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XXII INQUA INDIA 2027

FIELD GUIDE

INPRE - 02

TRACING THE FOOTSTEPS: LATE QUATERNARY GEOMORPHOLOGY & GEOARCHAEOLOGY UNVEILING HUMAN MIGRATION PATTERNS INTO ASIA







Hema Achyuthan and
Sudesh Kumar Wadhawan

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INQUA INDIA 2027
Field Guide Book

INPRE-02

Tracing the Footsteps: Late Quaternary Geomorphology & Geoarchaeology Unveiling Human Migration Patterns into Asia

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Hema Achyuthan is Emeritus Professor at the Centre for Environmental Studies, Anna University, Chennai, with over 36 years of teaching, research, and institution building. She established the soil micromorphology laboratory and supervised more than 25 PhD scholars, advancing geoscience education in India. Her research spans petrography, paleoclimate reconstruction, duricrust genesis, and isotope proxy applications. With an H-index of 36 and ~5,000 citations, she has published widely in leading international journals, contributing to global understanding of Quaternary climate dynamics and semi-arid geomorphology. She has led extensive field investigations on ferricretes, calcretes, and teri sands, clarifying monsoon variability, Critical Zone processes, and duricrust diversity — themes central to the Thar Desert margins. Her international collaborations include the Cambridge–Leverhulme Trust (Kenya), invited lectures at University College London, and active participation in IUGS. She is recognized for precise scientific writing and advancing planetary relevance in paleoclimate studies.



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Dr. Sudesh Kumar Wadhawan is former Director General of the Geological Survey of India (GSI) and a Gold Medalist in Applied Geology from the University of Delhi. After an early teaching role at Delhi College of Engineering, he joined GSI and served for over 36 years with distinction. He authored 40 technical reports, published 60+ peer-reviewed papers, and co-authored three books. His investigations spanned Quaternary geology, environmental geology, and geotechnical studies across deserts, river basins, coastal tracts, and urban centers. As a leader, he established the Geohazards Research & Management Cell at GSI

headquarters with five regional units, pioneering landslide research and launching the National Landslide Susceptibility Mapping Program (1:50,000 scale) integrating GIS, remote sensing, and field surveys. He has organized and deliberated in numerous geoscience conferences. Currently, Dr. Wadhawan serves as Adjunct Professor at Amrita University and Geoscience Advisor to government departments and commissions.

Abstract

The reconstruction of Quaternary climate variability remains a global priority, as dryland systems are critical yet under-represented archives compared to polar ice cores and marine sediments. Semi-arid landscapes, in particular, preserve alternating wet and dry phases that illuminate monsoon dynamics, glacial–interglacial cycles, and the environmental corridors that shaped human migration. Current international debates emphasize the need for geoarchaeological integration, linking archaeological evidence with stratigraphic and geochemical proxies, and for resolving uncertainties in duricrust genesis and isotopic pathways.

Within this global context, the Thar Desert transect offers a uniquely rich archive. Positioned at the semi-arid monsoon margin, it records alternating humid and arid phases that provide a nuanced perspective on monsoon variability. Its multi-proxy assemblage—including salt lakes, dunes, calcretes, palaeosols, and ferricretes - enables cross-validation of climatic signals within a compact geographic setting. Extensive OSL dating has established chronostratigraphic clarity, offering robust timelines for aeolian deposition and landscape stabilization. Moreover, the transect holds exceptional geoarchaeological significance, with Palaeolithic sites at Didwana, Sambhar, and Kuchaman directly linking climatic amelioration to human occupation.

By situating Indian dryland records alongside African, Australian, and South American archives, the Thar Desert transect strengthens global comparability and contributes to planetary Quaternary frameworks. This field workshop thus provides a living laboratory where participants can directly engage with stratigraphic sequences, proxy diversity, and human–landscape interactions, while advancing international collaboration in paleoclimate science and geoheritage.

Preamble

(Research problem as it stands globally and how the field transect is unique in the context of Quaternary Geology)

The reconstruction of Quaternary climate variability remains a global priority, as dryland systems are critical yet under-represented archives compared to polar ice cores and marine sediments. Semi-arid landscapes, in particular, preserve alternating wet and dry phases that illuminate monsoon dynamics, glacial–interglacial cycles, and the environmental corridors that shaped human migration. Current international debates emphasize the need for geoarchaeological integration, linking archaeological evidence with stratigraphic and geochemical proxies, and for resolving uncertainties in duricrust genesis and isotopic pathways.

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Regional Geology including stratigraphy, structure, palaeontology, Quaternary Geology

Regional Geology of the Jaipur–Sambhar–Kuchaman–Jayal–Didwana Transect

The field area from Jaipur westward to Sambhar, Kuchaman, Didwana, and Jayal lies within the eastern margin of the Thar Desert, where the transition from the Aravalli hill ranges to the semi-arid plains is sharply expressed. This corridor provides a natural transect across diverse lithologies, structures, and Quaternary landforms that are central to understanding northwestern India's geological evolution.

Stratigraphy

The bedrock framework is dominated by the Aravalli Supergroup, comprising Proterozoic metasediments and volcanics exposed near Jaipur and extending northeast– southwest. Westward, these rocks give way to Vindhyan sediments and younger alluvial deposits. The Sambhar basin is filled with Quaternary lacustrine clays, evaporites, and calcretes, while Didwana and Jayal preserve thick aeolian sand sequences interbedded with palaeosols. Stratigraphic transitions along the transect thus capture both Precambrian basement and late Quaternary depositional systems.

Structure

The eastern sector near Jaipur is structurally controlled by the Aravalli range, trending NE–SW, with associated faults and lineaments influencing basin development. The Sambhar Lake basin itself is tectonically controlled, bounded by faults that have accommodated subsidence and sediment accumulation. Further west, near Didwana and Jayal, the landscape is dominated by gently undulating plains with subtle structural control, but neotectonic activity has influenced drainage shifts and dune orientation.

Palaeontology

The lacustrine deposits of Sambhar and Didwana have yielded microfossils such as ostracods and diatoms, which serve as sensitive indicators of palaeohydrological change. In addition, vertebrate fossils and archaeological artefacts from calcrete horizons and dune sequences provide evidence of faunal adaptation and human occupation during humid phases. These palaeontological records link the region to broader Quaternary biogeographic patterns.

Quaternary Geology

The transect is particularly significant for Quaternary geology. Aeolian dunes, interdunal plains, calcretes, and playa lakes together form a multi-proxy archive of monsoon variability. OSL dating has established robust chronologies for dune stabilization and paleosol formation, while stable isotope studies of calcretes and lacustrine carbonates provide

insights into palaeoprecipitation. The alternation of humid and arid phases is clearly recorded, situating this region within global debates on monsoon dynamics and human dispersal.

Position of the Field Trip

This field trip fits strategically within the broader framework of Indian Quaternary studies. By traversing from Jaipur to Didwana, participants encounter a complete spectrum of geological contexts: Precambrian basement exposures, tectonically controlled basins, fossiliferous lacustrine deposits, and Quaternary dune–calcrete systems. The transect thus serves as a living laboratory, illustrating how stratigraphy, structure, palaeontology, and Quaternary processes converge to illuminate both regional geology and planetary paleoclimate frameworks.

Flora, Fauna and Climate, weather conditions

In January 2027, the Jaipur–Sambhar–Kuchaman–Jayal–Didwana transect will experience cool, dry winter conditions with daytime temperatures around 20–25°C and night temperatures dropping close to 5°C. This season offers comfortable weather for fieldwork, sparse desert vegetation in dormancy, and excellent opportunities to observe migratory birds and adapted desert fauna.

Flora

The vegetation is dominated by xerophytic species adapted to aridity. Common plants include sewan grass (Lasiurus sindicus), Prosopis cineraria (Khejri), Acacia nilotica (Babul), and scattered shrubs such as Capparis decidua. In January, most grasses are dry and dormant, but woody perennials remain green, sustaining pastoral livelihoods.

Sacred groves (orans) along the transect act as biodiversity refuges, supporting native thorn forest species.

Fauna

The region supports iconic desert fauna such as the chinkara (Indian gazelle), blackbuck, and desert fox.

The Great Indian Bustard, a critically endangered bird, is a flagship species of the Thar grasslands.

Winter months (October–March) are peak for migratory birds, including flamingos, cranes, and waders, especially around Sambhar and Didwana salt lakes. Reptiles such as spiny-tailed lizards and small mammals like gerbils are also common, though less visible in cooler months.

Climate and Weather in January

Temperature: Daytime highs of 20–25°C; nighttime lows near 5°C, occasionally dipping lower.

Rainfall: Virtually absent; January is part of the dry winter season.

Humidity: Low, typically around 30–40%.

Winds: Gentle northeasterlies, with occasional cold waves.

Field Conditions: Clear skies, excellent visibility, and minimal dust storms compared to summer.

Relevance to the Field Excursion

January provides optimal comfort for participants, avoiding the extreme heat of summer and erratic monsoon rains.

The dry season landscape allows clear observation of stratigraphy, dune morphology, and calcrete exposures without vegetation cover obscuring features. Migratory bird concentrations at Sambhar and Didwana lakes enrich the palaeoenvironmental context, linking present ecology to Quaternary records. The climate exemplifies the semi-arid monsoon margin, reinforcing discussions on monsoon variability and its imprint on Quaternary geology.

This synthesis situates the flora, fauna, and climate of the transect within the January 2027 field excursion, showing how ecological and weather conditions enhance both scientific observation and participant experience.

Flora
Xerophytic vegetation dominates: khejri (Prosopis cineraria), babul (Acacia nilotica), caper bush (Capparis decidua).
Grasses such as sewan (Lasiurus sindicus) are dry/dormant in winter.
Sacred groves (orans) preserve thorn forest patches, acting as biodiversity refuges.

Fauna
Desert mammals: chinkara (Indian gazelle), blackbuck, desert fox.
Birdlife peaks in winter: flamingos, cranes, pelicans, and waders concentrate at Sambhar and Didwana lakes.
Flagship species: Great Indian Bustard in grasslands.
Reptiles: spiny-tailed lizards; small mammals like gerbils less visible in cool season.

Climate & Weather (January 2027)
Temperature: Days 20–25°C; nights 5–8°C, occasionally lower.
Rainfall: Minimal; dry winter season.
Humidity: Low (30–40%).
Winds: Gentle northeasterlies; occasional cold waves.
Field conditions: Clear skies, excellent visibility, minimal dust storms.

Relevance to Fieldwork
Comfortable weather for participants compared to summer extremes.
Sparse vegetation allows unobstructed observation of stratigraphy, dunes, and calcretes.
Migratory bird concentrations enrich ecological context, linking present biodiversity to Quaternary palaeoenvironmental records.
Semi-arid monsoon margin conditions exemplify the climatic setting central to Quaternary geology.

Literature Review

Late Quaternary Paleoenvironments of the Thar Desert Margin

The eastern margin of the Thar Desert preserves a rich archive of

Late Quaternary climatic oscillations, geomorphic processes (Wadhawan 1996, 2010), and human occupation. Early lacustrine studies by Singh et al. (1974), Wasson et al. (1984), Enzel et al. (1999), and Mukherjee & Rakshit (2012) reconstructed hydrology and salinity changes. At Didwana, strata older than 12.8 ka reflected treeless savanna and aridity, while 12.8–9.3 ka showed shrub-savanna and intermittent lake infilling. Between 9.3–7.5 ka, freshwater plants increased, rainfall improved, and halite deposition weakened. The humid peak (7.5–6.2 ka) was marked by Graminae and Artemisia dominance, before aridity returned by 4.0 ka BP. The persistence of Artemisia, a winter rainfall indicator, suggests that winter rains contributed significantly to the hydrological regime until their disappearance at 4.0 ka BP.

Aeolian archives complement lacustrine records. Excavations at Didwana dunes revealed fourteen litho-units with in-situ Lower Palaeolithic artefacts (Misra & Rajaguru, 1989, Achyuthan etal.,2007a). Luminescence dating confirmed aeolian activity at ~180, 140, 125–110, 70, and 26–13 ka BP (Achyuthan et al., 2007b; Singhvi et al., 2010). Dhir et al. (2009) extended aeolian records to 200–250 ka at Chamu, showing alternating sand accumulation and calcrete formation. Regionally extensive episodes at ~90–100 ka and ~60 ka were reported from the Lower Luni basin and southern Thar (Kar et al., 2001; Andrews et al., 1998). Aeolian dynamism peaked during 17–11 ka BP, coinciding with monsoon re-establishment (Singhvi & Kar, 2004, Achyuthan et al.,2007a).

Calcretes provide further evidence of wetter phases. These secondary carbonate accumulations evolve from nodules to hardpan and laminar crusts, reflecting semi-arid climates with alternating wet and dry seasons (Courty et al., 1987; Dhir, 1995; Achyuthan, 2003). ESR dating at Amarpura Quarry yielded ages of ~797 ka BP, linking calcrete horizons with Acheulian artefact contexts (Kailath et al., 2000).

Archaeological records underscore the Thar Desert's role as a corridor for hominin migration during MIS 5–3. Acheulian artefacts at Singi-Talav and Amarpura Quarry (>0.8 Ma BP) demonstrate early human presence (Misra et al., 1982; Gaillard et al., 1986). Excavations at the 16 R dune revealed stratified artefacts dated 130–40 ka BP, including flakes, blades, and miniature hand axes (Singhvi et al., 2010; Blinkhorn, 2013). Jayal Ridge and Chhajoli yielded Lower Palaeolithic assemblages dominated by scrapers and hand axes (Achyuthan & Rajaguru, 1998). At Kataoti, OSL dating placed Middle Palaeolithic artefacts between 95–40 ka BP (Blinkhorn et al., 2015).

Together, these archives highlight alternating humid and arid phases, aeolian dynamism, calcrete formation, and human settlement. The eastern Thar Desert margin thus emerges as a critical zone for reconstructing paleoclimate variability, monsoon dynamics, and human migration corridors within global Quaternary frameworks.

Field Transect

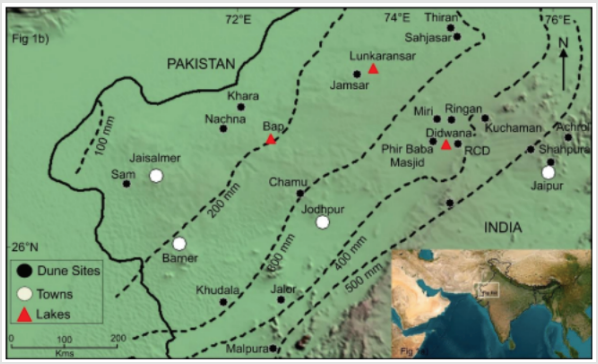


Fig.1. Field map with sites to visit.

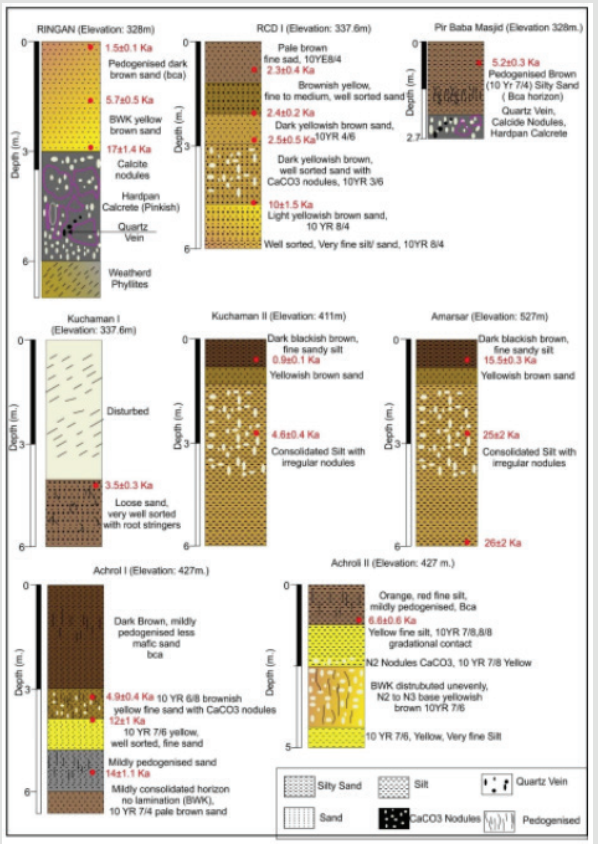


Fig. 2. Lithosections studied along the eastern margin of the Thar Desert.

Location(s) Description

Field trip and sites to visit a geological overview along the transects excusion stops

Day 1: 22. 01.2027, departure from jaipur via field stops:

8.00 AM: Assembly, Registration/ kit distribution and General Introduction and Orientation Talks by:

(i) Dr. Hema Achyuthan / Dr. S. K. Wadhawan on "GEOLOGY OF THAR DESERT MARGIN AND GEO-ARCHAEOLOGY" [as the Field Trip is Pret Congress, these talks can be organised even a day earlier or in the evening at a Jaipur Hotel (21.01.2027).

1. Venue: assembly point/ hall in Jaipur to be decided by INQUA Secretariat; 2. A Volvo bus and two Innova guide vehicles are to be arranged for proposed 40 delegates + Coordinators/ volunteers from New Delhi/ IGC Secretariat.

Day 1: 22.01.2027

9.00 AM to 7.30 PM Hrs: Along New Delhi – Jaipur National Highway [NH-8] in Rajasthan Tea/Coffee breaks at Midway Shiva Oasis.

Stop – 1 (10.30 Hrs – 11.45 Hrs) : 200 kms

On Shahpura – Triveni - Ajitgarh Tract- Near village Hathora [Location: 27° 25′ 06.48" :75° 51′ 08.52" 503m amsl]

Aravalli structural Hill ranges [600-737m amsl] trending NNE-SSW, comprise the Delhi Supergroup of Precambrian rocks - resistant varieties of Quartzite and thick aggraded sand sheets of fluvio-aeolian origin en route.

Obstacle sand dunes occur abutting against the high hills that show intense and deep dissection with a network of prograding gullies.

Jaipur Surface: Old flood plains, in-filled channels etc., forming undulating plain and low lying and flat tracts, in places occurring as erosional incised terraces fringing present day ephemeral streams. This sedimentation unit of silt-sand and clayey silt accretion phase represents the 6.6 ka to 3.1 ka humid/ sub-humid fluvio lacustrine domain along the Thar margin.

The overlying Post-Jaipur surface shows feebly oxidized aeolian sand with incipient pedocalcic pedogenesis. (up to 8m thick). Geomorphic expression is that of uneven sandy flats and moderate to weakly stable obstacle dunes and active river bank dunes, e.g. Sabi Nadi- ephemeral channel bank dunes NW of Shahpura; Terraces of present rivers. It represents less than 3 ka seasonal aeolian and semi-arid fluvial regime with frequent reworking of sediments by winds and water flow actions.

Shahpura stabilised aeolian deposits. [27°22′33.4"N: 75°49′13.8"E 427m]

Shahpura surface: represents a dominant aeolian activity now forming stable sandy flats and consolidated stable dunes; locally dissected. Fine grained sandy deposits are highly oxidized

(reddish-brown coloured), mostly compact aeolian sand and silt with deep pedalfer pedogenesis. Primary sedimentary structures preserved at places. (Unit up to 5m thick). These dune deposits are OSL dated to range from 19 to 11 ka BP.

Stop – 2 (12.00 Noon – 1.30 PM)

Ajitgarh area: Geomorphosites of granite hills [Landscape View from Bus]

Isolated granite denudational hills [526-631m amsl], isolated hills or monadknocks and exfoliated tors and core-stones and wind eroded and sculpted tafonis. Characteristic jointed/fractured and rounded weathered surfacesshow bare rocky outcrops without in-situ soils.

LUNCH BREAK at Hotel Highway King, Shahpura or Shiva Oasis on NH-8.

Lunch at Hotel Highway Kings, Antela, 8 km short of Shahpura on NH-8 Lunch 1.30 PM to 2.30 PM.

Stop – 3 (14.30 Hrs – 15.00 Hrs) : Amarsar area [27° 22′ 31.3″: 75° 49′ 19.3″ 527m amsl]

Aggraded fluvio-aeolian sand sheet at Amarsar area shows thick sand sheet deposits, intensely dissected terrain with near vertical cliffs of over 5 m height. Amarsar sequence exposes about 7m section having at least three sedimentary units indicating aeolian sand accretion and quiescence leading to surface stabilisation and kankar/ nodular calcrete formation. The uppermost 1m is fine grained aeolian sand showing reddish brown oxidation status of soil formation devoid of calcium carbonate accumulation. However, the concentration of calc nodules increased down depth and colour changes from yellow brown to greyish yellow brown. This unit is OSL dated to 16 to 11 ka.

The second underlying unit is between 2 and 6 m depth, shows a leached horizon in greyish white and pale-yellow silty sand and preserves several calcrete nodule rich and poor layers. This unit is dated and inferred to have been deposited between 59 and 34 k yrs. BP. The third and the oldest exposed sedimentation unit is light brown, medium to fine grained with fairly good sorting and enriched with diffused lime carbonates. It is dated to around 75 ka.



Fig. 3 Satellite photo of the Shahapura, Achrol surface.

Stop – 4 (15.30 Hrs – 15.45 Hrs) [27° 19′ 06.87″: 75° 51′ 59.94″ 516m amsl]

On way from Amarsar to Bishangarh via Rarawas[Badland topography.

Bad-land topography created over stable dunes and aggraded sand sheet under intense dissection - gullied landscape. Sub-parallel drainage courses appear to have been induced by neotectonic activities prevailing in the region. Dry channel of Madhbini Nadi seasonally flows towards Manoharpura in an easterly and south-easterly alignment.

Stop – 5 (16.15 Hrs – 17.00 Hrs) [27° 08′ 24.76″: 75° 56′ 53.78″ 428m amsl], Achrol Dunes and Loess deposits [off-NH-8]

5-A. Achrol Surface: represents multiple episodes of aeolian accretion interrupted by pedogenic landscape stability indicated by soil forming post-depositional modifications. It is locally exhumed older stabilised aeolian cover; highly dissected. Achrol village is nestled at the northern slopes of an NNE-SSW trending structural hill of the Delhi Quartzites that attain peaks at 629m to 635m amsl. The western/ north-western slopes of these hills west of Achrol are covered by aeolian sand deposits as obstacle dunes and sand sheet ramps. These show a network of north-western oriented ravines that are nearly vertical, ranging from 10 m to 20 m relief. The general ground elevation along the north-easterly coursing dry Gumti ka Nala is 440m amsl., that is presently flattened and cultivated for cash crops. Un oxidised grey to feebly oxidized grayish yellow aeolian sand and silt with deep pedocalcic pedogenesis and calcareous box-work hardpan formation (Unit up to 7m thick). It is OSL dated to more than 19 ka BP.



Fig. 4. Dissected dune landscape/ aggraded sand sheets with loess deposits at Achrol.

5-B. Study of dissected dune landscape/ aggraded sand sheets with loess deposits at Achrol. The area is occupied with NE-SW trending ridges, in the west of Achrol Amar reserve forest ridges/peaks at 600 m, 629 m, 653 m and flat peaks at 635 m near Achrol fort. On the western Hill slopes, the sandy accumulations forming obstacle dunes, sand sheet against the hills. Highly dissected formations of ravines, sub parallel drainage towards NW which ultimately meets ephemeral channel called Gumati Ka-Nala, which is flowing from SW to NE and is forming a valley flat (aggraded sand sheet) i.e., put to cultivation based on groundwater irrigation. Three aeolian episodes are recognised with their distinctive

post-depositional modifications, pedocalcic pedogenesis and calcrete formation events [Field Log at Achrol-I]. Loess deposits are exposed as pale to yellow brown Consolidated and homogenised fine silt as Field Log at Achrol-II.

Stop – 6 [27° 08′ 24.76″: 75° 56′ 53.78″ 428m amsl]

Distant view from Bus of the Amer Fort on Aravalli Hills and Jal Mahal Lake, Hawa Mahal, Jaipur. Visit to UNESCO Heritage Site Jantar Mantar, City Palace area, Jaipur.

Stay at the Hotel Ibis / Fern Residency, Jaipur Dinner at 8.00 PM onwards. Night halt at Hotel Jaipur.

Day 2: 23.01.2027

8.00 Hrs: Departure from Jaipur to Kuchaman City, via Bichchun, Sambhar field sites enroute.

Stop – 7 (10.00 Hrs – 10.30 Hrs) : Sambhar Salt Lake area [Ramsar Wetlands]: 75°02′28.0″ N: 26°54′58.2″ E

The Sambhar Lake depression consists mainly of sedimentary deposits in the form of horizontally bedded silt and clay. Such silty-clay deposition varies in thickness over the lake bed ranging from 22m deep in the center (near Mata Pahar hill, to 3–5m at the shores. Mostly the silt formation is argillaceous with considerable amount of mica; however, at some places hard and calcareous material is also reported. Salt resources of the lake are the impregnated brines. Recent sediment core study from the Sambhar Lake by Sinha and Ramanathan, 2004 revealed clastic and non-clastic evaporate minerals representing fluctuation in paleo-environmental conditions during its Quaternary evolutionary history. The clastic fraction of lake sediment contained quartz, alkali feldspar, mica, chlorite, amphibole, and weathering products such as kaolinite and goethite. The non-clastic evaporite fraction was dominated by calcite and halite. At deeper depths of sediment profile, thin layer of gypsum was found whereas shallower depth represented an assemblage of thenardite, kisserite, and polybasite. Such an observation was interpreted with varying geo-chemical conditions that favored a change in brine evolutionary path. Their studies have indicated that the geo-chemical evolution of Sambhar Lake has spanned for a period more than 30 ka.



Fig. 5. Google Earth Image of Sambhar Salt Lake along margin of Thar Desert.



Fig. 6a : Location map of Sambhar Lake.

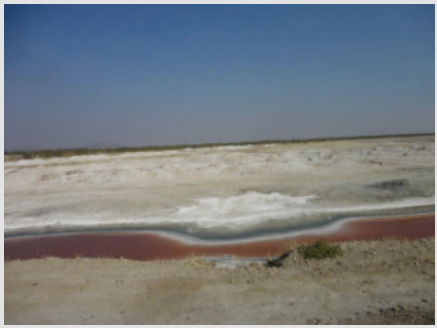


Fig. 6b : Sambhar Salt Lake and salt pans commercially extracting common salt

Tea / coffee break at Korsina village pond amidstthe Peepal/ Banyan trees near a Temple in a rural setting 7B Geo-archaeology: Shakumbari Mata Temple Area, Human occupation sites, Sambhar Salt Lake. 10.30-11.00 Hrs.

Several Paleolithic tools are found on the bordering dunes of the Sambhar Salt Lake. An ephemeral stream carrying coarse clastic of quartzite have provided for the durable and suitable raw material for humans to work on to produce hand tools ascribed to Middle/ Upper Palaeo-lithic tools and raw material. Occurrences of such human settlements also confirm availability of fresh water in the Sambhar Lake during that period about 60 ka ago.

Stop – 8 (12.00 Hrs – 13.00 Hrs) : KUCHAMAN LAKE [LACUSTRINE SEQUENCES, [27°08'50.82" N 74°51'23.58" E) ¬ 380 m amsl

Kuchaman Lake is a saline lake located near Kuchaman city, Nagaur district, Rajasthan with an area of about 8.5 sq km. The area shows an undulating topography with linear ridges, trending in NNE-SSW direction. The highest elevation is about 682m above sea level while the lake is delineated by a 380m contour line. The basin has a centripetal drainage with Palara River being the main incoming drainage towards the SW part of the lake. Few E-W trending drainages meet the playa near Kharia.

The rocks exposed in the area belong to the Delhi Supergroup represented by the Alwar and Ajabgarh Groups. The Alwar Group comprises of arkose, grit and conglomerate of Rajgarh Formation forming hill ranges south of Gagor.

The conglomerate occurs as lenses and bands inter-bedded with arkose and grit. The Ajabgarh Group is represented by ferruginous and feldspathic quartzite of Ajmer Formation. These are exposed in the hill ranges southwest of Kuchaman and Palara. The rocks of Delhi Supergroup show a general NNE-SSW trend with both easterly and westerly steep dips.

The core of the lake sediment reveals the presence of finely laminated dark gray clayey sand with no kankar at the top 60 cm followed subsequently below by dark brown silty clay and black silty clay at about 2.20m. This layer is about 60cm thick and contains lots of halite and gypsum crystals. This is followed below by a thick grey clay horizon containing minor halite.

The clay is soft, sticky and becomes lighter in colour up to a depth of 5.40m below which greenish coloured silt is seen with lots of kankar (also indicated from the grain size analysis showing a sharp change in the grain size). This layer is followed by greenish silty clay up to a depth of 8.30m (Jaiswal, GSI 2013). The considerable amount of kaolinite content supports humid climate in the recent past.

1. The lakes show significant variation in the mineralogy and inorganic composition with depth. This is a manifestation of variation in weathering condition, inflow and aeolian activity.

2. The geochemical proxies and mineralogical data of Kuchaman Lake enable to separate the profiles into four different phases of deposition.

The lower zone IV represents a transition from sub-arid to sub-humid phase while Zone III represents an arid phase.

Zone II again represents a transition from sub-arid to sub-humid phase while upper Zone I show higher concentration of Al2O3, K2O, Fe2O3, Zn, Rb and Ba corresponding to higher degree of chemical weathering of a humid phase in the Late Holocene history of playa sedimentation.



Fig. 7a : Panoramic view of the Kuchaman Salt Lake.

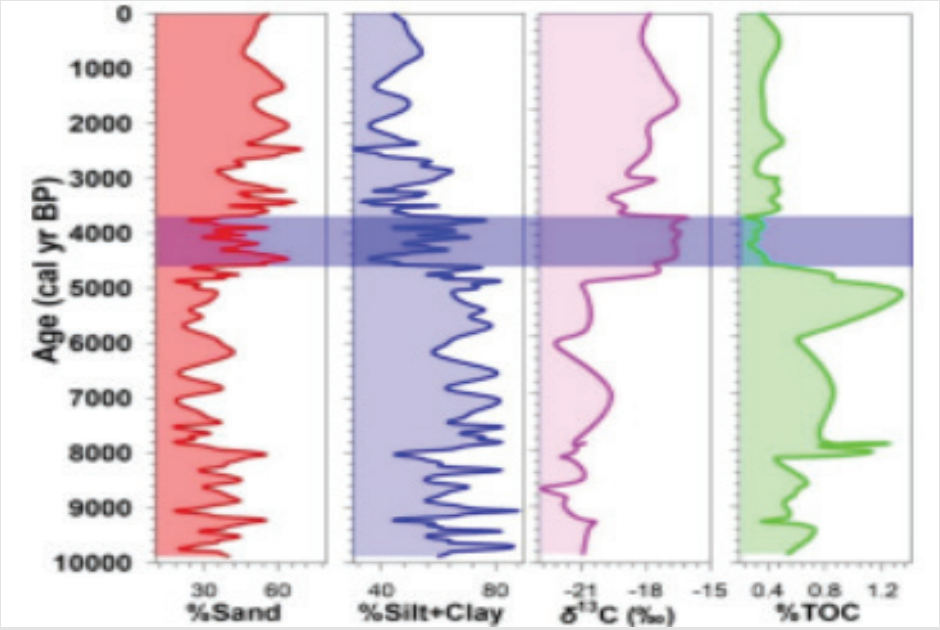


Fig. 7b : Stratigraphic variations in sediment texture, $\delta^{13}C$ (‰), and TOC (%) from the Kuchaman Lake core. The lower section (360–172 cm; ~10,000–4700 cal yr BP) is dominated by silty clay sediments, suggesting relatively humid conditions, enhanced monsoon precipitation, sustained lacustrine deposition, and a deeper lake with expanded marginal environments. In contrast, the upper interval (172– 100 cm; ~4700–3700 cal yr BP) exhibits an increase in sandy sediments, indicative of declining effective moisture, lake-level reduction, intensified aeolian influx, and stronger wind activity under increasingly arid conditions. Corresponding variations in $\delta^{13}C$ and TOC values reflect changes in organic matter sources, lake productivity, and hydrological balance associated with Holocene monsoon variability.

Kuchaman City Hotel check-in welcome drinks and refreshments, 12.30 – 12.45Hrs. 13.45-14.30 Hrs Lunch break at Kuchaman Hotel: Shivam Palace.

Stop – 9 (15.00 Hrs -16.00 Hrs) : Chotiyali - Amballi area–Lateritised rock with fracture filled Red ferricrete. [74°17'52.7" N:27°10'25.2" E, ~370 m amsl]

Laterite / iron oxide weathered clays / ferricrete Quarry site for red ochre [Geru] excavated/dislodged rounded boulders and gravelly pebbles are strewn on the slopes. Evidence of the ferricritisation of the basal boulder gravel was observed in the quarries at Ambali. A typical section of the ferricrete/ Laterite reveals a 3.50 m thick, indurated, iron oxide rich red- brown ochre with box-work weathering features and fine foliations. The ferricrete rests unconformably over the typical pink medium to coarse grained massive Nagaur Sandstones and shales belonging to the youngest stratigraphic group of rocks of the Marwar Supergroup of the Cambrian age [about 600 to 545 Ma]. The overlying deposit is the calcretised boulder-cobble gravel bed. Most of the boulders and cobbles comprise quartzite, vein quartz and chert, though gneisses and sandstones are present in minor amounts.

This gravel bed can be classified as petromictic conglomerate. There are sharp disconformities between the underlying ferricrete and the overlying calcretised boulder bed. This gravel bed is poorly sorted, ungraded, unimbricated with lenticular patches of silty sand and clayey silt. Carbonate coatings on the bolder, cobble and gravel are common. Boulder/cobble and gravel ridge with thermal weathering/ in situ shattering of boulders-gravels on ridge slopes, etc. are observed.



Fig.8 : Ferricrete profile at Ambali.

Geo-archaeology: This area shows several evidence of Human occupational sites belonging to Middle/ Upper Palaeolithic tools and raw material that is readily available in the vicinity. Geoarchaeologically, the surface of the gravel bed is littered with Acheulian and Middle Palaeolithic stone tools. These stone tools also occur in the re-deposited gravels in the nala cuttings. The gravel bed is considerably modified. The uncharacteristic presence of the gravel bed at a height, predominance of re-deposited gravels, palaeolithic tools in the nala cuttings at Kataoti, Jayal, Ambali indicates influence of neotectonic activities and post. depositional erosion. Based on geomorphology, field characters and archaeology, the gravel bed [Jayal Conglomerate] is dated to Late Neogene/basal Quaternary period. 9-B. Panoramic view of dryland erosional landscape from Kataoti-Ambali Gravel ridge. A series of rounded ridges with relief varying from 20 to 38 m [340 m to 378m amsl] are seen aligned along NE-SW directoion along Kataoti in the NE to Chhajoli in the south and Jayal in the SW. A small playa or Salt Lake is located near Khatu Khurd about 15 km from Ambali.

Geomorphology: apart from a few isolated hills and knolls of the Aravallis in the central and south-eastern part of Nagaur District, the area is marked by low sand dunes and defunct alluvial flats. The hill ranges consist of quartzites, sandstones, limestone, phyllites and rhyolites. The Aravalli metamorphics, exposed in the west central part of the area, strike NE-SW and N-S direction. Sandstone and limestone occur as flat-topped hills in the south eastern part of the district as at Khatu (27°7′ N: 74°31′ E) and exhibit butte and mesa topography. In general, all the rocky areas that are exposed appear to be pediplanes or remnants of ancient erosional landscape. Except in elevated areas, the erosional surfaces have a thick blanket of alluvium or aeolian sand. The most conspicuous relief feature of the area is the gravel ridge locally known as 'Magras'. It rises nearly 50-70 mts above the plain of Jayal and runs in a north-east to south- west direction about 14 km in length from Kataoti to Chhajoli. A part of it extends for about 10 km in a north to south direction, from Kataoti towards Ambali and Khatu Kalan. The width along lateral exposed extensions of this ridge varies between 150 mts and 300 m and are seen at Genana 23 km northwest of Didwana, near Rol east of Jayal and at Khinyala north of Jayal. The ridges have rounded summits, undulations and exhibit a rolling topography with slope of 3° to 8°. From a distance these ridges give the appearance of a continuous hill. Gravel spreads occurring near Jayal, Kataoti, Khinyala and Rol represent remnants of aggradation along prior braided channels.

Examinations of the lithological components reveals that the boulders and the cobbles have been derived from the Delhi Supergroup Quartzite (Ajabgarh Group) of the Aravalli Hills and transported by streams originating in the western slopes of the Aravalli Hill range. Well rounding of boulders, cobbles and pebbles, occurrence of the lenticular patches of sand, silt and clay with calcareous cement indicate that the gravel bed is product of a braided bed load fluvial system characteristic of a semi-arid landscape.



Fig. 9 : Jayal gravel ridge.

Stop - 10 (16.10 Hrs – 16.30 Hrs, Katoati area) : 74°18'24.9": 27°11'50.4" 335 m amsl

The site is located at the foot slope of 'bouldery gravel ridge' of Chhajoli near village Kataoti. It yielded Ostrich eggshells along with large and highly cortical cores and flakes. On the basis of presence of prepared point cores and retouched pointed artefacts the Kataoti assemblage has been classified as Middle Palaeolithic phase. The stratigraphic sequence at Kataoti site is well- supported by absolute chronology and it is within the time bracket of 95 ka to 40 ka by OSL dating method (Blinkhorn et al. 2015). Dissected consolidated aeolian deposits and gullied badlands topography over aeolian deposits [step like trench to be scrapped/ cleaned]. Ostrich eggs site and Middle Palaeolithic tools. Well rounding of boulders, cobbles and pebbles, occurrence of the lenticular patches of sand, silt and clay with calcareous cement indicate that the gravel bed is product of a braided bed load fluvial system characteristic of a semi-arid landscape.

Tea/Coffee break in the field and cultural programme in rural setting 17.00-1800 Hrs. [Abdul Gaffar's Qadari Farm site] [Rajasthani Folk songs and traditional instrumental performances]

Return to Kuchaman City Hotel by 20:00Hrs. Dinner and Night Halt

Day 3 - 24.01.2027

Departure Kuchaman City Hotel by 08.00 Hrs and reach Didwana.

Stop - 11 Singi Talav - Railway Cutting Dune deposits (RCD site), [74°33'24.4": 27°22'58.5" 347m], 09.00 Hrs – 09.30 Hrs South of Didwana Railway Track-cut exposed dune section with Palaeolithic tools. BWK, BC and BT Horizon Age: 22Ka to 24Ka.

A stabilized dune section is cut through for railways, south of Singi Talav on the Didwana-Delhi/ Jodhpur railway line was studied to correlate the 16 R dune section. CaCO3 nodules collected from this section at the depth of 0.46 to 0.66 m and 0.98 to 1.00 m were dated by conventional 14C method and the ages were 19,940+-930/530 and 15,340 +450 and -430 (PRL no. 912 and 913).

Another 14C date, but at a different sampled location (same site) at the depth of 9 to 9.2 m gave a date of 24,010+- 1200/1100 ys BP) (PRL No. 651). The lithological section at RCD site is well exposed with discernible aeolian units as described below.



Fig.10. a : Lithosection exposed of a dune, cut along the railway line at Didwana. A close look at the lower end of the lithosection reveals well rounded insitu formed calcrete nodules (2cm to 3cm across) in diameter.



Fig.10 b : Railway cutting Dune a Close up: An excavated lithosection exhibits rhizoliths and calcium carbonate nodules (N2-N3 types of nodules) representing a BK horizon.

Stop - 11 (09.45 Hrs – 10.00 Hrs) [74°32'03.9": 27°22'48.7" 347m], Didwana to Pir Baba Masjid section [Indola-Ki-Dhani]

Indola ki Dhani - Northern downslope of Hill top Mosque/ Pir Baba Ki Mazar

Hard pan calcrete formed over the pediment slopes of carbonaceous and mica schists / micaceous quartzite and reported with Upper Palaeolithic Tools. Palaeogene / Neogene-Basal Quaternary Jayal Formation: Lithic Calcrete and residual gravels occur cemented over the pediments formed at foot slopes of a ridge of the Delhi Supergroup quartzite and carbonaceous phyllites in the vicinity.



Fig. 11a.



Fig.11b

Stop - 12 (10.15 Hrs – 10.30 Hrs) Didwana – Singi Talav area [74°33'24.4": 27°22'58.5" 347m]

Singi Talav: saline-lake. Singi Talav: To the southwest of Didwana town and separated from the Didwana Salt Lake by sand dunes and sand sheets is a depression known as Singi Talav. It is 8.3 km long and 1 km wide and is oriented almost east-west. Calcareous marl is quarried from this depression for its lime and road construction. This quarry was excavated from 1981 to 1985 for establishing primary nature of Lower Palaeolithic artefacts and for understanding Quaternary environment during human occupation.

The General stratigraphy of quarry to the depth of 1.30 m is as follows:

Stop – 13 (10.30 Hrs – 11.00 Hrs) 74°32'18.8": 27°22'21.8", 348m amsl

Didwana R-16 Dune cut-section on newly excavated roadside. (on Didwana to Nagaur Road-at 1st milestone)

The 16R dune section (19 mts deep) has been divided into three lithological units based on color, texture, and the occurrence of calc bands at different depths. In lithological unit I, the top 80cm consists of well sorted, loose structureless homogenous fine sand, which is yellowish brown in colour (10YR6/4). This sand is non-calcareous and appears to grade to a very pale brown 10YR7/3, structureless loose fine sand, very well sorted and containing a few small powdery calcrete nodules (1 to 2cm in diameter and going to a depth of 4.90mts). The weakly pedogenised dune sand is represented not only in the study area, but over a major portion of the eastern desert fringes.

The sands of litho-unit I are clearly separated from those of Litho-unit II by a 10cm thick layer of coarse sand comprising angular to subrounded schists, phyllite and slate fragments, aswell asrounded quartz and quartzite grains. This layer is a colluvial wash. Underlying 3.05mts of Litho-unit II is characterised by alterations of densely coalesced calcitic nodules within light gray (10YR7/2), loose, well sorted, calcareous fine sand. These form calc bands of 3 to 5cm thickness. The sediments within the bands reveal a light yellowish brown (10 YR 6/4)to pale brown (10 YR 7/3), loose,massive, moderately sorted loamy sand.

The underlying sequence of 10.95 m of litho-unit III (Pl.II.15) is brown to pale red in colour (7.5 YR 7/4) with calcite nodules (7 to 8 cm across) forming bands and red sands interspersed within them. In addition, litho-unit III has seven calc bands, though the other characteristics of this unit are the same as those of litho-unit II. The calc band at 18.60 m is pinkish, strongly indurated and is classified as petrocalcic horizon. The difference in the colour between unit II and unit III is due to the absence of diffused carbonates in litho unit III.

Field observations reveal that the top 80cm of litho-unit I is a cambric horizon and that the 3.05 mts of litho-unit II is a complex BCa horizon of a soil profile. Litho-unit III represents a pedo-complex calciorthid of an aridisol. The occurrence of colluvial wash in the form of locally derived schist and slate fragments(just above the calc bands), fine lamination within the sands, and the presence of calcrete clasts in Unit II and III indicate episodic and seasonal local fluvial contribution within the dominant dune sands (Achyuthan et al 2007b).

Aeolian deposits with reported Middle Palaeolithic tools of the cultural horizon were luminescence dated between 40 -80 Ka. A step trench to a depth of 19.00m was excavated at one of the highest (33m above the lake level) obstacle topographical point - a linear dune marked as 16R on the eastern side of the Bangur Canal in the area. This site yielded Mesolithic, Upper, Middle and Lower Palaeolithic tools in stratified context embedded within the composite dune section. The horizon from which the human artefacts assemblage was recovered, at 5.4 to 6.1 m depth, overlie an erosional surface in sediment sequence and the deposits were dated as 80 ka, indicating that these artefacts post-date this level. Another major calcrete horizon at 5.65 below which this assemblage occurs is dated as 40 ka. Recent studies by Achyuthan et al (2012) and Blinkhorn (2013) on 16R dune site and elsewhere along eastern Thar Desert margin have confirmed repeated hominine occupations occurred in association with periods of enhanced humidity during late Pleistocene and appear to match well with results from similar landscapes in Southwest Asia.



Fig.12a

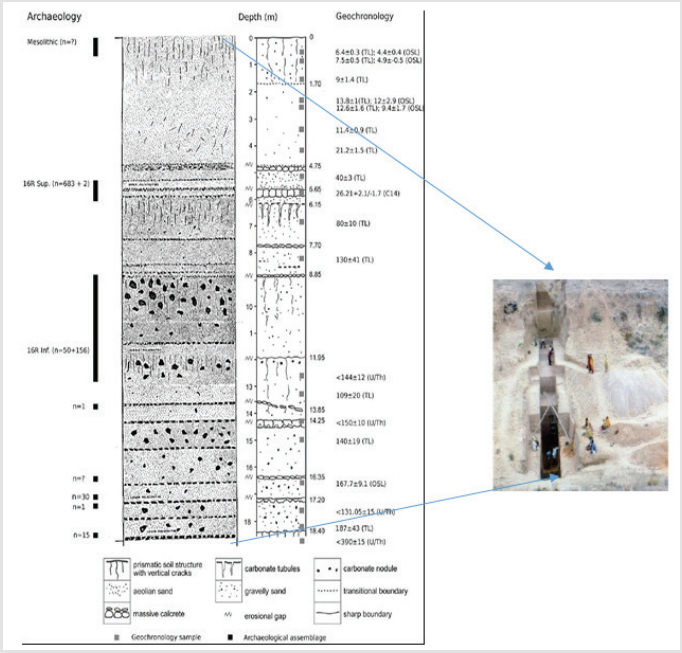


Fig. 12b : Lithosection of the 16R dune section, Didwana (Achyuthan et al.,2007a).

Stop – 14 (11.30 Hrs – 12.00 Hrs) 74°34'11.9": 27°21'37.1", 329 m amsl Didwana Lake area (Padhaya Mata Mandir)

Didwana Salt Lake – salt pans and processing, The lacustrine/ playa member of the Didwana Formation is represented in the salt lakes of Sambhar, Kuchaman, Didwana, Nawa, etc., along the Thar Desert margin. These lakes exhibit three distinct lithological units. The topmost unit varies in thickness from 0.80-1.10 m and is represented by grayish to brownish gray sandy silt or silty sand. These silts are faintly laminated, partially pedoturbated and have a very thin salt encrustation on the surface. These are underlain by well laminated, organic rich dark brown or blackish clayey silts (locally known as kajalia), varying in thickness from 1 to 2m. These silts are almost free of evaporation and have yielded a wealth of pollen which has suggested relatively wetter climatic conditions between 3,500 and 10,000 B.P. (Singh et.al, 1974). These organic rich silts grade into greyish and, at times, mottled sandy or clayey silts which are well laminated and rich in evaporating salts. Authigenic, well developed gypsum crystals are found to occur in partially oxidised or mottled clayey silts in the Nagauri well of Didwana Salt Lake. A massive crystalline halite layer having a thickness of 1.5 m was found to be interlayered with grayish clayey silts in wells dug in the vicinity (Khandelwal 1975:13-14). This halite layer seems to occur only in the deepest part of the Didwana Salt Lake. The Didwana Lake sediments show U concentration as high as 83.49ppm. The carbon phyllite rocks exposed near Indola ka Dhani, west of Didwana Lake, show 10.80ppm U concentration. No significant REE concentration is seen in the lake sediments.

Stop -15 : Jankipura Litho section (Deepak Jha et al., accepted in JQSR 2024).

A large number of multi-proxy time-series datasets have been derived from a 2.25-meter geological trench known as 'Jankipura,' located near Didwana town towards Jayal and in close. proximity to the Didwana Lake. Jankipura finds itself encircled by the IVC to its west and north, while the Jodhpura-Ganeshwar culture and Ahar-Banas culture mark its eastern boundary within the Thar Desert. The chronology of the Jankipura trench is constructed based on four 14C AMS dates ranging from 183 to 4656 cal yr. BP, aligning with the Mature phase of IVC (also termed the Mature Harappan phase) – a period characterized by settlement disappearances and population migration. At this site the study involved the assessment of macro-charcoal concentrations (>125 µm, differentiating grass from wood) to reconstruct the climate-vegetation-fire relationships during and after a major period of disruption of the IVC.

The findings highlight an arid phase between 4656 and 2932 cal yr. BP, characterized by a mixed C3-C4 vegetational landscape with limited fire events. A significant fire event took place during the period from 2932 to 1960 cal yr. BP, indicating abundant C4 vegetation. Between 1960 and 183 cal yr. BP, three minor fire events occurred amid fluctuating rainfall conditions and a landscape dominated by mixed C3-C4 vegetation. The discovered macro-charcoal predominantly comprised woody fragments over grass fragments. Notably, an increasing trend in isotope values, reaching its peak in macro-charcoal, is observed between 183 cal yr. BP to the present, signifying increased aridity compared to the mature phase of the IVC. The observed weak relationship between vegetation and fire suggests that the reconstructed fire events in this study largely stem from anthropogenic activities. This sheds light on the significance of vegetation, particularly the use of wood, during the Mature phase of the IVC and offers insights into the behaviours of IVC populations."

Lunch At Didwana City Hotel [13.00 –14.00 Hrs]

Stop – 16 [15.00Hrs – 17.00 Hrs, Kuchaman Fort atop a hill, 545m amsl

Heritage walks through Kuchaman City traditional bazaar and visit to an isolated denuded hilltop Kuchaman Fort [545m high] that is over 304 years old Thikana of the Rathore Rajputs and Geoheritage, Traditional Water Harvesting and Conservation Systems at the Hill top. The Fort is replete with rare examples of exquisite art paintings in traditional designs and parts have – now been renovated and converted into a Heritage Hotel and Museum. View of desert landscape and the temple city dwellings [Meera Bai spiritual lineage] around the isolated hill palace. Sun set view from the Kuchaman Hill top.

Perched atop a 545m high quartzite cliff, the Kuchaman Fort isthe most important attraction in historic Kuchaman City. It was built by a Gurjara- Pratihara king. The facades command a spectacular scenic view of the city and surroundings below. The fort displays a rich collection of original inlay work in semi-precious stones, glass, and gold paint. The Sheesh Mahal (Glass palace) is a sight for marvel. A colourful bazaar, located en route the fort, is a great place to shop for traditional handicrafts and fabrics.



Fig.13 : Kuchaman Fort and the painted decors inside of Diwan-e Aam.

Dinner/ High Tea and cultural programme at hill Fort premises.

Return to Kuchaman City Hotel for Night Halt.

Day 4 - 25.01.2027

08.00 Hrs Visit to Mitri hard pan calcrete section.



Fig. 14 a



Fig.14 b



Fig. 14 c

Fig. 14 a, b, c. Hardpan calcrete formed by weathering of the Precambrian hornblende schists bedrock. 30 a and b. The hardpan calcrete rests with a sharp contact with the overlying pedogenised dune sediments.30c. Unweathered, fractured quartz vein cemented by calcium carbonate forming within the hardpan calcrete.

11.30 AM Visit to Talchhapar Salt Lake and Black buck Sanctuary Talchhapar Salt Lake.

The geomorphic depression formed under tectonic control in the eastern Thar Desert. Radiocarbon dates from lacustrine deposits indicate humid phases around 9,000– 7,000 yrs BP, when strengthened monsoon rainfall expanded the lake. Subsequent arid intervals (~5,000–4,000 yrs BP) are marked by evaporite crusts and saline facies, reflecting monsoon weakening. During the Medieval Warm Period (~1,000– 800 yrs BP), isotopic enrichment and reduced carbonate deposition point to aridity. The Little Ice Age (~600–200 yrs BP) shows enhanced effective moisture, with carbonate mineralogy and diatom assemblages indicating strengthened winter precipitation.

Parihara Salt Lake

Located near Talchhapar, also a tectonically controlled saline basin. Radiocarbon ages from carbonate-rich horizons suggest humid conditions around 8,000–6,500 yrs BP, synchronous with stronger summer monsoon. A pronounced arid phase (~4,500– 3,500 yrs BP) corresponds to regional desertification across the Thar Desert. Medieval deposits (~1,000 yrs BP) show shallow water levels and increased salinity, consistent with monsoon weakening. The Little Ice Age (~500–200 yrs BP) records higher lake levels and isotopic evidence of cooler, wetter winters.



Fig. 15a : Talchhapar Salt Lake.



Fig.15 b : Talchhapar Black Buck Sanctuary.

Paleoclimate Reconstruction

Talchhapar and Parihara Salt Lakes preserve Holocene monsoon variability through alternating lacustrine and evaporitic facies. Radiocarbon ages place humid phases between 9,000–7,000 yrs BP and 8,000–6,500 yrs BP, reflecting strengthened monsoon rainfall. Arid intervals around 5,000–4,000 yrs BP and 4,500–3,500 yrs BP mark regional desertification. Medieval Warm Period deposits show isotopic enrichment and salinity increase, while the Little Ice Age records enhanced effective moisture and cooler winters. Together, these archives situate Rajasthan's salt lakes within the broader South Asian paleo monsoon framework.

Day 5 - 26.01.2027

09.00 Hrs. Departure and Check out from Kuchaman City Hotel with luggage.

Stop – 19 (08.15 Hrs – 08.30 Hrs) 74°50'03.82": 27°07'47.9" 411m amsl Kuchaman City area - Obstacle dunes.

Study of Obstacle dunes, stabilised and recently active aeolian deposits against structural Aravalli hills, southwest of Kuchaman City [500 m west of Hotel Shivam Palace on the State Highway bye-pass].

The area is surrounded by NNE-SSW Aravalli hills predominantly consist of quartzites. The obstacle dunes forms in the shadow zone of these hills, i.e. trending NNE-SSW direction mostly, however certain dune in E-W direction also recorded near these Aravalli hills supports the view of bi-directional wind directions prevailing in the area. At this site, at least two generations of dunes are identified. The topmost horizon of yellowish-brown silty sand is relatively compact and consolidated up to 1.4m depth followed by the unconsolidated yellowish-brown silty sand up with vertical to sub vertical rhizo-concretions/ root casts stringers to the depth of 7.0 m. The contact of the horizon is gradational.



Fig.16 : Kuchaman obstructed dunes.

Arrival at Jaipur: Dinner at Hotel and Stay at Jaipur 26.01.2027

Day 6 leave in the morning to Jaipur for Lucknow 27. 01.2027

Geoheritage, UNESCO heritage, archaeological sites in the vicinity, cuisines and culture

Jaipur, Kuchaman, Didwana, and Jayal together form a rich cultural–scientific corridor: Jaipur is a UNESCO World Heritage City with iconic forts and observatories, Didwana preserves prehistoric Acheulian tools and a saline playa lake of geoheritage value, Kuchaman boasts its historic fort and vibrant Marwari traditions, while Jayal lies close to the Didwana palaeolithic belt. These sites combine geoheritage, archaeology, and living culture.

Geoheritage Highlights

• Jaipur Geopark: Proposed geopark covering 33 sq. km, showcasing Delhi Supergroup rocks, baoris (stepwells), and heritage stone architecture.

• Didwana Lake: Hypersaline playa with 20 m thick sediments of gypsum, halite, and calcite; preserves Pleistocene climate records and supports salt production.

• Singi Talav: Acheulian archaeological site dated to ~800,000 years, yielding hand axes and cleavers.

• Aravalli Range near Jaipur: One of the world's oldest fold mountain systems, forming the backdrop of Jaipur's geopark and cultural landscape.

UNESCO Heritage Sites

• Amer Fort (Jaipur): Part of the Hill Forts of Rajasthan, inscribed in 2013.

• Jantar Mantar: World's largest stone astronomical observatory, UNESCO site since 2010.

• City of Jaipur: Recognized in 2019 as a planned heritage city.

• Other Rajasthan UNESCO sites (Chittorgarh, Kumbhalgarh, Ranthambore, Gagron, Jaisalmer, Keoladeo National Park) contextualize Jaipur's inclusion.

Archaeological Sites

• Didwana Acheulian sites: Excavations at Singi Talav and nearby dunes yielded >300 Acheulian bifaces, dated 400,000–700,000 years.

• Jayal sites: Linked with Didwana palaeolithic belt, preserving Middle Palaeolithic records.

• Bairath (near Jaipur): Ashokan edicts and Buddhist heritage, unique in Rajasthan.

• Ganeshwar (Sikar district, near Kuchaman): Copper artefacts dated 2800–2200 BCE, linked to Harappan trade.

Culture and Traditions

• Jaipur: Known as the Pink City, rich in Rajput courtly traditions, jewellery, textiles, and festivals like Teej and Gangaur.

• Kuchaman: Historic Kuchaman Fort, colourful attire (lehenga–choli, safas), folk music, and desert festivals with camels and puppetry.

• Didwana–Kuchaman district: Famous for salt production, marble from Makrana, and fairs like Veer Tejaji cattle mela.

• Jayal: Part of Nagaur district, sharing Marwari traditions, fairs, and pastoral culture.

Synthesis

• Geoheritage: Didwana Lake and Singi Talav are globally significant for Quaternary geology and Acheulian archaeology.

• UNESCO Heritage: Jaipur anchors the region with Amer Fort, Jantar Mantar, and its planned city status.

• Archaeology: Didwana–Jayal belt preserves India's earliest stone tools; Bairath adds Mauryan Buddhist heritage.

• Culture: Kuchaman and Didwana reflect Marwari traditions, salt and marble industries, and vibrant fairs.

Local Conveniences

Bazars

Local Conveniences Table

City	Hospitals	Bazars	Stolen Passport Help	Helplines
Jaipur	Manipal Hospital, Mittal Hospital	Johari, Bapu, Tripolia, Nehru, Chandpol	FIR at nearest police station Passport Seva Kendra Jaipur	Police 100, Fire 101, Ambulance 108, Emergency 112, Control Room 0141-2572067
Didwana	Laganshah Memorial Hospital (Joosri Road)	Local town markets	FIR at Didwana Police Station Passport Seva Kendra Jaipur	District helpline 18002122300

Jayal	Covered under Nagaur district (nearest: Kuchaman/Didwana)	Local Nagaur Markets	FIR at Jayal Police Station Passport Seva Kendra Jaipur	Nagaur district police helpline
Kuchaman	Asha Dental, Manawata Panchkarma, Krishna Hospital, Marwar Zanana Hospital	Kuchaman Town Bazaar	FIR at Kuchaman Police Station Passport Seva Kendra Jaipur	Help Line 18001219400, 8696000263

Passport Loss — Key Steps

1. File FIR at nearest police station.
2. Apply online at Passport Seva Portal.
3. Book appointment at Passport Seva Kendra Jaipur.
4. Carry FIR copy, Aadhaar, address proof, DOB proof, photos, and old passport details.

Bazaar Tips

- Bargain at least 30–40% below asking price.
- For gemstones in Johari Bazaar, insist on certification.
- Bapu Bazaar is best for textiles and handicrafts.

Emergency Checklist Medical Help

- Save nearest hospital numbers (Jaipur: Manipal, Mittal; Didwana: Laganshah Memorial; Kuchaman: Krishna, Marwar Zanana).
- Carry basic first-aid kit (bandages, antiseptic, painkillers, ORS).
- Note ambulance helpline: 108.

Passport & Documents

- Keep photocopies/scans of passport, visa, Aadhaar, and tickets.
- In case of loss:

(i) File FIR at nearest police station.
(ii) Apply online at Passport Seva Portal.
(iii) Visit Passport Seva Kendra Jaipur with FIR copy + ID proofs.

Helplines

- Police: 100
- Fire: 101
- Ambulance: 108
- Emergency: 112
- Jaipur Control Room: 0141-2572067
- Didwana: 18002122300
- Kuchaman: 18001219400, 8696000263

Bazaars & Safety

- Bargain smartly (start 30–40% below).
- Johari Bazaar: jewellery & gemstones (ask for certification).
- Bapu Bazaar: textiles & handicrafts.
- Keep belongings secure; beware of pickpockets in crowded markets.

Transport & Travel

- Use prepaid taxis or trusted apps.
- For intercity travel, book via RSRTC buses or Indian Railways.
- Keep local contacts handy for Didwana, Jayal, Kuchaman.

General Safety

- Avoid isolated areas after dark.
- Stay hydrated — Rajasthan heat is intense.
- Inform someone of your travel plans daily.

Keep cash + digital payment options.

Conclusions

The late Quaternary palaeoenvironments of the Thar Desert margin provide a unique archive of climatic variability, geomorphic evolution, and human dispersal across southern Asia. Situated at the eastern edge of the Saharo–Arabian desert belt, the Thar Desert has experienced repeated oscillations in aridity and humidity driven by fluctuations in the Indian summer monsoon. These oscillations are recorded in dune stratigraphy, lacustrine sediments, calcrete development, and archaeological horizons, each of which contributes to a more comprehensive understanding of how climate change shaped landscapes and influenced human migration corridors. By integrating multiple proxies—stable isotopes, micromorphology, sedimentology, geochemistry, and archaeological evidence—this study highlights the dynamic interplay between environmental processes and human occupation during the late Pleistocene and Holocene.

The dune sequences at Didwana and other sites on the eastern margin of the Thar Desert reveal long-term vegetation shifts linked to monsoon variability. Stable carbon and oxygen isotope analyses of pedogenic carbonates demonstrate alternating dominance of C4 grasses and C3 vegetation over the past 250,000 years. High $\delta^{13}C$ values correspond to phases of strong monsoon circulation, warm conditions, and expansion of C4 biomass, while lower $\delta^{13}C$ and $\delta^{18}O$ values mark cooler intervals with enhanced winter rainfall and expansion of C3 vegetation. These isotopic signals correlate with Indian Ocean core records of upwelling and sedimentation, underscoring the regional coherence of monsoon-driven

environmental change. The dune archives thus provide critical insights into the resilience and adaptability of vegetation communities under shifting climatic regimes.

At Kataoti, on the northeastern margin of the desert, sedimentary analyses combined with archaeological evidence identify repeated hominin occupations during humid phases between ~96 and 60 ka. Micromorphology, stable isotopes, magnetic susceptibility, and geochemical proxies reveal that enhanced humidity created favourable conditions for human settlement. The uneven distribution of humidity across the desert margin, with longer and more frequent wet phases toward the southern margin, likely influenced the timing and pathways of human dispersal. These findings reinforce the role of the Thar Desert as a corridor for early human migration out of Africa and into South Asia, highlighting the importance of palaeoenvironmental reconstructions for understanding human prehistory.

Calcretes formed over diverse Precambrian bedrock units in western Rajasthan represent another dimension of Quaternary landscape evolution. Their mineralogical and geochemical signatures reflect pedogenic processes under semi-arid conditions, contributing to the mosaic of desert margin environments. As durable features of the landscape, calcretes provide evidence of long-term soil formation and weathering processes, linking geomorphology with climatic fluctuations. Their occurrence across the Nagaur–ChuruJaipur tract emphasizes the widespread influence of Quaternary climatic regimes on soil development and landscape stability.

The lacustrine records from Kuchaman, Talchhapar, and Parihara offer detailed reconstructions of hydrologic oscillations during the late Quaternary. Stratigraphic sequences of laminated silts, ripple cross-bedded sands, gypsum-rich clays, and organic carbon layers reveal alternating phases of freshwater and saline lake conditions. Radiocarbon dating situates these oscillations within the broader framework of monsoon variability: ephemeral lakes existed prior to ~13 ka, freshwater conditions prevailed between 9 and 7 ka, and saline regimes dominated between 6 and 1.3 ka, followed by the establishment of semi-arid conditions after ~1.2 ka. These records demonstrate the sensitivity of closed-basin lakes to monsoon rainfall and aeolian processes, with dune stabilization and reactivation shaping basin morphology. The presence of habitation sites on stabilized dunes, dated to the last few centuries, further illustrates the enduring relationship between human communities and desert margin hydrology, including the exploitation of lake brine for salt production.

Taken together, these diverse archives underscore the complexity of late Quaternary environmental change in the Thar Desert margin. The interplay of dune dynamics, lake hydrology, calcrete formation, and vegetation shifts reflect the overarching influence of monsoon variability, modulated by local geomorphic and lithologic factors. The archaeological evidence situates these environmental changes within the broader narrative of human dispersal, emphasizing the role of humid phases in enabling migration and settlement. The Thar Desert margin thus emerges as both a sensitive recorder of monsoon dynamics and a critical landscape for understanding human–environment interactions.

The broader significance of these findings lies in their contribution to global paleoclimate research. By situating Indian records within the wider Saharo–Arabian and Asian monsoon systems, this study highlights the interconnectedness of regional climate regimes.

The isotopic and sedimentary evidence from the Thar Desert complements records from Africa, Arabia, and the Indian Ocean, reinforcing the global coherence of late Quaternary climatic oscillations. Moreover, the integration of archaeological data underscores the importance of environmental corridors in shaping human migration, linking South Asia to broader patterns of dispersal across Eurasia. The Thar Desert margin thus provides a valuable case study for examining the nexus of climate, landscape, and human history.

In conclusion, the late Quaternary palaeoenvironments of the Thar Desert margin reveal a dynamic landscape shaped by monsoon variability, geomorphic processes, and human occupation. Dune stratigraphy records vegetation shifts tied to rainfall regimes; lacustrine sediments capture hydrologic oscillations and monsoon transitions; calcretes reflect longterm soil formation under semi-arid conditions; and archaeological horizons document human responses to climatic opportunities. Together, these archives emphasize the significance of the Thar Desert margin as a key region for reconstructing monsoon dynamics, understanding human dispersal, and situating Indian paleoclimate records within a global framework. The synthesis presented here contributes to advancing knowledge of how climate change has shaped both landscapes and societies, offering insights that extend beyond regional boundaries to planetary relevance.

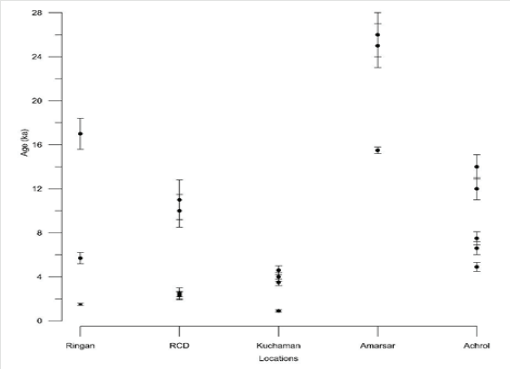


Fig. 17. OSL ages indicating phases of aeolian deposition that cluster around mid-MIS 3 (26–25 ka), followed by episodes at 17–15 ka, 14–11 ka, 7.5–5.7 ka, and 4.93.5 ka. Later pulses of aeolian activity, particularly after 3.5 ka and 2.3 ka, correspond to weakened monsoon dynamics and intensified aridity.

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Annexure

Field Excursion Guidelines: Do's and Don'ts

To ensure the safety of all participants and to promote responsible scientific field practices, all participants are requested to adhere to the following guidelines throughout the field excursions.

Keep a valid passport (for international participants) or a government-issued photo ID (for Indian participants) with you at all times during the field excursion.

Do's	Don'ts
1. Follow the instructions of the excursion leaders, coordinators, and local authorities at all times. 2. Remain with the group and inform the excursion leader before leaving the designated route. 3. Wear appropriate field attire, including sturdy closed-toe footwear, full-length trousers, a hat or cap, and weather-appropriate clothing. 4. Carry sufficient drinking water, personal medications, sunscreen, insect repellent, and other essential field supplies. 5. Keep a valid photo identification and your excursion registration details with you during travel. 6. Respect local customs, religious sites, cultural heritage, and private property. 7. Follow the Leave No Trace principles by carrying back all waste and helping to keep field sites clean. 8. Use designated trails and approved observation areas to minimise environmental disturbance.	1. Do not collect rocks, fossils, archaeological artefacts, biological specimens, or any other materials without prior authorization. 2. Do not damage, deface, or remove material from geological outcrops, caves, monuments, heritage structures, or other natural features. 3. Do not wander alone or separate from the excursion group without informing the field leaders. 4. Do not climb unstable slopes, cliffs, rock formations, or enter hazardous areas unless specifically instructed or supervised. 5. Do not swim or enter rivers, lakes, lagoons, or coastal waters unless expressly authorized by the excursion leaders. 6. Do not consume alcohol, recreational drugs, or engage in unsafe or irresponsible behaviour during the excursion. 7. Do not operate drones or other restricted equipment without obtaining the necessary permissions.

9. Observe geological, ecological, archaeological, and cultural features carefully without causing any damage.

10. Record field observations systematically and collect samples only with prior permission from the excursion leaders and the relevant authorities.

11. Exercise caution near cliffs, riverbanks, caves, unstable slopes, road cuts, and other potentially hazardous terrain.

12. Respect wildlife by maintaining a safe distance from animals, birds, reptiles, insects, and their habitats.

13. Immediately report any illness, injury, emergency, or hazardous situation to the excursion organizers.

14. Be prepared for changing weather conditions and comply with all safety advisories issued by the excursion leaders.

8. Do not photograph restricted installations, sensitive locations, or local residents without prior permission.

9. Do not create excessive noise or disturb local communities, religious activities, wildlife, or natural habitats.

10. Do not leave valuables unattended or rely solely on mobile phone connectivity in remote areas.

11. Do not undertake any activity that may compromise your safety, the safety of fellow participants, or the conservation of the area's geological, ecological, archaeological, or cultural heritage.

Disclaimer

Participation in the field excursions is entirely at the participant's own risk. While the Organising Committee and excursion leaders will make every reasonable effort to ensure participant safety and provide appropriate guidance, they shall not be held responsible for any personal injury, illness, loss of personal belongings, property damage, delays, or unforeseen incidents arising during travel or field activities. Participants are expected to act responsibly, follow all instructions issued by the excursion leaders, and comply with applicable local laws and regulations throughout the excursion.













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