical approachis used to identify the end members and their proportion contributing to the textural pattern and supported by discriminant analysis for depositional environments and CM plot for its dynamics. End member contribution is used to understand the sediment exchange in the beach in relation to its hydrodynamics.

The study shows appreciable homogenization of samples in Bakkhalias compared to the Talsari region. Shoreline analysis indicates an average of 0.238m/year erosion for both the regions however, and average rate of accretion is 0.423m/year and in Bakkhali and 0.302m/year for Talsari. The end-member (EM) modelling showed relatively high contributions of medium- to fine-sand (ranging ~2.0Φ to 3.5Φ) along with minor amount of fines.

To minimize erosion of the beach-dune complex, beach nourishment is done by filling it with sediments. However, beach filling with the right material size is needed that is pertinent to the prevailing hydrodynamics. This is important because if a beach is filled with large material size, it will initiate erosion at other spots to reach equilibrium. The inferences drawn from this study will support advanced coastal resilience programs and climate adaptation planning for coastal erosion and hazard mitigation.

Where Is My Sediment Stored?

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Sediments produced within the critical zone or the "weathering engine" of a hillslope is routed from the source to sink by diffusive and advective processes or a by a complex route comprising of a series of these processes along hillslopes. However, over shorter scales, only a part of this sediment manages to reach the sink while a significant fraction gets arrested and stored within the catchments. The stored sediment may get re-mobilized during high magnitude hydraulic activity.

Many workers have modelled hillslope hydrology establishing their relationships with sediment transportation capacity, sediment output of high magnitude hydraulic events etc. However, the underlying questions still stand – how much sediment is available within a catchment to get mobilized and where is this sediment located within a catchment? How is the topography or the land use patterns controlling location and the volume of available sediments?

In our study, we have analyzed the sediment connectivity within the hillslopes of Pranmati Catchment, Uttarakhand. We calculated a sediment storage index that gives a storage potential of a point as a function of upslope contributing area and downslope length of flow path till the nearest point in the stream network, both of which are weighted by surface gradient and cover management factor of RUSLE.

Results show a control of land use on connectivity and storage index. We also observe an inverse relationship between connectivity and storage potential i.e., sediments get stored in specific poorly connected zones that are outside the influence of the stream network and have a sufficiently large contributing area with high sediment production capacity. Mapping these zones, we also see that they are also located at the junctions two land cover units of contrasting sediment connectivity e.g., edge of barren lands and forested lands, grasslands surrounded by forests etc.

We conclude that the storage zones are characterized by three major properties – low connectivity, high flux input and transport limited condition. We have identified few probable storage zones – (1) boundary of an upslope well connected zone and a downslope poorly connected zone, (2) high sediment yielding pockets within poorly connected zones, (3) central parts of hillslopes outside the direct influence of channels, and (4) talus cones at the toes of slope failure zones/landslides. We also propose a model of evolution of sediment storage zones along hillslopes that feeds on a positive feedback system of growth. This growth is attenuated by high magnitude hydrological events that mobilize the stored sediments, resetting the process. Land use change can severely lower the threshold magnitude of the resetting event.

Understanding the past debris flow of Leh valley, Ladakh and its susceptibility assessment

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The Leh Valley which lies within the Trans Himalayan state of Ladakh, India is known to be affected almost annually by debris flows and the disasters are getting magnified due to increase in urbanization. Though these flows are triggered by intense and abnormal rainfall events the conditioning factor has always been the topography and sediment availability. The 2010 flood of Ladakh caused series of debris flows, claimed at least 600 lives and led to the destruction of 71 villages. In this study we investigated several past debris flows and dated those using optically stimulated luminescence (OSL). For assessment of present vulnerability, a complete acknowledgement of the terrain condition and the degree of vulnerability of such events becomes necessary. For this a detail investigation of sediment availability, topographic conditions and their relation with known events are crucial. However, as the study area is extensive (~700 sq km) and the rough terrain makes most of the upstream areas inaccessible, the total sediment source area determination in the field is unfeasible. So, to cover this gap we used the index of connectivity (IC) model to quantify the sediment source-sink connectivity and farther applied Flow-R model to simulate the probable scenario of events through predefined algorithms. We then use the Weights of evidence (WOE) method to compute the statistical probability of debris flow occurrence basedon the relationship between known events verified in the field and factors (topographic) antecedent to debris flows. We developed an overview of the past flows, their role in landscape evolution and then studied the predictability of the future occurrences in a highly rugged terrain of Ladakh which is a region of frequent debris flows onslaught.

Characterization of rainfall spells initiating landslides in parts of East Sikkim, Eastern Himalaya: comparative analysis of IMD and NASA daily rainfall data

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Landslides have always been a major problem in mountainous region. Different intrinsic and extrinsic factors combine together to initiate slope instability. Rainfall is the main extrinsic factor that most frequently contribute towards landslide initiation. Rainfall spells from 2010 to 2018 that triggered landslides in parts of East district of Sikkim in Eastern Himalaya are discussed in this study using two different set of data viz., IMD grid (.25×.25) and NASA POWER. Landslide inventory of the study area for this period was prepared from different sources viz., GSI, SSDMA, news articles, published research articles and government reports etc. Intensity (I, mm/hour), amount of rainfall or cumulative antecedent rainfall (E, mm) and duration (D, hour) of rainfall spells are analyzed for the span of 2010 to 2018 along with all landslide events of the study area. Average annual rainfall of the study area is 3042.33 mm and 1511.22 mm according to IMD and NASA respectively. From 2010 to 2018, a total of 180 and 154 numbers of rainfall spells were recorded in the area of interest by IMD and NASA. I, E and D plots demonstrate two different cluster of rainfall spells, one kind of spell i.e., high intensity less duration, low cumulative rainfall and another kind of spell i.e., low intensity long duration thus, higher amount of cumulative rainfall. All 180 rainfall spells' I and E from 2010 to 2018 (IMD) show that rainfall spells in the study area are high I and less E dominated. Less number of rainfall spells only accumulate high E. It can be concluded on IMD data for the study area that rainfall spells are dominated by short duration moderate to high I and less E spells. Again, 154 rainfall spells' I and E from 2010 to 2018 (NASA) show that rainfall spells are mostly dominated by low to intermediate I and less E spells. In the study area, spells that initiated landslides can be characterized as mostly moderate to high I, less E spells and few numbers of high E spells (IMD). Again, according to NASA data spells that initiate landslides are characteristics of moderate I and high E. Analysis of rainfall spell I & D power law relation of all the spells is $I=0.0089D^{0.6}$ (IMD) and $I=0.0004D^{0.8}$ (NASA). Whereas, I & D of spells that initiate landslide is $I=0.814D^{0.3}$ (IMD) and $I=0.01D^{0.4}$ (NASA). Moreover, E & D relation show that overall relation of I and D of all the spells is $E=0.008D^{1.6}$ (IMD) and $E=0.0004D^{1.8}$ (NASA). Again, E & D of spells that initiate landslide is $E=0.0814D^{1.3}$ (IMD) and $E=0.01D^{1.43}$ (NASA).

ID and ED power law equation has implication on determination of rainfall threshold of slope failure. These determined equations in this study can be used in rainfall threshold study of East Sikkim. It also emphasizes on the fact that understanding of basic characteristics of rainfall spells accused of initiating landslide come before hand applying statistical analysis to determine threshold of rainfall. Comparison of IMD and NASA

data depict that there is huge difference in both data set. NASA data values are much lower and as half as of IMD data values. Moreover, it has been revealed that IMD data set depicts ground scenario precisely than NASA POWER data in East Sikkim, Eastern Himalayas.

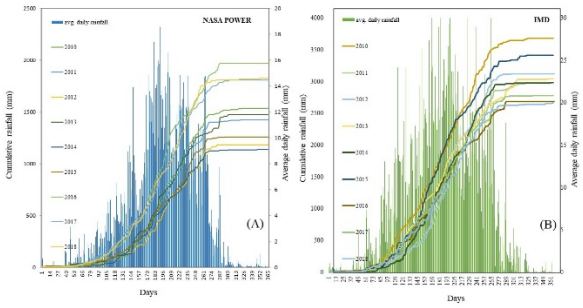

Figure 8: Cumulative rainfall and average daily rainfall NASA POWER (A) & IMD (B) of the study area from 2010 to 2018.

Flood Dynamics of Ghaghara River: Case Study from Bahraich to Ballia, Uttar Pradesh, India

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Flood and flood plain regions are a global risk that land and life in terms of development and strategic activities. Ghaghara river, one of the largest tributaries of the Ganga River plays a dynamic and vibrant role in bringing flood. Flood along the Ghaghara River was identified from the Bahraich, to Ballia, Uttar Pradesh. We used Survey of India (SOI) toposheet on 1:50,000 scale and satellite imageries for the flood dynamics in aforesaid districts usingremote sensing and GIS application. The flood-affectedzones have been broadly divided into three parts, active channel, active flood plain (zone of higher loss in the agricultural land), river valley terrace (zone of soil than the settled areas). These areas along the river are prone to flooding. The settlements located at the bank of the Ghaghara River are under threat of fluvial disasters.

The impact of flooding can be minimized with structural control includes the construction of embankments, artificial levee, vegetation, dams, dumping of boulders, sand and cement bags and non-structural factors (forecasting, warning system, emergency security, delimitation of flood zone and land use&planning). Damage impacts can be minimized by floodplain and river valley management, control measures for flood, improved disaster awareness and setting up of forecasting and warning system. The flood erosion zone map has been prepared as people have no idea that they are living in the danger zone of the river. There should be strong scientific management; rather, there is a need to keep people away from the hazard zone of the river. The policy should be made so that people do not make their settlements in the peril zone of the river.

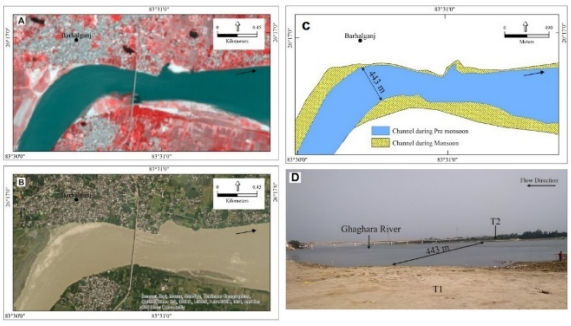

Figure 9: (A) Sentinel 2A Imagery-2019 with10-meterresolution showing channel during pre-monsoon season (B) Satellite imagery with 5-meterresolution showing flood during monsoon toward left valley side; the river water entering in

the city area as well as cause the lateral erosion. (C) Channel condition during monsoon and pre-monsoon season (D) Fieldphotographshowing channel condition pre-monsoon toward left valley side.

Geochemical characteristics of river sediments near Dauki Fault, Shillong Plateau, NE India: An emphasis on environmental changes

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Sediment section of 2.5 m, along the Dauki River, Shillong Plateau was geochemically analyzed to understand the environmental changes. By using the geochemical parameters, e.g., major oxides and their ratios (CaO/MgO, CaO/TiO_2, MgO/TiO_2, Na_2O/TiO_2, TiO_2/Al_2O_3, Na_2O/K_2O and Fe2O3/TiO_2), major elements and chemical index of alteration, the profile is divided into two climatic zones. Zone I is characterized by increasing Fe, Fe/Mn, K_2O, Fe2O3 and CIA as well as declining values of Na, Ca, CaO, Na_2O, CaO/MgO, TiO_2/Al_2O_3, Na_2O/K_2O, Na_2O/TiO_2, Na/K and Na/Al. A drop in Na_2O/TiO_2, Na/K and Na/Al values may be linked to the better precipitation during warmer/wetter conditions and this is supported by high CIA in this zone. A fall in Ca and Na also indicate the reduced erosion intensity. Increased K_2O, Fe2O3 and Al_2O_3 with relatively low values of Na_2O and CaO may be a sign of stronger chemical weathering from increased precipitation that would result in the loss of more soluble and mobile elements of Na_2O and CaO. Zone II records higher Na, Ca, Na/K, Na/Al, Na_2O, CaO, CaO/MgO, Na_2O/ TiO_2, TiO_2/Al_2O_3 values and low Al, Al_2O_3, Fe_2O_3, K_2O and CIA values. Al_2O_3, Fe_2O_3 and K_2O show positive relationship but are negatively correlated with Na_2O and CaO. The low CIA indicates absence of chemical alteration under arid condition. This is supported by elevated values of Na/K, Na/Al, Ca and Na. Low Al with higher Ca and Na are further suggestive of weaker erosion intensity in the catchment under the reduced monsoonal precipitation. The lower values of Al_2O_3, Fe_2O_3 and K_2O with relatively high values of Na_2O and CaO reflect a stronger hydrodynamics and poor chemical weathering under deprived precipitation and deteriorating conditions.

Sediment characteristics and clay mineral assemblage of modern Kori Creek sediments, Kachchh basin, western India

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The Kori Creek in the western Kachchh region is the most significant feature that connects the Arabian Sea and the Great Rann of Kachchh (GRK) basin. This highly tidally influenced region has a complex evolutionary history through the mid-late Holocene period. However, historical events like the 1819 Allah Bund earthquake, sinking/abandonment of several human structures (forts/custom houses) point towards the strong control of the active tectonics in this region, which is yet to be explored well. To understand the overall evolution of this region requires studies on considerably deep sediment core

sections, which is not available to date in the published literature. However, to characterize the modern sediment distribution across the Kori Creek and to provide a preliminary dataset on its clay mineral composition, we raised five short sediment cores (~50 cm) across the Kori Creek with manual sediment coring. Our objective was to investigate the sediment characteristics, observe inundation pattern changes across the creek and to characterize the clay mineralogical composition of the Kori Creek sediments in modern times. The collected sediment cores were split into equal halves and subjected to x-radiography, optical imaging, and sub-sampling for further analysis. The optical images of core split sections and x-radiographs helped to mark multiple drying events related to the inundation cycles across the creek in the GRK basin. These drying events are well marked by the presence of salt layers, whereas the thickness of the salt layer is observed to be related to the local undulations of the GRK surface. Down core particle size analysis shows a characteristic pattern across the Kori Creek segment that broadly contains coarser sediments in the upper part of the cores, whereas the lower part contains more muddy sediments. Statistical parameters on particle size show deposition under turbid conditions. Clay mineral composition of the Kori Creek sediments shows dominance of Illite and Chlorite over the Smectite and Kaolinite which is typical of GRK basin as recorded from the central and northern GRK basin. Therefore, Kori Creek clay mineral assemblage is in contrast with the modern Indus Delta sediment composition. Our results shows that the Kori Creek region does not get significant clay mineral transport through the coastal current sediment re-distribution from Indus influenced region in modern times.

Grain roundness a key to the paleo climate of Late Quaternary clastic sediment: An example from the North-western Arabian Sea

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The shape of sedimentary particles is an important physical feature that may provide information about the sedimentary history of a deposit and the behaviour of particles in a transporting medium. Roundness reflects the degree of abrasion of clastic particles and provides evidence about the medium, time, and distance of transport. Quartz is the standard mineral for grain-shape analysis. The shape of detrital quartz grains changes due to mechanical and chemical processes during erosion, transportation, and deposition. The main objective of this work is to correlate clastic grain roundness to the paleoclimate of Late Quaternary sediment transported to the northwestern Arabian Sea.

The terrigenous contribution at the ODP site 723A (Lat. 18°03´N, Long. 57°86´E) water depth (808 meters) located on Oman margin was more during the glacial stages in comparison to the interglacial stages. It was mainly due to low sea level and erosion of exposed continental shelf by wind. The cold and dry periods during glacials were responsible for physical

weathering and contribution of higher amounts of clastics into the northwestern Arabian Sea. The roundness of quartz grains shows that the mean roundness value increases during the glacial stages in comparison to the interglacial stages. This again indicates that the eolian activities were dominant during the glacial stages. The dominant presence of sub angular to sub rounded sand sized quartz grains indicates a short distance of transportation pathways. This further indicates that sediments at this site were mainly contributed by adjoining Arabian Peninsula. The wind system responsible for transport of eolian sediments to this site is the northwestern wind originated from the Arabian Peninsula.

Weathering rates determined using Uranium series isotope disequilibrium in granite weathering profile from Lesser Himalayas

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Endogenic and exogenic processes are evolving the landscape of Himalaya since its formation in Cenozoic time by collision of Indian and Eurasian continental land-masses. Among the exogenic processes, weathering is a major phenomenon which in itself is governed by the climate, topography, vegetation and lithology of the area. In Indian context, weathering studies are meagre, though few studies are documented in Peninsular India but almost no work has been done in Himalayan sector because of the lower preservation potential of weathering profiles owing to its dynamic nature. However, there are several slopes which are relatively stable and climatic conditions are favorable in developing the in-situ weathering profiles over bedrock. One such slope is explored from Lesser Himalayan terrains encompassing porphyritic granite rocks. The area receives more than 3m/year average rainfall which is suitable to induce chemical alterations in the rocks. Weathering profile exhibits a clear trend from fresh rock at the base to partially disintegrated to fully weathered towards the top and likewise mobile elements (Ca, Na and K) exhibit down profile enrichment and other conservative elements like Al, Ti and Fe show an opposite trend. Under the oxidizing conditions dominating on Earth's surface, hexavalent U dissolves in meteoric waters and weathering products enrich in Th relative to U. Weathering rates ~21.5mm/kyr are estimated by using this disequilibrium in U-series isotopes with topmost regolith zone ~295kyr old. This in-situ regolith production rate is much lower than the previously established erosion rates in the region, which signify that preservation of soil profiles in Himalaya is only possible in stable state. Also, intensified weathering is observed during some specific times in the weathering history, which is controlled by the climatic conditions at that particular time. In short, the regolith production in Himalayan sector is largely controlled by the topography and climatic conditions.

Extreme mass movement event on February 07, 2021, Chamoli district, Garhwal Himalaya, India

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Chamoli one of the most disaster-pronedistricts of Uttarakhand, experienced the huge massmovement event on February 07, 2021 in the Ronti glaciated valley. This event not only claimed the life of more than 200 people but also vanish the existence of Raini village completely and severely damaged the two hydropower projects. The analysis of high-resolution pre-disaster and post-disaster images of Sentinel-2 clearly specified that a huge rock mass having 0.530 km2 area and 1.8 km length collapsed suddenly along the earlier developed crack at an elevation 5600m asl.

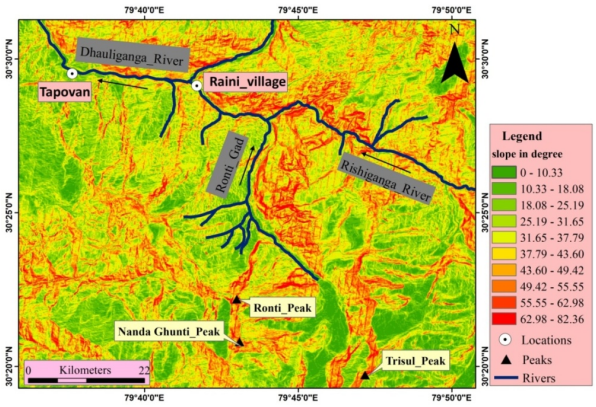

Figure 10: Slope map of the extreme mass movement affected region

The detached rock mass amalgamated with large debris and ice, encroached the course of Ronti Gad (Tributary of Rishiganga River) and blocked the Rishiganga valley temporarily. The Normalized Difference Water Index (NDWI) also shows that how the large debris flows had affected active channel of Rishiganga and Dhauliganga River. The slope failure was the most causative factor behind this catastrophic event.

Influence of Slope on Landslides: A case study of Sikkim Himalaya Using Landslides Inventory

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The slope is an important factor for the landslides in hilly areas. Movement of rock mass such as debris or earth down is due to instability of slope. Rainfall, snowmelt, changes in water levels, stream erosion, changes in ground water, earthquakes, volcanic activity, disturbances caused by human activities, or any combination of these factors can cause landslides to occur on slopes. Sikkim is the mountainous state of India in the North Eastern Himalayas. This is suffered by numerous landslides and loss of human life. An attempt has been made to correlate landslides inventory point with slope in the area. The slope of the study area is generated using AlosPalsar (resolution 12.5m) with the help of Arc GIS software. DEM data has been classified for Slope angles 0-5, 6-10,11-15,16-20, 21-25,26- 30, 31-35, 36-40, 41-45, 46-50, 51-55, 56-60 degree.The results show that the slope angle between 10-60 degree is highly sensitive to the landslides, however,the frequency of landslides is maximum between 20- and 40-degree of slope.Any type of human

settlement and other infrastructures must take proper structural care for construction in order to avoid any casualty within these slopes.

Oceans in Quaternary

Palaeo-productivity variation based on Planktic Foraminifera record from Agulhas Plateau IODP Site U1475

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The Agulhas Plateau region has strong water mass transport, which involves the water column from the surface to the Circumpolar Deep Water. The Agulhas Return Current, which constitutes the component of the Agulhas Current, is not leaked to the South Atlantic Ocean but rather flows eastward from the retroflection, dominates the hydrography of the upper ocean. The Agulhas Return Current is usually seen in close proximity to the Subtropical Front in the Southern Ocean (STF). During periods of high phytoplankton productivity, *Globigerina bulloides* is abundant. It has a wide temperature tolerance limit and has been found in every possible range of sea surface temperature in the world oceans. As a result of upwelling of nutrient-rich cold water from deeper depths to the surface, locations with high phytoplankton populations have a higher abundance of *G. bulloides*. Upwelling caused by seasonal strong winds is often associated with high productivity places in the Indian Ocean. As a result, the temporal variation in the relative abundance of *G. bulloides* in the Indian Ocean region has been proposed as an effective tracer for previous changes in surface productivity caused by wind-driven upwelling associated with the summer monsoon. Based on the delta O-18 of specimens obtained in sediment traps, a surface to near surface habitat for *G. bulloides* was inferred in the Southern Ocean.

Here, we present high-resolution planktic foraminifera *G. bulloides* record up to MIS-5 from the marine sediment core obtained from the International Ocean Discovery Program (IODP) Site U1475 (41°25.6052'S, 25°15.6441'E, 2669mbsf) from the southern Agulhas Plateau. *G. bulloide* is one of the abundant species in the core, with an occurrence of > 17 percent. In our records, the relative abundance of *G. bulloides* has increased during MIS-2 and the later part of MIS-3, indicating high surface productivity during these periods, and has decreased during the MIS-2/1 transition, the early part of MIS-3, and MIS-5, indicating low productivity during these periods.

Rapid oceanographic and climate variability in the NE Atlantic Ocean across the Terminations I and II: Foraminiferal evidence from the IODP Site U1385

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Marine sediments from the SW Iberian Margin have been used in numerous pioneering paleoclimatic and palaeoceanographic studies as these sediments record a remarkable response to climate change over orbital and millennial time scales. Previous works have demonstrated the significance of this region as it archives the signals of both the polar climate systems (Antarctica and Greenland). Also, its location at the northern edge of the Canary eastern boundary upwelling system and the southernmost limit of the ice rafted debris (IRD) belt makes it a crucial region to preserve signals of both the North Atlantic atmospheric and hydrographic systems. Finally, its proximity to the continental margin makes it suitable for correlating the terrestrial and oceanic records. Therefore, the SW Iberian Margin is a key location to study the Quaternary climate variability and its impact.

Here, we present high resolution planktic foraminiferal assemblages and Artificial Neural Network (ANN) derived sea surface temperature (SST) records to reconstruct the palaeoceanographic changes that occurred during the last two terminations and the following interglacial on the SW Iberian Margin (IODP Site U1385). We used temporal variations in relative abundances of ecologically sensitive species to infer past meridional oscillations of polar/subpolar front (% *Neogloboquadrinapachyderma*and *Turborotalitaquinqueloba*), Azores front (% warm water species/group) and palaeoproductivity variations (% *Globigerina bulloides* and *Globigerinitaglutinata*) related with seasonal atmospheric wind strength. Our records reveal pronounced stadial events during both the deglacials i.e., Heinrich 1 (H1) and Heinrich 11 (H11) as recorded by peaks in *N. pachyderma* abundances and steep drops in SST. Even though H1 was colder, both H1 and H11 show a similar trend in SST and productivity i.e., two distinct drops sandwiching a sharp rise. Both the inter-glacials (Holocene and MIS 5e) and glacial maxima (LGM and PGM) seem very similar in terms of average surface temperatures and productivity conditions at the study site. During both the inter-glacials, the Azores Front shows a northward migration (as evident from increased abundances of warm water species) which results in north-easterly winds at the study site, promoting wind-driven upwelling.

South west monsoon response to surface hydrographic variations in western Arabian Sea through the last 172 kyr

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To understand the long-term-seasonal surface hydrographic variation in the Western Arabian Sea (WAS) during the last ~172 kyr, we have used Oxygen isotope record of planktonic foraminifera ($\delta^{18}O_{G.ruber}$) and faunal assemblage of *Globigerina bulloides* from marine sediment core (VM35-04PC). The chronology of the core was established by using five radiocarbon ^{14}C and $\delta^{18}O_{G.ruber}$with global isostack LR04. The $\delta^{18}O_{G.ruber}$ marked the glacial-interglacial variation. The significant variation in $\delta^{18}O_{G.ruber}$mostlytowards positive excursion which shows the cooler period during MIS 6, 4 & 2. In contrast, MIS 5, mid-MIS 4 (~65.6 - ~60.3 kyr), MIS 3 & MIS 1-mark negative excursion in $\delta^{18}O_{G.ruber}$ representing the warmer period. During MIS 5, $\delta^{18}O_{G.ruber}$ signatures suggested significant changes in the surface hydrography of the WAS due to Southwest monsoon (SWM) intensification. The $\delta^{18}O_{G.ruber}$ values ~ -0.74 (‰) at 52 cm depth corresponding to ~12.5 kyr, marking the MIS 2 shift towards the onset of MIS 1, attributed to intensified monsoonal precipitation. Simultaneously, *G. bulloides* is an important species of the faunal assemblages with minimum and maximum abundance ranges from 2 to 45 %, respectively. *G. bulloides*abundance in WAS is related to cold, upwelled nutrient rich water and it is commonly used as proxy for SWM productivity and intensity. The relative abundance of *G. bulloides* is higher during warmer period (MIS 5 & MIS 3 & MIS 1) while lowest relative abundance of *G. bulloides* was during MIS 6. It is suggested that increased upwelling and high nutrient availability due to strong SWM during MIS 5, MIS 3 & MIS 1. Significantly reduced upwelling occurred during MIS 6 &2, as evident from low relative abundance of *G. bulloides*. Based on $\delta^{18}O_{G.ruber}$ and *G. bulloides* abundance, the mid-MIS 4 are warmer due to SWM superimposed the Northeast monsoon (NEM) s. The mid- MIS 4 warming is not coherent with palaeoclimate record from the WAS.

Changes in deep-water circulation in the equatorial Indian Ocean during the last 25 ka BP: evidence from carbon and oxygen isotope of benthic foraminifera

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Atlantic Meridional Overturning Circulation (AMOC) plays a vital role in modulating the Earth's climate by redistributing the heat from low latitude to high latitude and controlling carbon storage. Atlantic Meridional Overturning Circulation involves formation of $\delta^{13}C$ rich, well-ventilated North Atlantic Deep Water (NADW) in the North Atlantic Ocean, which is exported southward where it mixes with southern sourced poorly ventilated water. During the last glacial-interglacial cycle there was weakening/strengthening of AMOC due to changes in the NADW production. Deep water in the Indian Ocean being ventilated solely from the south, can be an ideal location to record changes in NADW

formation. In this study we have used stablecarbon and oxygen isotopic records of benthic foraminifera (*Cibicidoideswuellerstorfi*) from a deep water core from the equatorial Indian Ocean to infer changes in deep-water circulation for last 25 ka BP. Gravity core SSD-044/GC-01 used in this study was retrieved from the Central Equatorial Indian Ocean at water depth of 3160 m. Variation in stable carbon and oxygen isotopic record suggests changes in deep water circulation. The $\delta^{18}O$ values of benthic foraminifera ranged from ~2.6- 4.4 ‰. The $\delta^{18}O$ shiftof ~ 1.6 ‰from LGM to Holocene exceeds the ice volume change by 0.4 ‰ which indicate cooling of deep water by 2 °C at this time compared to the Holocene.Low values of stable carbon isotope ($\delta^{13}C$) recorded during the Last Glacial Maximum (LGM) and early deglaciation indicates reduced export of NADW in the northern Indian Ocean. We suspect that this reduction in NADW export was due to decreased production of NADW in the North Atlantic, which lead to weakening of AMOC at that time. A positive excursion in $\delta^{13}C$ from 14 ka BP onwards points to enhanced flow of NADW in the Indian Ocean due to resumption of AMOC.

Deep water circulation in the Arabian Sea during the ast glacial cycle

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Since no deep water is formed in the northern Indian Ocean, it ventilates from the south and acts only as a host for deep water circulation. The absence of active deep water formation makes the north Indian Ocean an ideal location to assess the extent of southern source waters and their role in past CO_2 variability during the G-I climate cycles. This study provides the first record of deep water circulation in the Arabian Sea, during the past 136 ka based on authigenic Nd isotope record (ε_{Nd}). The Arabian Sea ε_{Nd} record shows large variability ranging from –8.8 to –6.5 with more radiogenic values during the glacial stages (MIS 2 & 6) and less radiogenic values during the interglacial stages (MIS 1 & 5) indicating changes in water mass sources. The observation of more radiogenic ε_{Nd} values similar to the glacial Antarctic Bottom Water (AABW) indicates enhanced flow of AABW (95–100%) and substantial reduction and/or almost complete retreat of North Atlantic Deep Water (NADW, 0–5%) during the glacials, whereas less radiogenic values indicate enhanced flow of NADW (~20–40%) during the interglacials. The Arabian Sea ε_{Nd} record followed an exactly similar pattern to that of the equatorial Indian Ocean (EIO). However, amplitude of their variations differed significantly during the interglacials (MIS 1 & 5); the Arabian Sea ε_{Nd} values were more radiogenic than the EIO. This suggests that during the interglacials, the Arabian Sea received more fraction of AABW through the western pathway, whereas the EIO

received more fraction of NADW through the central pathway. This highlights differences in deep water exports from the Southern Ocean to the Arabian Sea and the EIO during the interglacials whereas export of similar water masses and its uniform distribution up to the northern Indian Ocean during the glacials. Our findings of significant G-I changes in AABW and NADW exports to the Indian Ocean and intra-basinal differences in their distribution have important implications for regional biogeochemical processes and paleo-redox conditions in the water column.

Antarctic Circumpolar Current strength variability along the Drake Passage and its influence on microbiota productivity distribution

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The Antarctic Circumpolar Current (ACC) flow from west to east connecting Pacific, Atlantic and Indian Ocean. This current is driven by westerly wind and buoyancy forcing along the Drake Passage, a coldroute for ACC flows. The ACC strength is variable along the Drake Passage, having a significant influence on ocean productivity and current regulating atmospheric CO_2. Various studies have suggested the ACC strength variability during the glacial-interglacial period along the Drake Passage, but minimal information is available about the microbiota distribution and productivity with ACC strength variability. Hence, to assess the current strength and microbiota distribution along the Drake passage, we have analyzed the sediment core of Site U1544 situated at the continental crust of Chile continental margin in the eastern South Pacific at 55°32.2192'S, 71°35.6194'W ~30 nmi southwest off the Chile coast and at ~2090 m water depth. The ACC strength is reconstructed bymeasuring sortable silt abundance and its mean size and influence of glaciation by counting coarser sediments and Ice-rafted Debris (IRD). Further, microbiota productivity and distribution are ascertained by counting planktic foraminifera, benthic foraminifera, radiolarian and diatom abundance in the >125 µm sediment fraction. The preliminary result suggests periodic variability in the sortable silt influences foraminifera productivity. High productivityindicative species of planktic and benthic foraminifera are dominant when current strength is stronger, and it varies with glacial-interglacial changes until Marine Isotope Stage 3. In general, the abundance of IRD and detrital is higher than any microbiota. However, during the high productivity events, microbiota abundance significantly increased, dominated by planktic foraminifera in >125 µm sediment fraction.

Variations in the intensity of denitrification and oxygen minimum zone of the Arabian Sea: controlled by monsoons or circulation?

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The Arabian Sea and the Bay of Bengal encompass two tropical open ocean oxygen minimum zones (OMZ) of the world ocean. During the present day, denitrifying conditions in the intermediate waters are observed in the Arabian Sea but not in the Bay of Bengal. The Bay of Bengal has experienced similar conditions of low oxygen in the intermediate waters in the past. These denitrifying conditions are unique and are considered to be source of greenhouse gases like N_2O. Changes in water circulation, productivity and water masses play an important role in formation of OMZ. Past changes in circulation and water masses have resulted in intensification/reduction of these OMZs. Changes in OMZ are often inferred from the denitrification changes retrieved from the sediment cores based on nitrogen isotopes. Most of the studies on the Arabian Sea OMZ changes point out control of the southwest monsoon intensity. A relook at sediment cores studied from the Arabian Sea show that there have been changes in the denitrification at the glacial inter glacial levels and within the Holocene that may be probably controlled by the changes in circulation and water masses.

Two phased variability of denitrification and South Asian Monsoon from Marine Isotope Stage (MIS) 18 to 28

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Denitrification can be defined as a biogeochemical process where nitrate ($NO3^-$) is reduced to molecular nitrogen (N_2) through a series of intermediate gaseous nitrogen oxides –one of which (N_2O) is a powerful greenhouse gas. Thus, denitrification plays an important role in the marine nitrogen cycle and global climate variability. We analyzed sediment samples from IODP 355 for $\delta^{15}N$, TN, $\delta^{13}C$ and TOC spanning from Marine Isotope Stage (MIS) 18 to 28. We observed that denitrification and monsoon induced productivity was very intense during the MIS 28 to MIS 22. During the MIS 21 to MIS 18, the denitrification became moderately strong and covaried with monsoon induced productivity. The denitrification is stronger during the interglacials after MIS 22, however, no such trend is found during the MIS 28 to MIS 23. We saw a two-phased variability in denitrification during the span of study, stronger in the early MPT (MIS 28 to MIS 24) and moderately high denitrification during MIS 21 to MIS 18. We compared the denitrification record with the precession and monsoon index (Lithogenic grain size index; Clemens et al., 1996) from the Western Arabian Sea (WAS). We find that denitrification and productivity followed precession and insolation gradient I 30N-I 15S. The monsoon index from the WAS also shows a close match with precession and insolation gradient corroborating our observation.

A significant shift in the upper water column structure of the Bay of Bengal post Mid-Pleistocene transition

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The unique water column structure and seasonal change in the hydrodynamics make the Bay of Bengal an interesting area to understand the effect of monsoon on the water column stratification.We have reconstructed a 1.16myr(MIS 47- MIS 8) record of planktic foraminifera assemblages and the difference in the stable oxygen isotopic ratio ($\Delta\delta^{18}O$) between the mixed layer dwelling *Globigerinoidesruber* and thermocline dweller *Neogloboquadrinadutertrei*from the IODP Site U1446 to understand the change in water column stratification and its relationship with the monsoon. We report a comparatively higher mixed layer assemblage abundance during the cold glacial intervals. The $\Delta\delta^{18}O$ was low during the cold glacial and increased during the warm interglacials. We report a large difference in $\Delta\delta^{18}O$ prior to the mid-Pleistocene transition (MPT). Interestingly, the glacial-interglacial shift in $\Delta\delta^{18}O$ significantly decreased post MPT. From the glacial-interglacial shift in$\Delta\delta^{18}O$, we infer a stronger stratification during the warm interstadials and comparatively weaker stratification during the cold stadials. The strengthened summer monsoon induced high direct rainfall, and riverine influx inhibited mixing in the upper layer and created a shallow thermocline during the interstadials. A stronger upwelling and deeper mixed layer reduced the glacial-interglacial shift in $\Delta\delta^{18}O$ post mid-Pleistocene transition. Therefore, we report a strong influence of MPT on water column stratification in the Bay of Bengal.

Sediment depositional pattern in the Northern Japan Sea over the last 1200 ka and its linkages to orbital forcing

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The semi-enclosed marginal Japan Sea is sensitive to global changes and responds to orbital scale variability. However, the role of East Asian winter monsoon and westerlies on sedimentation patterns is yet to be ascertained on the orbital time scale. One hundred one sediment core samples covering 1200 ka of Integrated Ocean Drilling Program (IODP) Site U1423 were processed for grain size and semi-quantitative mineral analysis. The IODP Site U1423 is situated on the north-eastern Japan Sea at 1785 m below sea level, and ~100 km northwest of the entrance of the Tsugaru Strait close to the Japanese Archipelago. Tsushima Warm Current is the only surface current that supplies nutrients, heat and organic matter to the Japan Sea during the interglacial/warm periods. The average time resolution per sample is 12 kyr. The mean grain data

suggest the dominance of silt size fraction over sand and clay in all sediment samples, which are moderate to poorly sorted and coarse to nearly symmetrical skewed. The end member energy modelling of grain size data suggeststhe presence of two energy conditions over the last 1200 ka. The low energy conditions dominate the period between 1200 and 600 ka marked by the presence of permanent sea ice and decreased in seasonal sea ice. Later, increased seasonal ice conditions between 600 and 0 ka caused periodic fluctuations between higher and lower energy conditions. The spectral analysis of both energy conditions and sand, silt and clay fractions suggest the presence of 41 and 23 kyr orbital cyclicity. This cyclicity matches the 41 and 23 kyr cyclicity present in normalized quartz mean grain size of Zhaojiachuan, Lingtai sections on the south-central Chinese loess Plateau. The semi-mineralogical analysis suggeststhe dominance of Quartz grain, which may be transported as eolian dust along with the westerlies. Our study suggests the presence of 41 and 23 kyr cyclicity influenced by the westerlies and East Asian winter monsoon, which governs sedimentation patterns over the northern Japan Sea.

A review and preliminary study on Indian Ocean dipole variability and its impact

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The surface and sub-surface hydrographical variations in the tropicalIndian Ocean play a major role in the global climate system. The Indian Ocean dipole (IOD), a coupled Ocean-atmospheric phenomenon involving a sea surface temperature and thermocline depth anomaly, was created due to the propagations of baroclinic Kelvin and Rossby waves in the Equatorial Indian Ocean. The range of SST anomaly in the tropical western and eastern Indian Ocean is defined as (50–70°E, 10°S–10°N) and (90–110°E, 10°S–Eq) respectively, called dipole mode index (DMI). The positive phase of IODcrates dry conditions over the Indonesia and Australia while higher precipitation over the east Africa and India and opposite conditions are observed during negative phase of IOD.

Here we present a review work of the previous IOD study, and the preliminary results of the high resolution planktic foraminiferal faunal records from a deep-sea sediment core (VM29-045) obtained from WEIO (6° 00’ S, 69° 02’ E; 2860 m water depth) to understand the past IOD variability and its effect on the Indian monsoon in the Late Quaternary. It was observed in the previous study with proxy data and model simulations that the eastern equatorial pole is very intuitive for watching SST across the equator. Many authors have estimated thermocline variability. It shows a shallower (deeper) thermocline along the eastern (western) equatorial Indian Ocean because IOD shifted gradually towards the more positive in the late Holocene. Very limited studies were done beyondthe Holocene and instrumental records. Paleoclimatic proxy data and model simulations have limitations in observing IOD trends, variability, and impact. So more emphasis

is needed to understand the IOD and enhanced proxy based data for the longer time scale (glacial-interglacial cycle). Our preliminary planktic foraminiferal records of the sediment core (VM29-045) show significant IOD variability in the late Quaternary period.

Rock magnetic and geochemical signatures of palaeo-flood events in a shelf system

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Marine shelf system represents an important archive of the sedimentary processes and preserves a record of the past (normal, extreme) sediment depositional events through geological time.The sediment core retrieved from the inner shelf regionoff Goa, Arabian Sea provided an opportunity to employ sensitive rock magnetic, grain size and geochemical methods to reconstruct a history of the climate-controlled extreme (flood) events and linked sedimentary processes. Based on the rock magnetic signatures, we demarcated the sediment record into five distinctsediment magnetic zones. Two events exhibiting higher magnetite enrichment were identified at ~ 6.77 – 6.43 ka and ~ 6.14 – 5.56 ka, respectively. Palaeoflood event layers showed distinct change in rock magnetic and geochemical properties. The sediments from these zones (Z-II, Z-IV) are marked by increased amount of ferrimagnetic minerals, calcium carbonate and lower organic carbon. We propose that two periods of anomalously distinct change in magnetic and sedimentary characteristics (Z-II, Z-IV) off Goa, were strongly modulated by the abrupt paleoclimatic changes and greatly modified the shelf sedimentation. During these periods, fluvial (Mandovi, Zuari) system might have transported large amounts of heterogeneous sediments into the shelf region off Goa which resulted in increased supply of detrital (ferri and antiferromagnetic) magnetic minerals. Comparatively Z-I, Z-III and Z-V are characterized by remarkably low values of magnetic mineral concentration (magnetic susceptibility, SIRM), magnetic grain size (ARM/SIRM) and mineralogy (HIRM, S-ratio) diagnostic proxies suggesting the presence of coarse-grained, highly coercive magnetic (hematite, goethite) minerals in these zones and probably indicate the periods of normal sedimentation. Hematite content remains uniform throughout, except in Palaeoflood layers which showed marked dominance of ferrimagnetic (magnetite) minerals as confirmed through concentration and grain size diagnostic magnetic proxies. Further study is in progress to determine whether there are specific provenance changes linked with flood events, apparent extent of flood outburst and the underlying controls.

Late Holocene Indian summer monsoon variability revealed from the foraminiferal records of the Bay of Bengal

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Indian summer monsoon (ISM) plays a crucial rolein the subsistence of about two billion people in the Indian subcontinent. Therefore, it is essential to understand the past, present, and probable future variability in the monsoon-associated climatic changes of the region. The sediments from the Bay of Bengal and the Andaman Sea are the ideal archives for reconstructing the past climatic changes in the adjacent hinterland. We studied foraminiferal assemblages from nine short cores (water depth range between 30 and 260 m) covering an age from present to 2800 ka. The age controls are based on accelerator mass spectrometry (AMS) dates on mixed planktic foraminifera. The study shows significant variations in ISM during the Roman warm period (RWP), Dark age cold period (DACP),Medieval warm period (MWP)andLittle ice age (LIA). The foraminiferal records show a considerable decrease in the intensity of monsoons during the Roman warm period (2200-1800 yearBP), Dark age cold period (1391 to 1623 years BP), and Little ice age (600-200 years BP), along with an increase in the intensity of the precipitation during Medieval warm period around (1200 -800 years BP). Our results demonstrate that themonsoon climate variability in the region is in general agreement with other records from terrestrial and marine environments.

Reconstructing dynamics of northern and southern sourced bottom waters using sortable silt records in the lower Bengal Fan during last 200 ka

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Indian Ocean plays an important role in the Global Overturning Circulation (GOC) by exporting warm and saline waters to higher latitudes prerequisite for the formation of bottom waters. Lack of deep water formation in the Indian Ocean makes it an ideal location to monitor the variability of northern and southern sourced deep waters such as North Atlantic Deep Water (NADW) and Antarctic Bottom Water (AABW) and rearrangement of the GOC during glacial-interglacial (GI) cycles. Mean SS (*SS*)size records in hemipelagic deposits of the Site U1452C (IODP 354) in the lower Bengal Fan is presented here to reconstruct the bottom current competence during the last 200 ka (MIS 1 to 6). To eliminate any possible sediment source related signatures in the SS records, sedimentation history at the site is decomposed using End Member Analysis (EMA). EM1 (~ 3 µm; clay) represent deposition from the suspension load of Ganges- Brahmaputra discharge during the summer monsoon whereas EM2 (~ 7 µm; fine silt) deposited during the winter monsoon as windblown dust. Sedimentation is dominated by EM1 and

EM2 (> 90%) and very little contribution (< 10%) from EM3 (~ 22 μm) and EM4 (~ 56 μm) which represent elements of turbidity deposition and Younger Toba Tuff in the core respectively. *SS* size records indicate reduced abyssal current strength during glacials (MIS 2 and 6) whereas increased strength during interglacials (MIS 1, 3 and 5). Most detectable amplitude shift in *SS* size records appear during the climate optima at MIS 5.5 and other warm substages of MIS 5 as well as during the Holocene, contemporary to the reinitiation of Atlantic Meridional Overturning Circulation (AMOC) and greater import of deep Atlantic derived waters to the Indian Ocean and BoB. Decline in bottom current strength during 5.5 to 5.4 transition in BoB indicates impact of large scale density reversal in Southern Ocean (SO) and rearrangement of GOC. Sluggishly ventilated deep water in the BoB during the transition co-vary with the global atmospheric CO_2 decline and Antarctic cooling indicating a tight coupling of ventilation in BoB with deep circulation changes in the SO and Antarctic climate. Also the millennial timescale variability in circulation strength in the BoB are linked to the oceanic frontal shift in high north latitude and associate well with local cold anomalies culmination into glacial inception at 5.4. SS records respond to the obliquity and precessional frequencies and imprints Northern Hemispheric climate events such as Heinrich stadials (HS) and Dansgaard-Oeschger (DO) events. Changes in bottom water provenances during GI cycles are found to be associated with large scale variation in the marine productivity in the BoB.

Reconstruction of Sea Surface Hydrography and Indonesian Through flow (ITF)-Indian Ocean Dipole (IOD) Variability in the Eastern Equatorial Indian Ocean During the Late Glacial – Holocene Period

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The Asian Monsoon system (East Asian monsoon and Indian monsoon) being one of the most dynamic regional climate systems on Earth largely controls climate in Asia and the Indo-Western-Pacific realm; the monsoon system is tightly coupled to the northern Hemisphere climate through annual zonal migration of the Intertropical Convergence Zone (ITCZ) and periodic development of the monsoon winds. The Indo-Pacific Warm Pool's intensity acts as a switch in the climate system, and it has a significant impact on longand short-term global climate change. Therefore, understanding the Indo-Pacific Warm Pool's history and interplay between interoceanic exchange (Indonesian through flow; ITF), ocean-atmosphere coupled process (Indian Ocean Dipole; IOD) and regional monsoon variability dynamics and their relationship with other climate factors is critical for improving monsoon prediction in the equatorial eastern Indian Ocean (EEIO).

The study of the ITF-IOD variability and their impact on EEIO region during episodes of major climatic changes in the geological past can provide important insights to improve future climate models.

The long-term variation in the quantitative distribution of planktic foraminifera reflect changes in paleoclimate and palaeoceanographic circulation in the upper water column structure such as sea surface temperature, salinity gradient, water column stratification, depth of mixed layer, depth of thermocline and biological productivity.

Here, we present high-resolution planktic foraminiferal assemblages records from a deep-sea sediment core collected from off South Java Island (5.31° S, 97.42°E; 3890m water depth) and sediment core collected from easternmost part of the Timor Sea (9.05° S, 129.14°E; 1421m water depth) in the eastern equatorial Indian Ocean spanning the past 45 Kyr and 30 kyr years respectively. $\delta^{18}O$ isotope records from the Timor Sea core were compared with the faunal assemblage records of boththe sediment cores. This study provides an opportunity to estimate past variations in upper water column structure and thermal gradient (i.e., depth of thermocline) of this region which ultimately helps to assess the role of IOD variability andITF variability during the late Quaternary.

Reconstructing the variability of deep-water circulation in the Indian sector of the Southern Ocean during the last glacial cycle

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Deep Water Circulation (DWC) in the Southern Ocean is a crucial component of thermohaline circulation that modulates the transport of heat, carbon, and other nutrients around the globe and plays a significant role in global climate. The prevailing hypothesis states that relative changes in the formation and export of deep water masses (the North Atlantic Deep Water (NADW) and the Antarctic Bottom Water (AABW)) to the Southern Ocean in the past affected the basin's carbon sink capacity and resulted in the glacial-interglacial CO_2 variability.The Indian sector of the Southern Ocean is an ideal location to test this hypothesis as it does not have any deepwater mass formation butonly acts as a host for two deep water masses; NADW and AABW. However, limited proxy evidence for the DWC from the Indian sector of the Southern Ocean restricts the understanding of past deep-water circulation of the region. In this study, we have reconstructed the DWC in the Indian sector of the Southern Ocean using authigenic Nd isotopes (ε_{Nd}) of a sediment core SK200/33 (55°01'S-45°09'E, 4204m) for the last glacial cycle. Our DWC record, together with published records of Winter Sea ice and productivity, also enables us to test the influence of sea ice in the formation of AABW. The ε_{Nd}valuesof the core vary between -5.3 and -8.1, with more radiogenic values during the glacial periods and less radiogenic values during the interglacial periods, reflecting a change in the water mass sourcing during glacial-interglacial periods. More radiogenic ε_{Nd}values during glacial periods suggest

incursion of a dominant Pacific sourced water to the Southern Ocean. The similarity in the glacial ε_{Nd} values of our record with South Atlantic and Pacific records further corroborates our observation of dominant Pacific water input. The higher proportion of Pacific waters to the Southern Ocean has significant implications for global atmospheric CO_2 variability.

Ecological parameters control the abundance of living benthic foraminifera morphogroups in the southeastern Arabian Sea

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The ambient environmental parameters have a great bearing on the morphology of living flora and fauna. In this study, we tested this hypothesis on one of the most dominant group of living unicellular marine microorganism, benthic foraminifera, in the dynamic region of the southeastern Arabian Sea. The living benthic foraminifera from 43 surface samples collected between 25 to 2980 metres of water depth were segregated into eight morphogroups (tapered/cylindrical, flattened-ovoid, biconvex, planoconvex, flattened-tapered, spherical, rounded-trochospiral, and rounded-planispiral). We report that the high organic carbon availability combined with deficiency of oxygen results in benthic foraminifera with low surface area to volume ratio and mostly consists of tapered/cylindrical, flattened-ovoid forms, with a preference for infaunal habitat. However, the tests of the living benthic foraminifera thriving in the oxygen-rich bottom waters have a high surface area to volume ratio, commonly reported as epifaunal, consisting of biconvex and planoconvex forms. Additionally, we also report that the abundance of other morpho-groups, namely flattened-tapered, spherical, rounded-trochospiral, and rounded-planispiral, is also controlled by the distinct environmental parameters. We suggest that the living benthic foraminifera are an excellent indicator of the ambient environmental parameters and can be used to reconstruct paleoenvironments.

Planktic foraminiferal response to the surface hydrography of the southeastern Arabian sea during last 140ka: linkage to the tropical /or equatorial climate dynamics?

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Surface hydrography of the South-Eastern Arabian Sea (SEAS) is readily influenced by the strength of seasonally reversing monsoons, characteristic of the tropical northern Indian Ocean. The monsoonal dynamics can also drive the inter-basinal exchange of surface water between perennially less-saline water -Bay of Bengal (BoB) and more saline water-the Arabian Sea (AS). Here, we present a planktic foraminiferal assemblage record

from a sediment core (SK-129-CR-05; 9.21°N; 71.59°E) from the SEAS at the water depth of ~2300 m to reconstruct the change in surface hydrographic condition during the last three glacial-interglacial intervals. Our data set (selected planktic foraminifera, eutrophic/oligotrophic species, *G. bulloides* / G. *ruber,* Planktic foraminiferal fertile species, C-org content, and oxygen isotopic ratio of *G. ruber)* shows three distinct regimes *(MIS-6/MIS-5 to MIS-5/MIS-4, MIS-4 to MIS-2 and MIS-1)* in the study region. The MIS-5a, c, e *(*warm phases*)* shows strong surface eutrophication (extremely high nutrient condition), MIS-4 to MIS-2 exhibit high oligotrophic (low-nutrient) condition and MIS-1 reflect weak eutrophication (weak productivity) in the study region. A high level of eutrophication at the site during MIS-5a, c, e is probably related to summer monsoon-induced strong upwelling conditions. Then, between MIS-4 to MIS-2, extremely high oligotrophic condition were seen, which might be related to the transport of the Bay of Bengal waters, which can lead to thermal stratification in the study region. Then, during the MIS-1, the relatively less productive conditions at the site might be associated with the weak upwelling conditions.

Penetration of Antarctic Intermediate Water into the Eastern Arabian Sea during the last deglaciation

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Carbon and oxygen isotope ratios serve as beneficial tool for reconstructing the changes in ocean circulation, air sea exchange, global carbon cycle and temperature variations of water masses. In this study we present the carbon and oxygen isotopic ratios of epifaunal benthic foraminifera from sediment core AAS-9/21, retrieved from a water depth of 1800 m, from the southeastern Arabian Sea, for last 25 ka. The *Cibicidoideswuellerstorfi* $\delta^{13}C$ values ranged between ~ 0.28 ‰ and - 0.28 ‰ whereas $\delta^{18}O$ values ranged between ~ 2.1 ‰ and 3.7 ‰ for the study period. The $\delta^{18}O$ values show the evolution of cooler to warmer water mass from last glacial maximum (LGM) to Holocene. The $\delta^{18}O$ values showed a shift of 0.4 ‰ which suggests bottom water cooling of ~ 2°C during the LGM. The lowest $\delta^{13}C$ values of -0.28 ‰ were observed during the LGM which indicate the presence of nutrient enriched and less ventilated water mass. The rise in $\delta^{13}C$ values during the Heinrich Stadial (HS1) indicates propagation of Antarctic Intermediate Waters (AAIW) in southeastern Arabian Sea at core depth. The shift in $\delta^{13}C$ from negative values during the LGM to positive during the Holocene, indicates the presence of nutrient depleted and ventilated water mass, which could have resulted from resumption of North Atlantic Deep Waters (NADW) flow. Overall the variation in $\delta^{18}O$ and $\delta^{13}C$ values indicate changes in deep water circulation from the LGM to Holocene. The observed cool, nutrient rich and less ventilated waters during LGM could be due to the penetration of cooler

southern sourced waters which were than replaced by the warmer, nutrient depleted and ventilated North Atlantic Deep Water (NADW) during the Holocene. Changes in deep water circulation from the LGM to theHolocene in the southeast Arabian Sea could arise from varying strengths of the Atlantic Meridional Overturning Circulation (AMOC).

Humans in Quaternary

Evidences and cultural attributes of Human in Quaternary era: a case study of Math Pimpi from Bhima basin, Ahmeadnagar, Maharastra

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Quaternary is the most recent period of earth's history, because it is characterized by repeated climatic changes of considerable amplitude. Analysis of these fluctuations reveals the ubiquity of change and the fundamental dynamism of earth systems and its effects on human lives. Therefore, it is important to reconstruct the paleoenvironment of an archaeological site.

The present paper is concerned with a quaternary site, Math Pimpri, located in south Ahmednagar district and can be accessible easily from Rui Chattishi, a weekly market place located on Ahmednagar Solapur State Highway. The site is located on the left bank of Sina river, on the island developed in between the present and palaeo channels. It is seen on toposheet 47J/13 of 1:250,000 and 1:50,000 scale respectively, of Survey of India, on geo coordinates 18°53.334' N Latitude and 74° 52.712' E Longitude.

This site shows the different cultural phases ranging from Mesolithic, Historical and extending up to Late Medieval Period. The habitation deposits were exposed on surface, rests on Holocene underlain by Lower Pleistocene deposits, which rests on hard rock Deccan Trap Formation. To understand the man- land relationship of the basin, quaternary geoarchaeological excavations of the site were carried out in three (2011 -14) field season. From this scientific excavation many cultural remains as well as plants and animal fossils and litho sections were recovered.

In order to study these deposits systematically, three trenches were taken from top to bottom in three respective deposits i.e. the uppermost has habitation deposits, middle layer has Holocene deposits and the bottom most has the Pleistocene deposits. The sites were excavated up to the hard rock i.e. Deccan Trap. In addition to the cultural studies, the Holocene and the Pleistocene deposits were studied systematically and the samples were collected for different scientific analysis to understand its paleoenvironment. The floral and the faunal remains observed in different layers were taken for the biostratigraphical studies. The detailed sedimentological and other analysis of each layer were carried out systematically to understand it's lithostratigraphy and the important samples were sent to different labs for age calculations, i.e. chronostratigraphical analysis.

In short, the litho, bio and chrono stratigraphy with cultural stratigraphy were very well studied from this site to understand the human and land interaction in connection with the exploitation of natural resources in a severe chronic, drought region of upper reaches of Sina Basin since the Quaternary.

Long term natural and anthropogenic forcing on aquatic system - evidence based on biogeochemical proxies

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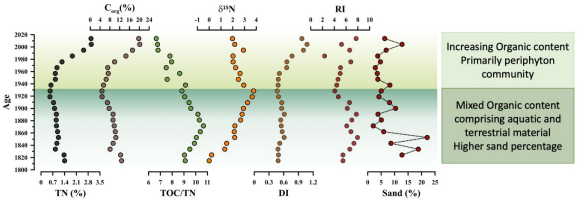
Freshwater aquatic systems are subjected to rapid deterioration driven by multiple stressors such as climate change and human activity. The understanding of the long-term history of eutrophication and their trends provides an opportunity for developing relevant management strategies. In this study, we examine the natural versus anthropogenic impacts on Ahansar Lake using a multiproxy approach (total organic carbon (TOC), total nitrogen (TN), amino acid composition, $\delta^{15}N$, lipid biomarkers, grain size, climate and pollen data) on a $^{210}Pb/^{137}Cs$ dated sediment core spanning the last 200 years. The amino acid datasets clearly show that the organic matter in Ahansar sediment core is less degraded and can be utilized to understand the paleoproductivity changes. Organic matter (OM) within this core is mostly derived from aquatic sources as deduced from C/N (6–11) and $\delta^{15}N$ (0–3.2‰) values and lipid biomarkers. The aquatic productivity gradually increases from 1880s, becoming accelerated after the 1930s, and peaked between 1970 and 2016 AD. This enhancement of primary productivity in the lake indicating the increased eutrophication through time due to anthropogenic activities in the recent decades. The results provide baseline information for policymakers and environmentalists to develop strategical framework for future environmental changes in an aquatic system subjected to anthropogenic stressors.



Slow-accumulating Palimpsests: Accessing its potential for characterising pediment surface Palaeolithic sites of South Asia

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Current paradigms in Palaeolithic archaeology focus on the importance of highly stratified site contexts, such as those found in low-energy fluvial, lacustrine or cave contexts. While one cannot discount the importance of such sites, this emphasis has led to the concentration of Palaeolithic research in specific regions of the world where such contexts are preserved, usually at the cost of study at sites of an 'open-air' nature. The secondary role ascribed to open-air sites has led to such Palaeolithic contexts having a peripheral, if any, contribution to our current understanding of the prehistoric record. Moreover, such

open-air contexts, usually in regions of stabilised landscapes, i.e., low rates of sedimentation, have been discriminatorily acted upon by various anthropogenic agencies, such as agriculture, urbanisation, industrialisation and others, which have a deeper history, and increased impact, on these 'flat' lands and surfaces. This presentation highlights the importance, and ubiquity, of such pediment surface sites, especially towards the reconstruction of the Palaeolithic of South Asia. The presentationalso throws light on the nuances necessary when dealing with these pediment surface sites, which are slow-accumulating palimpsests, resulting from repeated and frequent hominin activities over extended periods of time. Further, it also highlights how, when dealing with such slow-accumulating palimpsests, time is distorted both vertically (as with the classical understanding of time in archaeology) and horizontally. Thus, such slow-accumulating palimpsests that distort both time and space require rethinking current archaeological paradigms to include such vital, rapidly disappearing, records of the archaeological past.

Newly Discovered Prehistoric sites in Hasdeo river valley, Chhattisgarh: Preliminary report

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History of Prehistoric studies in Indian sub-continent can be traced back to the beginning of mid-19th century. Since then several prehistoric sites were reported throughout the region and few of them were studied in detail. However, regions such as northeast India, western India and parts of eastern India were given little attention as the most of these areas were covered with dense forests due to which they were thought to be inhospitable for the hominin populations. In this background the present study aims at exploring the Hasdeo river valley in Kartala Block of Korba District to understand the prehistoric cultural developments in the region. Our surveys yielded prehistoric sites belonging to Lower Palaeolithic to Mesolithic cultures. Lithic artefacts were observed as clusters at these sites exposed due to sheet and rill erosion. The current paper discusses the geological context and the nature of artifact assemblages recovered from our explorations. Our surveys indicate that the Hasdeo River had rich prehistoric past and offer good potential to understand the hominine behavior and adaptations in the forested landscapes.

Imprints of Palaeolithic Man in the Sagileru River Basin, Andhra Pradesh

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This paper presents the preliminary findings of the exploration conducted in the Sagileru river basin, Andhra Pradesh. The re-investigation of the Kondapeta and Ramapuram sitesuncovered two new prehistoric sites namely Modampalle and Nallaguntla. The surface scatters of the artefacts showed the mixed assemblage of tools which is further classified based on

their typo-technical features. A qualitative analysis of stone artefacts is presented in this paper which is substantiated using previous studies conducted in this field domain.

Stable isotope study of Pleistocene mammalian teeth from western and central India: Preliminary results and palaeoanthropologicalimplications

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The oxygen ($\delta^{18}O$ values) and carbon ($\delta^{13}C$ values) isotopic ratio of bioapatite from fossil dental elements of fossil mammals are well-established proxies to reconstruct climatic conditions as well as dietary patterns. In the present study, a total of 23 Late Pleistocene mammalian teeth (species of *Cervid*, *Bovid*, *Sus*, *Hippopotamus*, *Canis*, *Equus*) from Gopnathin Gujarat and nine separate localities from the Narmada Basin (Sher River, Maua Khera, Luknu Nala, Barman Ghat, Gehra Nala, Sokalpur Ghat, Raja Nala, Devakchar – in Narsinghpur District and Nehlai – in Hoshangabad District) in Madhya Pradesh were analysed for $\delta^{13}C$ and $\delta^{18}O$ values to understand palaeoclimatic conditions and associated dietary habits during ~MIS 3 - 5 indirectly based on stratigraphic and archaeological evidence. The $\delta^{13}C$ values in the sample fractions of Gopnath and Narsinghpur range from –3.1 to 2.3 ‰, and–3.2 to 1.33‰, respectively. The higher $\delta^{13}C$ values in these specimens suggest a predominantly C_4 based dietary pattern. On the other hand, relatively lower and large range of $\delta^{13}C$ values from Nehlai (-11.1 to -3.45 ‰) suggest a predominately C_3 based dietary pattern. The relatively higher $\delta^{18}O$ values in Gopnath (–4.1 to –3.1), Nehlai (–4.74 to –2.09) and Narsinghpur (–4.0 to 1.93) point towards hot and humid climatic conditions. The regional contexts are dominated by Late Pleistocene geological records and associated Middle Palaeolithic evidence and the preliminary isotope results indirectly hint that contemporary hominin groups were adapted to hot and humid environments. This work represents the first attempt of stable isotopes on Pleistocene vertebrate mammals from these respective regions and chronological contexts of western and central India.

Beach Rating and Coastal values: Tourist's perspective and socio-economic development. A case study from East Coast of India

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Beaches are one of the popular attractive places to spend outings, cultural and recreational activities of the tourists. Of late, the coastal zone of the study area is already under vulnerable stages from different polluting sources from inland, visitor's wastes, plastics, sewage and many other wastes dumped at the sea. The overall sanctity of the coastal environment is the only factor that attracts the tourists and in tandem elevates the socio-economic status of the coastal community. The socio-economic status of a coastal region depends

on how a tourists rank the beach and there are various factor of ranking depending upon the requirement of the visitor. The present study indicates that environmental issues and appealing of a beach are the important variables that are preferred for visiting a beach and is its reason for sustainability. The present study provides an opportunity to compare the pros and cons of the different studied beaches irrespective of seasonality with regard to beach rating through different variables and its assessment for sustainable socio-economic development.

Mesolithic Culture and Ostrich Eggs Shells: A Case Study of Gaudgaon Village, Tehsil- Akkalkot, District-Solapur, Maharashtra

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Gaudgaon village (Latitude - N 17° 25'17" and Longitude - E 76° 16'10") is settled on the left bank Bori river and 6 km east of Akkalkot tehsil headquarters. Site is located near the KT were of Bori river on the right bank and Survey of India Toposheet no. 56 C/ 3on 430 AMSL. Ostrich eggs shells are used for domestic and wild life studies of hunting gathering society. This study is carried out for the culture period chronology of lower Bori River a left side minor tributary of middle Bhīma basin in Akkalkot tehsil. Morgaon, Patane, Gaudgaon etc. sites are Paleolithic and Mesolithic cultural study carried out with the help of C-14 Shells of (*Gastropod*) Early Pleistocene toEarlier, Florin/Phosphates Dating of Faunal material and AMS dating of Ostrich eggs shells is Early Pleistocene age of biological material. Bori River originates from the Harichandra hill ranges of BalaghatPlateu from the Tulajapur tehsil of Osmanabad District. It flows through Solapur District with Harani and Bori tributary and confluence with Bhima River in Afzalpur taluka of Gulbarga District, Karnataka. Fauna of Bori River is Quaternary Age and Late Middle Pleistocene toEarlier periods and Lower Palaeolithic stone tools types Hand-Axe, Cleaver, Scrapers etc. are found on the surface of the Bori river bank and dug-wells sandy-pebble boulder gravel. This study is highlight on the Gaudgaon village prehistoric culture chronology and comparative study with upper middle and lower reaches of the Bhīma basin.

Geoarchaeological Investigation in Lower Bori Basin: A Case Study of Hallali, Akkalkot Tehsil, Solapur District (Maharashtra)

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Archaeological sites found along the river systems in semiarid regions of peninsular India are not only important in reconstructing Quaternary Paleoclimate but are great help in understanding man-land relationship of that particular basin. The river in dry region flow through a variety of geological-geomorphological features and avail different type of natural resources for the exploitation of human is being.

Bori River were documented 2013 to 2021 and presently the differential investigation is carried out. The lithostratigraphy of a complete section was studied through an exposed complete section in dug-well at the site locality. The animal fossils were recovered from the lower part of section along with Lower Paleolithic stone tools. To understand Chrono-stratigraphy, the important samples were collected studied by using flouring dating method. On the basis of litho, bio, chrono stratigraphy and cultural stratigraphical were studies, it becomes easy to reconstruct the paleoenvironment of the site.

Fossils in Quaternary

A remarkable cranium of *Palaeoloxodonturkmenicus* (Proboscidea, Elephantidae) from Kashmir, India

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A geological exploration of a quarry near GalandarPampore by G. M. Bhat, A. M. Dar, and M. S. Lone in 2000 yielded the remains of one of the most complete *Palaeoloxodon* skulls known. The skull was found in a sandy channel within the Pampore Member of the Nagum Formation of the Karewa Group in Kashmir. The PamporeMember is tentatively dated to the late Early-to-Middle Pleistocene. Excavation of adjacent channel deposits, up to 20 m along the quarry edge to the southeast of the skull, revealed further fragmentary elephant remains and a series of 57 stone tools. The collections from the site are now housed in the Wadia Museum of Natural History at the University of Jammu. In 2019, an Indo-British team resumed studies on the fossil and lithic assemblage from the site. This project, under the leadership of Dr. Ghulam M. Bhat, has the following goals: 1) to describe the faunal assemblage from the site, 2) describe the lithic material and anthropogenic bone modification, 3) place the site within a relative chronological context using amino acid racemization, 4) study the paleoenvironmental history of the site.

Here, we present a section of this study describing the large cranium of *Palaeoloxodon* found at the site, perform a taxonomic analysis, and discuss ecological implications of finding this kind of an elephant in the Kashmir Valley. The cranium is currently encased in a display case, which permitted a comparative study of the frontal and lateral surfaces and the molars. The cranium preserves the left and right third molars and partial tusks. The morphology of the cranium is intermediate between that seen in the Early Pleistocene *Palaeoloxodonrecki* from East Africa and Israel, and Middle Pleistocene *Palaeoloxodonnamadicus* from the Indian

Subcontinent, *Palaeoloxodonantiquus* from Europe, and *Palaeoloxodonnaumanni* from Japan. Like *P. recki*, the Galandar specimen has a weak parieto-occipital crest, not extending beyond the facial plain; elongated and laterally flaring premaxillaries, and incipient loxodont sinuses on the molars. However, the wide frons is reminiscent of other Middle Pleistocene species of *Palaeoloxodon*. The nasal margins are also rounded, much like those seen in skulls of *Palaeoloxodonnamadicus* from Central India. Parieto-occipital crest growth occurs during ontogeny, but the molar wear stage indicates that this specimen was an older individual, and there, it is unlikely that the crest would have developed further. The mosaic characters seen in the Galandar specimen are also found in the poorly studied species *Palaeoloxodonturkmenicus* from Turkmenistan. While *P. turkmenicus* has been synonymized with *P. antiquus* by other authors, we regard *P. turkmenicus* as a distinct species and refer the Galandar specimen to this taxon. *P. turkmenicus* likely represents an intermediate stage in the evolution of *Palaeoloxodon*.

Palaeoloxodon was a grazer, indicating that the Kashmir valley, especially the regions around paleolake Satisar, had started to open up during the Middle Pleistocene from a more forested environment earlier. The presence of horses in the Pampore Member adds further evidence to this hypothesis. *Palaeoloxodon* was most likely widespread in South Asia during this time and perhaps entered the high montane valley by following riverine corridors.

Phytolith Analyses from Agaram (Keeladi cluster), Tamil Nadu

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Keeladi (9°51'00.2940" N; 78°11'00.6960"E) is an urban settlement on the banks of River Vaigai where seven seasons of archeological excavations have been carried out so far and have been dated, using AMS radiocarbon dating of buried paddy husk and other organic cereals, to be between 6th century BCE and 1st century CE suggesting that the urbanization of Vaigai plains happened in Tamil Nadu around 6th century BCE. To study furthermore about this important ancient settlement, the sites around Keeladi were also excavated since 2020, namely, Agaram, Kondagai, and Manalur (Figure). Agaram (9º51'5.4540" N; 78º12'33.5736" E) is a village located in Kalugerkadai Taluk of Sivagangai district. It revealed a habitation mound of greyish silty deposit raised 1.5 m above the existing road located 650 m east of Keeladi archaeological mound and two seasons of excavation have been carried out here at Agaram. The most prominent discovery at the Agaram excavations is the occurrence of microliths in large quantity relative to the other artefacts and it is in these levels that we focus on phytolith analyses.

Paleoecological studies are ongoing at this cluster of sites and this abstract presents the first results from phytolith studies at different depths at Agaram. Phytolith recovery in all the samples studied – from 10 cm close to the surface up to a depth of 320 cm was very good. All samples showed a dominance of phytoliths diagnostic of the grass family (Poaceae); other diagnostic phytoliths included sedges (Cyperaceae), dicotyledenous trees and palms (Arecaceae). The ancient environment in which people had settled here seems to have been a grass dominated landscape dotted with dicotyledenous trees and Palm trees such as the palmyra (*Borassus flabellifer*) or possibly *Phoenix* sp. It was also a landscape with pockets of moisture suitable for the growth of sedges and Oryzoid grasses. Pollen analyses on the same sediment samples could help unravel the dicotyledenous tree taxa present in this environment. Here we present finer phytolith analyses around the depth of 300 cm which had archeological artefacts with interesting patterns in terms of phytolith assemblages, indicating vegetation dynamics that we hope to link to human habitation.

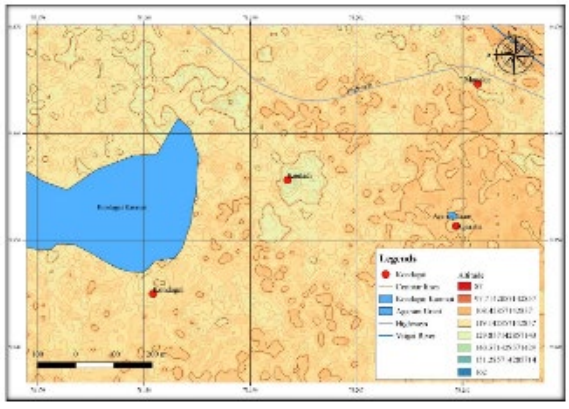

Figure 11: Contour map showing Keeladi and the cluster sites

Understanding paleodietary and habitat using carbon and oxygen isotope of herbivorous mammals from Marginal Ganga Plain

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Herbivore fossils are good records of past vegetation which is well documented in the isotopic composition of their molars. The extinct large Asian elephant *Elephas(=Palaeoloxodon) namadicus*was widespread in the Indian subcontinent during the Late Pleistocene, whose fossil information is reported from Narmada, the Godavari and the Marginal Ganga plains (MGP). However, reconstruction of palaeo-vegetation and dietary habitat from vertebrate molar fragments of the Marginal Ganga plains (MGP) are rare. The present study is based on preserved fossil dentitions of herbivorous mammals acquired from the two stratigraphic sections of the Marginal Ganga Plain (MGP), which represent carbon and oxygen isotope compositions and provide

dietary habits of large mammals in the northern Indian alluvial tract throughout the Late Pleistocene. At the Jigni section, we recovered *Elephas namadicus* from the channelized gravel litho-unit, dated 56±5 ka with a predominantly C_4 dietary system. Bovini fossil specimens recovered from the top part of channelized gravel litho-unit dated between 54±10 to 51±5 ka, additionally favour a C_4 dietary system which suggests pure grazers living in open grassland habitats.

Late-Quaternary Coastal Changes Inferred from Invertebrate Fossil Assemblages of Central Kerala, South India

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The Holocene coastal sediments in Kerala are preserved in two distinct geomorphological settings; in palaeo-mudflat/ coastal swamp deposits occurring inland, which are bordered by medium to fine sandy beach-ridge sequence, sub-parallel to the modern shore. While the palaeo-beach ridges are generally devoid of shells, the equivalent ancient low energy tidal flats and coastal lagoon deposits show well preserved shells, mostly autochthonous. The study aims to understand the change in palaeo-environments using the abundance of species assemblage of shells in the sediments and radiocarbon dating to constrain the age of deposition. Shells from the sediments were collected from five different locationsof Thrissur district, Kerala. The locations are 5-10 km. inland from the present shoreline. The sections display lenticular bedding within the mudflat sediments and fossil shells where embedded in the grey sandy clay to clayey substratum at variable depth (between 2-10.5m). The taxonomic compilation of the shells shows that the specimens are largely composed of bivalves and gastropods in the invertebrate macro-fauna with their characteristic environment of occurrence ranging between marine, marginal marine and estuarine. Radiocarbon ages constrain the timing of these deposits in distinct periods of shell accumulation during 6870±220, 7080±200, 3350 ±160 yrs. BP and >40 ka BP. The shell deposit displays an abundance of well-preserved Holocene shell specimens and slightly altered shells due to the effect of differential taphonomic conditions during the late Pleistocene. The marine influence in the species assemblage and hence the evidence of the formation of these landforms as a consequence of late-quaternary sea-level fluctuations and associated environmental response is deduced.

First Known Fossil Ratite Eggshells from the Siwalik Frontal Range near Chandigarh (Northern India) and their Multidisciplinary Scientific Analyses

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Fossil ratite eggshells and Struthioid (ostrich-like) skeletal remains have been known from Miocene to Middle Pleistocene deposits of the Siwalik Hills in Pakistan and India since the 19th century. Siwalik exposures in Pakistan have yielded Aepyornithid and Struthioid in deposits dating to 11.35-1.25 Ma and 1.15-0.58 Ma, respectively. Ratite eggshells from Haritalyangar, the 10.1-million-year-old Miocene-fossil ape locality in northwestern India, show a close affinity with the Neogene fossil taxon *Struthiolithus.* Here we report the discovery of the first known fossil ratite eggshells (n = 36) from 3 localities in the Siwalik Frontal Range near Chandigarh in northern India. Collected from the surface of fine sediments mapped earlier as the Pinjore Formation at Choti-Badi Nangal, the specimens fill critical geographic and chronological gaps in South Asian Struthioidpalaeobiogeography. We applied optical and Scanning Electron Microscopy to understand the ultrastructure and pore pattern. Pore morphology shows a close affinity to *Struthio camelus subsp. molybdophanes* (Somali blue ostrich). Energy Dispersive X-Ray Analysis was used to understand the elemental composition of the eggshells and was supplemented by X-Ray Diffraction to check for the extent of diagenesis. We also present preliminary results of stable carbon and oxygen isotope analysis of ostrich eggshells to infer their environmental context and diet.

Quaternary landscape evolution

Assessment of erosional and depositional Environment at Majuli Island, Assam, India

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Majuli is a piece of land situated in between two adjacent and parallel rivers is the world's largest inhabited freshwater river Island bounded by 3 important rivers-The KherkutiaSuti in the east, The Subansiri River in the north and The Brahmaputra River in the south. The Island formed in response to depositional processes of large sediment load carried by Bramhaputra River and Subhansari River. For decades, it is changing their morphological depositional behaviour by

greater significant rate of ongoing erosion as compared to the deposition which is severely threatening the existence of the Majuli Island and its rich cultural heritage. These erosion processes are exposing the depositional record of the Island and provide opportunity to study these sedimentary deposits. This paleodepositional record is very well analyzed through adopting methodology of facies identification and their relationship diagram. Total numbers of 6, 5, 4 & 3 exposed outcrop sections of Brahmaputra, Kherkutia, Luit and Subansiri River respectively were studied. The detailed sedimentological documentation and facies identification was carried out and symbols were assigned to facies and a sequence model (FRD) was constructed, which provides a complete set of lithofacies that have been developed in the entire Island sequentially. This study also reveals that sedimentary sequences developed by Bramhaputra River are mud dominated mainly in south central part of Majuli Island, and in remaining stretches from east to west both sand and mud dominated sequences are present, while at Subhansiri River both mud and sand sequences are common. This reflects the differential source to sink transport of sediments, as Bramhaputra River carries sediment load for a longer distance compared to Subhanshiri River. This study also reveals that areas of sand dominated facies show comparative higher erosion than mud dominated facies. Therefore, sedimentary records show both the Subhansiri River and Brahmaputra River are more vulnerable to erosion than the remaining Luit and KherkutiaSuti.

Late Quaternary Sedimentation and Tectonic History of the Chitwan Intermontane Valley, Central Himalaya

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The sediment routing system of the Himalaya is largely influenced by local sinks viz., intermontane valleys/duns that store and release sediments episodically. Duns are relatively broad, longitudinal basins flanked by the Lesser/Sub-Himalayan ranges and the Outer Siwalik hills in the north and south respectively. Intermittent tectonic activity and climatic fluctuations affect the sediment flux and transport capacity of the Duns rivers. Repeated periods of aggradation and incision have resulted in the geomorphic development of the duns over timescales extending 100,000 years. Several studies have explored the geomorphic evolution of the Soan, Pinjaur and Dehra duns in the NW Himalaya. Detailed investigations are lacking in duns of the central Himalaya viz., Dang, Deukhury, Chitwan and Hetauda duns.

In this study we present results from the Chitwan dun, where we have investigated the history of landform evolution and its link to tectonic activity and climatic shifts during the Late Quaternary. Four major phases of aggradation are identified in the Chitwan, i.e., ~112 ka, ~112–70 ka, ~70–25 ka, and ~18–11 ka, which coincide with periods of stronger monsoonal

precipitation. The differentiation of the landforms (fans, surfaces, terraces) into multiple levels of surfaces/terraces is strongly influenced by the intermittent tectonic activity in the dun along several thrusts that have uplifted and truncated the geomorphic units. Our study shows that rivers in the Chitwan dun were strongly affected during the Last Glacial Maxima. Comparison of our results with other intermontane valleys of the Himalaya, suggest that the major aggradation and incision cycles are similar. Thus, we infer a strong influence of Late Quaternary climatic perturbations on the sedimentation history of the intermontane valleys.

Landscape evolution and climatic variability of Ladakh, NW Trans-Himalaya, India duringthe Late Quaternary

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Climate systems play an important role in the geomorphological dynamics of a region. The cold, arid, high altitude, tectonically-active areas of Ladakh, western Tibetan Plateau are no exception, where a drastic change in the landscape and depositional regimes has occurred in the last 30 ka. A fluvial regime around 48 ka and 30-21 ka with comparatively arid conditions and dry phases interspersed by flooding at ~3.5 ka is recorded. The overall geomorphological evolution of Ladakh is basically governed by two sets of geological processes- the continental scale geological processes that have primarily provided the basic framework for the landscape and second the regional/local scale geological processes in which the role of tectonics and climate which has been significant in determining the glacial, fluvial, lacustrine and aeolian processes. Shift from fluvial to lacustrine regime at ~10 ka is attributed to the well-documented early Holocene northward advancement of the ITCZ causing wetter conditions in this dry area and a 182 km long palaeolake that was connected to the present Pangong Tso lake, during Holocene has been completely replaced by fluvial regime today. In spite of being washed away by the combined effects of neotectonics, weathering and intense erosion, the lacustrine facies remain preserved almost continuously on both banks of the river valleys. A composite and complete picture of the climatic variation and forcings using the sediment archive and multiproxy analysis shows five prominent arid phases (~10800-10000; ~8800-8600; a longer arid phase at ~5200-2600 with increasing aridity towards the top part; ~1700-1500 and ~500 calyr BP) intervened by comparatively warmer conditions in between. Two sources of precipitation (Westerlies and ISM) are responsible for governing the hydro-climate of the region. The westerly dominates in the beginning of Holocene while the mid Holocene sees the advent of ISM to the region. Westerlies further take over from mid Holocene to ~3200 calyr BP and from this period onwards the ISM again seem to dominate the hydro-climate of the region. The lake records and other published records from the region show that this change in the moisture source has occurred several times in the Holocene-7200, 5200 and 2600 calyr BP although the westerly has been a dominant precipitation

source in the Ladakh region through most of Holocene.

High altitude regions of northwestern Himalaya are also considered as vulnerable zones against concurrent anthropogenically induced climate change. It is because slight variations in the regional demography vis-à-vis prevalent regional climate can lead substantive change in the overall monsoonal climate of South and Southeast Asia. To capture concurrent climate variability, it is essential to know in detail the natural climatic variability along with its both biotic and abiotic manifestations on multi-decadal timescales which is the need of the day.

Influence of sea level variation on fluvial architecture of Brahmaputra foreland basin

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Indus-Ganga-Brahmaputra foreland is basin formed on a crustal flexure formed continent-continent collision and formation of Himalaya. Climate variability, Himalayan tectonics and the peripheral bulge are thought to be important forcing factors in filling a large portion of the Ganga plain with Himalayan and craton bound sediments. However, with this study we try to show that the stratigraphy of the Brahmaputra foreland appears to be substantially driven by sea level variations instead of the foresaid factors. The vertical stratigraphy of a relict alluvial fan in the western Assam lowlands is investigated in this study. Geomorphic mapping, lithofacies analysis, and geochemical (Sr Nd research) provenance characterization, as well as optically stimulated luminescence, are used in the study to provide a better understanding of the area. The relict fan surface lies 50-30 m above mean sea level and has southward gradient. The relict fan surface is incised and forms a regional valley terrace T1 which was composed of meandering channel deposits. Modern rivers are braided and flow on T0 surface. The results suggested that alluvial fan is made up of three distinct facies association. The bottommost gravelly-sandy braided channel system; overlain by facies association dominant by sheet flows. Towards the top lies deposits of fine grained muddy meandering channels and flood plain facies association. The borehole data from upper Bengal Delta suggests that the basal gravelly channel unit sits on a regional pedogenic surface which is located ~100 m below modern sea level. The basal and middle units of the fan were deposited during ~22 to ~17 ka that coincides to last glacial maxima (LGM). This indicates that alluvial fan was prograding in response of lowered sea level during LGM. The LGM bound drop in the sea level would have increased the gradient of the transverse Himalayan Rivers and allowed the rivers to cSarry the gravels much downstream into the foreland as compared to present day. During early-Mid Holocene rainfall increased and the upper most unit was deposited in response of rising sea level when rivers lost gradient and inland sedimentation in muddy channels took place. Sea level reconstruction in the east coast of India

suggest a rapid sea level rise from 15-9 ka, stabilizing between 9-8 ka and then rising again to +5 m at ~6 ka and then dropped to present level at ~5 ka. We suggest that mid Holocene sea level dropped and increased precipitation allowed river incision and gullying of fan surface. Subsequently, the rivers were meandering on the incised valley. We also suggest the earlier discussed gravel units found in bore hole stratigraphy of Upper Bengal Delta are relate to progradation of alluvial fans in response to lowered sea-level rather than an extreme flood events in axial channel of Brahmaputra as envisaged in earlier study. The Sr and Nd isotopic fingerprints have also referred to sediment origins on the Himalaya's southern front (i.e. lesser and Higher Himalaya) which is not the case for extreme event sediments in which primary source of sediments is Tibetan sedimentary sequence.

Palaeo-tsunami and palaeo-storm events along the Gujarat coast (Western India) during the Holocene period

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A lot of research has focused on exploring and reconstructing records for the palaeotsunami/palaeostorm deposits during the Holocene period but lacks in predicting future possibilities of such extreme events. This is primarily because the inventory still remains fragmentary owing to the lack of preservation potential of these events. Understanding of cyclic reoccurrence of such oceanographic extreme events is very essential as it has vital societal concern for the rapidly developing coastal regions. The Makran Subduction Zone (MSZ) in the northern Arabian sea is major tsunami source for Indian, Pakistani, Iranian and Omani shorelines. We report a total of six major extreme wave events, out of which at least two have been identified to be associated with palaeotsunami deposits, whereas three are storm surge deposits and one is designated as a washover deposit. Archeological findings like the presence of thick walls around Dholavira (an ancient Harappan coastal trading centre) is also supportive of Harappan learning from the wrath of marine waves they would have faced. This study reports the wider time gap between the events, attributed to lack of preservation, difficulty in recognition, higher reworking or lack of detailed investigation making the task of estimating recurrence a mammoth effort. The study shows that the shoreline of Gujarat has remained vulnerable to extreme wave events atleast during the Holocene period, and have affected ancient settlers as well as modern anthropological activities.

A multi-proxy sedimentary record of last 2.6ka climate and vegetation from the Mahanadi River Delta, East coast of India

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Present study integrates biotic and abiotic proxy records to reconstruct the climatic change during the past 2600 years in the Mahanadi delta region, along the east coast of India. A 2.8m thick, AMS radiocarbon dated fluvial sedimentary sequence from the southeastern part of Mahanadi delta imprints abrupt climate change, weathering intensity, depositional paradigm, and vegetation changes in the delta region since 2600 calyr BP. Provenance study depicts a close association of Mahanadi delta sediments with the charnockite and granite of Eastern Ghats granulite belt. The climate in the study region progressively shifts from arid to humid during 2634-2105 calyr BP as indicated by vegetation indices and deposition of more coarse than fine end member (EM3, 48µm) corresponding to the Iron Age cold period (IACP). Period from 1870-1353 calyr BP shows a decline in mangrove taxa like *Rhizophora*and *Barringtonia* with abundance of herbaceous taxa like Poaceae/Cyperaceae and Chenopodiaceae members indicating anarid climate coinciding with the Dark Age cold period (DACP). A shift towards warm and humid climate indicating Roman Warm Period (RWP, 2105-1870 cal yr BP) and Medieval Climatic Anomaly (MCA, 1353-858 calyr BP) is depicted by intense weathering, enhanced fluxes of medium to coarse silt sized sediments (EM2, 10µm; EM3, 48µm) and higher values of secondary clay minerals. The pollen data also indicate high species diversity of mangroves and terrestrial tree taxa during these periods. After ~850 calyr BP, the region experiences a sharp fall in all weathering parameters as well as a minimum value of Rb/Sr ratio and a decline in vegetation which may correlate with Little Ice Age (LIA, 858-322 calyr BP). Herbaceous taxa like Poaceae/Cyperaceae and Apocynaceae members start appearing after 322 calyr BP which indicates the onset of Recent warming period. A major change in depositional paradigm in the delta is depicted via deposition of sand dominated EM4 (153 µm) since 850 calyr BP possibly indicating channel migration and/or breaching during high river discharge and increased monsoonal precipitation around 600 calyr BP as reconstructed from the speleothem records of Central Indian cave.

Characterization of tectonically active zones in the Island Belt Uplift region, Kachchh Basin, Western India using GIS and Geodectic techniques

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The present study depicts identification of tectonically active zones along Island Belt Uplift (IBU), an upthrown block of E-W trending Island Belt Fault (IBF) (a buried basement fault) which is dissected by several major and minor transverse faults that have segmented the IBU in four sub-uplifts viz. Pachham Uplift (PU), Khadir Uplift (KU), Bela Uplift (BU), and Chorar Uplift (CU) from west to east, respectively. The work includes preparing the structural and lineament map followed by morphotectonic analysis using GIS and Remote Sensing techniques. The Normalized Steepness Index (Ksn) analysis uses swath profiling to mark the tectonic activity variations. Further, the Ksn contour map was prepared by using a power-law function of slope (S) of the longitudinal profiles of the river, concavity index (ɵ), and upstream area (A), which is an integral part of the stream power incision model (SPIM). The Ksn analysis suggests that the maximum amount of tectonic activity is restricted along the northern escarpment of the IBU, which falls in the vicinity of IBF and associated longitudinal and transverse faults of various nature. Based on results of Ksn analysis, we have marked tectonically active zones along with IBU, which shows that amongst four sub-uplifts, the PU and BU were found most active (Zone-I), the KU expresses moderately active (Zone-II), while CU demonstrated to be least active (Zone-III). The results were also confirmed by documentation of active tectonic features within the active zones of IBU. The ongoing tectonic activity in the study area is also manifested by moderate seismic activities in the identified active zones. The active deformation pattern calculated using the Global Positioning System (GPS) data-set of 2009 to 2019 along IBU reveal maximum deformation rate of ~2.5 ± 0.5 mm/yr in the PU, ~2.0 ± 0.5 mm/yr in the BU while, the KU region shows the deformation rate of ~1.2 ± 0.5 mm/yr, which coincides well with the results of Ksn. The results of Ksn analysis were also validated by comparing them with existing Gradient Length Anomaly (GLA) and Differential Interferometric Synthetic Aperture Radar (DInSAR) data. The tectono-geomorphic features and fault scarp geometry were analysed and compared with the existing experimental models of basement fault and overlying sedimentary covers that allow us to understand the subsurface nature of buried IBF. The present study shows that IBF contains both dip-slip and strike-slip fault components of motion in forming the present day landscape, which needs to be confirmed by other geophysical methods. The results of Ksn analysis and field evidence were merged to prepare the Active Fault Map of the IBU region that can be implemented for future seismic hazard assessment in the region on the verge of infrastructural and economic development.

Morphostratigraphic and Lithostratigraphic Studies of Quaternary Sediments in Lendi river, tributary of Manjra River, India

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The Quaternary period is unique because of its relevance to present and it is contributing towards understanding the past environmental conditions. It also witnessed series of major climate changes which had pronounced effect on the physical as well as the organic world.

The study is carried in Lendi river sub-basin (18°17'20"N and 18°41'26"N of 76°53'23"E and 77°45'9"E) covering an area of about 2536.26 km^{2}is a tributary of Manjra river, which originates in Balaghat hill range on eastern slope. The climate of the study area is semi-arid, sub-tropical dry, characteristically hot summer. The rainfall in the area is mainly because of south-west monsoon winds starts from month of June till September. The post monsoon or retreating monsoon rainfall is in the October and November. During May the maximum temperature goes up to 44.0°C. The average rainfall in the area is 799.0 mm. Geologically, the river is flowing over Deccan Volcanic Basalt (DVB) - Upper (late) Cretaceous to Lower (early) Eocene age, and Peninsular Gneissic Complex (PGC) - Precambrian age. Quaternary sediments are exposed along the main river and its tributary streams (Gurav and Babar, 2021). In the study area, at Degloor 129 small faults are observed in PGC out of theses 90% faults are strike-slip and out of these 72% are of NE trending. Based on this evidences authors designated these zone is 'Degloor Strike-slip Shear Zone' (Babar et al., 2018).

The study was undertaken using the morphostratigraphic and lithostratigraphic studies of Quaternary sediments deposited along the river. The morphostratigraphic study is carried at six places including Ravankola, Mukarmabad, Malkapur, Begam Takali, Hanuman Hipperga and ThadiHippergaalong the river channel (Gurav, 2019). Based on this three river terraces are studied namely terrace T2 (oldest), T1 (in between oldest and youngest terrace) and T0 (youngest) being the active channel. This terraces lies at 343 m msl.

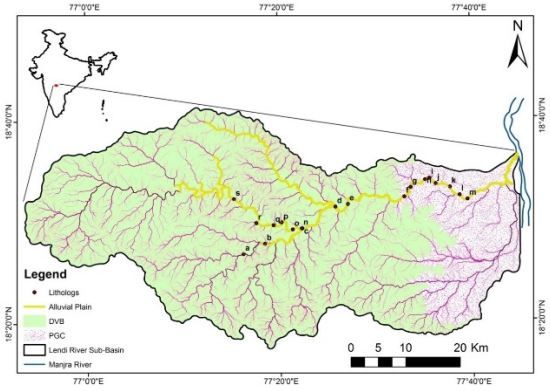

Figure 12: Location map of the study area.

In order to the study Quaternary geology of Lendi river, the lithologs are prepared for selected locations from Lendi river and its tributary river Tiru. Quaternary sediments collected from selected sites along Lendi river are Ravankola (a), Halni (b), Mukarmabad (c), Ravangaon (d), SangaviBhadev (e), Malkapur (f), Degloor (g), BagamTakali (h), Hawarga (i), Sundgi (j), Hanuman Hipperga (k), Gojegaon (l) and ThadiHipperga (m)(Gurav, 2019). Along Tiru river the selected villages are Mukarmabad (n), Bhamani (o), Tagyal (p),

Kalambar (q), GundappanDapka (r) and Atnur (s) (Figure 12)

Lithostratigraphically the Lendi river Quaternary sediments belong to three informal formations such as;

(i) Dark grey silt formation (Hanuman Hipparga) – Late Holocene

(ii) Light grey silt formation (Mukaramabad) – Early Holocene and greyish brown silty clay formation (Gojegaon).

Age dating of the fossils collected during the fieldwork is carried out using Fluorine: Phosphate Ratio. The occurrence of calcretes in the Quaternary sediments and presence of vertebrate fossils 'Bos nomadicus', 'Elephas sp' and mollusca fossils of Gastropods from the Lendi river suggests that the Older alluvium is older than the sediments of present floodplain and is possibly of Upper Pleistocene period. The fossils, dating back to the late Pleistocene period about 50,000 years ago, draw our attention to the amazing completeness of their skeletal remains.

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Lithologic and Tectonics controls on flexural bulge of the Indian Plate

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The multiple extrinsic and intrinsic factors guide the ability of the channel to erode its bedrock. The intrinsic factors consist of properties, such as rock erodibility, lineaments/joints orientation, and fracture density. Such intrinsic factors can spatially affect the landscape evolution of a slowly uplifting terrain. The regional-scale variation in the intrinsic factors may result in heterogeneity in fluvial erosion rates, which can result in false signal of active tectonics.

The emergence of the Himalayan mountain chain has resulted in an upward flexure in the Indian shield known as the flexural forebulge. The uplifted Vindhayan plateau marks the depiction of this flexure. The bending of the Indian plate has resulted in the generation of tensile(fiber) forces in this area. These Tensile forces have resulted in the formation of large-scale lineaments, which are aligned parallel to the axial plane of this forebulge. This study highlights the role of forebulge tectonics and its impact on lineament orientation, rock strength, and fluvial erodibility in this region.

We used an N-type Schmidt hammer to measure the intact rock strength of lithologies found in the Vindhayan plateau. We calculated the Normalized

steepness index (a proxy to measure fluvial erosive power in bedrock channels) to assess the fluvial erodibility of the streams. We calculated swath profiles and local relief distribution to understand topographic variation. Further, we looked at the knickpoint distribution and correlated it with major lineaments and lithological boundaries. Finally, we attempted to understand the relationship between the lineament distribution and regional tectonics of the forebulge.

We observed a significant difference in fluvial erodibility between the weakest and strongest lithologies. Further, the lineaments act as conduits for rapid erosion and knickpoint formation. The Ksn values are relatively high where the harder lithologies are present and this results in the generation of waterfalls (knickpoints). We have observed a correlation between, Rock strength variation, topographic relief, knickpoints, and Normalized steepness index. Our results suggest that spatial variation in rock strength and lineament pattern plays a crucial role in the landscape evolution of the Vindhayan plateau. We finally propose a model to relate lineament orientations and lithological variations with slow uplift of the forebulge.

Gradual climatic changes in an undated Quaternary fluvial section at Mahadeo Piparia, Madhya Pradesh

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Understanding past climatic changes may provide valuable perspectives on the impacts on human adaptations and regional habitation over time. In this study, sedimentological and geochemical analyses have been deployed on the fluvial deposits present along the bank of River Narmada at Mahadeo Pipariavillage, Madhya Pradesh, which preserves Palaeolithic evidence studied since the 1960s. The primary objective of this work is to establish the climatic conditions of the region by the above-mentioned multi-proxy approach and discuss the implications for hominin presence. While absolute dates are currently unavailable, the study proposes broad hypotheses in relation to the regional Quaternary environments and hominin adaptations. Sediment samples were collected from a 16-meter fluvial section and selectively processed for geochemistry and sedimentology. Significant climatic variation was observed as indicated by the grain-size and geochemical parameters suggesting a change in hydrological regime of the region. The mean particle size variation shows that the river was initially in a low-energy state before abruptly shifting to a high-energy state. This was followed by a gradual shift towards low energy conditions. The fluctuation in elements content (Al, Si, Ca) confirms the

grain size analysis conclusion that aridity is gradually intensifying.

We were able to quantify the degree of chemical weathering and its fluctuation over time using ratios of these elemental concentrations and indices like CIA, CWA, and IVA. This, in combination with the grain size characteristics, is used to rebuild the climatic variance discussed above. Comparison of available geoarchaeological data as well as paleoclimatic records indicate pronounced weaking of Indian Summer Monsoon leading to possible shift in prehistoric landuse patterns in the region.

Timings of fluvial aggradation and Sequential reactivation of Central Himalayan Thrusts, India

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The geomorphic anomalies, morphometric attributes, and the bedrock strath terraces are some of the widely used features to ascertain the nature and timing of down cutting (bedrock incision) and exhumation (surface uplift). In the present study the Kali River, which traverses through four terrain boundary thrusts in Central Himalaya have been investigated to understand the spatial and temporal variability in phases of aggradation/incision in response to climate variability and crustal deformation. The oldest aggradational phase (fill terrace) is dated between 44 ka and 30 ka, a period corresponding to the Pluvial Marine Isotopic Stage-3 (MIS-3). The second phase occurred during the MIS-2 (dated between 26 to 16 ka) when the Indian Summer Monsoon (ISM) is weakening. The post glacial strengthening of the ISM is well represented by valley wide aggradation (dated between 14 ka to 10 ka) whereas the youngest aggradation phase is dated to the Middle to Late Holocene (8 ka to 2.5 ka). Further, the study observed that, sporadic high sediment fluxes during phases of strengthened ISM was responsible for the development of abandoned channels and valleys and associated epigenetic gorges. The study observed spatial variability in the incision rates (crustal deformation) during 35 ka and 5 ka which ranges from 2.89 mm/yr in the proximity of the Main Central Thrust (MCT) to 2.14 mm/yr near North Almora Thrust (NAT). We ascribe the variability in river down cutting to a combination of climate (ISM) and high uplift rates in the vicinity of major structural discontinuities.

Transient Fluvial incision in the Upper Zanskar, implication for Late Quaternary activity on the STDs, Western Himalaya

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In the Ladakh Himalaya, ~150 km long stretch of South Tibetan Detachment system (STDs) is known as Zanskar Shear Zone (ZSZ), along the strike of which two major tributaries of Zanskar River- Tsarap Lingti Chu and Doda River flows. STDs is a synorogenic extensional structure comprising of north dipping normal faults, and is exposed near the crest of Himalayan orogeny to accommodate the crustal thickening and elevated topography due to subducting Indian plate. Geomorphologically, most of the STDs is characterized by the presence of wide valleys and huge quaternary sediment cover with low gradient river profiles. The Tsarap Lingti Chu, contrary to the rule, flow in a steep, narrow V-shaped valley, with numerous shear zones and landslides. The longitudinal river profile shows an average gradient of ~8 m/km, which is almost twice of its trunk channel- Zanskar River, along with many convexities marking the Knick point zones. The S-L gradient index of the river varies from 20 to as high as 13000 in the lower segment of Tsarap Lingti Chu. Two levels of strath terraces in the lower valley at an elevation of 157 and 57 m above river level gives an OSL age of 57±8 ka and 34±13 ka respectively. This suggests a long-term fluvial incision rate of ~2.8 ± 0.4 and ~1.7± 0.6 mm/a along the ZSZ in the Tsarap Lingti Chu valley. Across the Himalaya and Trans- Himalaya, Pleistocene incision rates are comparable with the exhumation rate. Thus, long term fluvial incision is in dynamic steady state with exhumation and can be used to infer the long-term rock upliftment rate. Although, the study lacks in sufficient data but preliminary study favours the hypothesis of episodic Pleistocene tectonic activities along some of the segments of the STDs.

Glacio-fluvial response of the Late Pleistocene-Holocene climate changes: A preliminary study from Dhauliganga valley, NW Himalaya

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The imprints of Late Quaternary climate change are preserved in various sedimentary archives of Dhauliganga valley in NW Himalaya. The February 2021 flashflood event of the Rishiganga-Dhauliganga motivates to identify whether this valley had experienced such events in the recent past in response to climate change or not. We identified the paleo-foods sequences, debris flow and other fluvial deposits in the Dhauliganga valley. The preliminary observations and chronology show a connection between the debris-flow events and regional patterns of climate during the Late Pleistocene-Holocene. These deposits have a few distinct horizons of fining upward

angular to sub-angular, matrix-rich clasts indicating hyper-concentrated flow conditions within the rounded to sub rounded think gravel sequences. These prominent debris-flows (hyper-concentrated flow) events were identified from the exposed sections of the deposits at Suraithota and Jumma locations. In addition, a few sequences of fine sand-silt indicating a temporary ponding were also identified. Two AMS radiocarbon dates of Late Holocene 1705 ± 68 calyr BP and 1395 ± 51 calyr BP, obtained from peat samples collected from near Rwing Village, suggest terminal stages of Debris flow and outwash gravel deposits, respectively, which indicates warm and moist weather after 1700 calyr BP. The study suggests that the Late Quaternary landforms (deposits) of the Dhauliganga valley were developed by Glacio-Fluvial System in response to the dynamics of the Indian Summer Monsoon (ISM). In addition to this, the study calls for detailed geomorphological mapping, sedimentological and chronometric analysis of these deposits to establish the relationship between climate change and landform evolution. The preliminary finding of this study has implications for understanding the flash-flood and debris flow mechanism in response to climate change.

Spatial analysis of cirques in NW Himalaya: Application in palaeo-environment reconstruction

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Glacial cirques are bowl-shaped depressions with steep headwall and nearly flat base carved by glaciers. Since cirques indicate initiation of glaciation in the mountains, their morphology, distribution, altitude, aspect can serve as valuable palaeo-climate indicators particularly in the remote and inaccessible locations where often other proxies may be absent. In the present study an attempt is made to categorize and understand the evolution of both the relict and modern cirques in NW Himalaya (Karakorum, Ladakh, and Zanskar) along the precipitation gradients of Indian Summer Monsoon (ISM) and the mid-latitude westerlies. The relict and modern cirques were mapped in the Karakorum, Ladakh, and Zanskar ranges using Google Earth Imagery, Landsat 8 (30m), Sentinel-2A (10m) and ALOS Palsar Digital Elevation Model (12.5m). Various parameters such as peak elevation, minimum elevation, relief, area, circularity, mean slope, mean aspect and hypsometric maxima (indicate cirque floor elevation) were derived to understand the influence of precipitation gradient, wind pattern, lithology, structure, and aspect in evolution of cirques and thus, glaciation. The preliminary results show that cirques are dominantly deepened and clustered in the western sector of the ranges suggesting that the evolution of cirques is strongly influenced by moisture supplied by the mid-latitude Westerlies. On the contrary, the cirque floor elevation (indicative of the Equilibrium Line of Altitude-ELA) decreases to the north along the precipitation gradient of the ISM following the global ELA vs latitude pattern. The modal aspect of the palaeo-cirques in the Zanskar and Ladakh ranges is aligned along with prevailing palaeo-wind direction during the LGM (NE direction) as observed

in northern hemisphere cirques, where are in Karakorum, its towards NW. The study indicates dominance of glacial erosion in the NW Himalaya (glacial buzzsaw).

Glacial geomorphology of Nubra Valley, Ladakh, India

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The Nubra valley known for one of the largest glaciers on the continents (Siachen, 72 km) is a mystifying glaciated landscape sandwiched between the Karakoram and Saltoro mountain ranges. Previous studies have reported widely differing and generalized interpretationsof the glacial landforms and current understanding of the glacial events inthis area is partly restricted by the absence of field observations aided detailed glacio-geomorphological landform mapping. To address this, extensive field work was carried out along the Nubra valley and some valleys of Karakoram in the summer of 2021 (Figure). Glaciallandform mapping with excellent field photographs combinedwith interpretation of fine resolution satellite imagery and Digital Elevation Models (DEMs) has revealed a varietyof glacial, fluvial, eolian, periglacial and permafrost landforms within the valley. We have identified different glacial sediment-landform assemblages (moraine and debris types), lake sediments indicating damming of valleys, rock glaciers, glacial benches, rochemoutonnées, trim lines, and dissected glaciogenic material etc.

Figure 13: Panoramic view of two glaciers with proglacial area, moraines and glacial features in upper Saser valley, Karakoram.

The present work provides detailed observations on the Nubra valley glacio-geomorphological aspects particularly the glacial landforms and processes operating in this vastly glaciated terrain. These landforms directly and without doubt define the past extent and the relative thickness of ice bodies in the Nubra valley.

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