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Late Holocene uplift in the lower Narmada basin, western India

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A late Holocene depositional surface has been identified in the lower Narmada basin of western India. This terraced surface occupies the valley formed by the incision of the mid–late Holocene surface. Radiocarbon dating of organic-rich clay horizons indicates that these terrace sediments were deposited between 1900 and 1200 yrs BP, well corresponding with the large-magnitude palaeoflood records of the central Narmada basin. These terraces occur as 2–4 m high uplifted surfaces and point to a latest phase of tectonic uplift in the lower Narmada during the historical times.

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IN western India, basement controlled tectonics have been extensively investigated[1–5]. Horst and graben structure in the subsurface is basically the manifestation of the reactivation of basement trends[3]. Having originated during the Mesozoic[2], the Cambay and the Narmada Mesozoic basins occupy a large part of mainland Gujarat. These basins have undergone several phases of subsidence and uplift since their formation. Repeated movements along faults in several phases throughout the Mesozoic and Cenozoic have shaped the landscape of mainland Gujarat. In the lower Narmada basin the reactivation of the basement trends since Precambrian is well established[4]. The tectonic uplift in phases during the Quaternary has exposed the Tertiary and Quaternary sediments along various rivers. The study area is located within the lower Narmada basin, between lat. 21°35′ to 21°55′N and long. 73°00′ to 73°25′E (Figure 1 *a* and *b*). It lies on the Narmada–Ankleshwar block of the Cambay rift basin, bounded by the ENE–WSW seismically active Narmada–Son Fault (NSF) in the north. The detailed tectonic and geomorphic history of the lower Narmada valley up to mid–late Holocene is well understood[4,5]. Here we report the occurrence and significance of a late Holocene depositional surface within the mid–late Holocene surface of the lower Narmada basin.

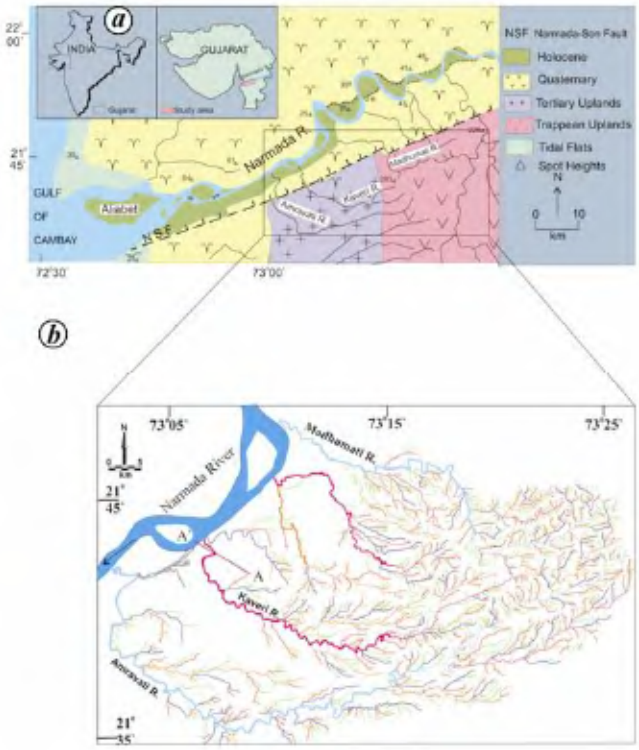

Figure 1. ***a***, Location map showing the general geology and geomorphology of the area[4]. ***b***, Area of study comprising Amravati, Kaveri and Madhumati rivers, meeting the Narmada river in its lower reach. Line *A–A′* marks the cross-section of Figure 3 *b*.

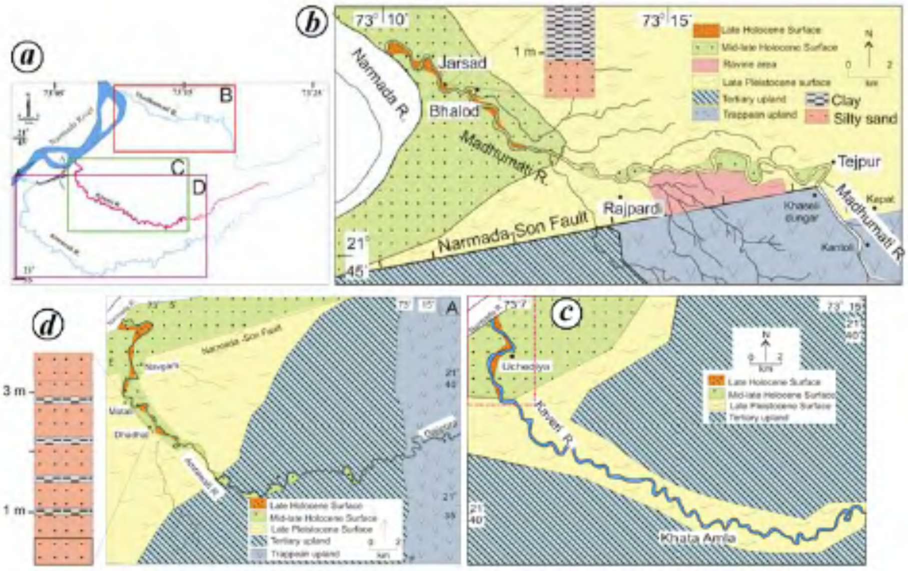

Figure 2. ***a***, Map showing the areas of detailed geomorphic maps (***b***) Madhumati, (***c***) Kaveri and (***d***) Amravati river basins. Note the late Holocene sediment succession at Jarsad (***b***) and Dhadhal (***d***). Red box in (***c***) marks the area of Figure 3 *a*.

The course of the Narmada river is controlled by the NSF which defines a major tectonic boundary, dividing the Indian shield into a southern peninsular block and a northern foreland block[6,7]. The NSF remained active all through the early Quaternary[4] with continuous subsidence of the northern block, which led to the accumulation of thick Quaternary sediments north of the NSF. In the southern block, the differential subsidence of various sub-blocks led to varying thickness of Tertiary rocks along the faults. Due to the N–S-directed compressive stress regime the Tertiary sediments were folded into a huge syncline, the E–W axis of which lies to the north of the Narmada river and corresponding anticlines are found toward the south of Narmada basin[8,5]. Due to renewed tectonic activity during early Pleistocene, the Tertiary rocks in the area were subjected to differential vertical uplift resulting in the deformation, fracturing and uplift of Tertiary and Trappean rocks[9]. Evidence for this comes from several observable geomorphic features in the form of partly uplifted basaltic ridges, palaeobanks, changes in the thickness of Quaternary alluvium, incision in the Quaternary sediment succession, occurrence of several tectonic inliers within alluvium and vertical scarps all along fault planes. These also point towards ongoing tectonic activity in the region. Some geomorphic evidence indicating that the area is undergoing recent tectonism comes from the study of streams in the area[10]. Data generated so far suggest that the middle to late Holocene sea levels have not fluctuated much up to the present[11,12]. The mid–late–Holocene sediments show tilting, which is more pronounced in the vicinity of the NSF suggesting that the incision and uplift of the mid–late Holocene valley-fill terrace well above the present-day tidal limits are related to the continued differential uplift along the NSF[4].

We have identified three broad geomorphic zones (Figure 2 *a–d*). The area showing rugged hill and valley topography in the northeast is the Trappean upland zone. This zone is delimited by the north-facing escarpments marking the surface expression of the NSF (Figure 2 *b*). The Tertiary upland zone shows hummocky topography. The alluvial zone comprises a more or less flat terrain, occupying the northern part of the study area. Within the alluvial zones certain areas show prominent ravine development (Figure 2 *b*).

In the present study, two erosional and three depositional surfaces have been mapped (Figures 2 *b–d*). The older two depositional surfaces correspond to the late Pleistocene to mid–late Holocene depositional surfaces of the neighbouring river basins[4]. The third late Holocene depositional surface has been identified in this study in the Gujarat alluvial plains (Figures 2 *b–d* and 3). This depositional surface has been identified in all the three tributary river basins of the lower Narmada, i.e. Madhumati, Amravati and Kaveri rivers at Jarsad, Dhadhal and Uchediya respectively (Figures 2 *b*, *d* and 3 *a*). The Uchediya section (Figure 3 *a*, *b*) located on the right bank of Kaveri river is identified as the type section for the late Holocene depositional surface and was studied in detail. At Uchediya, this terrace occurs as an unpaired, about 4 m high surface, abutting against the mid–late depositional surface on one side and the river on the other (Figure 3 *b*). The sedimentary record of this 4 m-high terrace surface shows fine alternations of silty sand and organic-rich clay (Figure 4), occurring as alternating bands of light and dark colours. The succession starts with a unit of silty-sand and the base is not exposed. The silty sand units show parallel bedding and at places weak bidirectional cross-stratification. This alternating sequence of coarse silty-sand and clay is similar to the flood units of central Narmada[13]. We have dated the organic-rich, dark-coloured clays which range in age from ~1950 ± 90 to 1280 ± 70 yrs BP (cal BP 1924 to cal BP 1172, at 1 sigma level (Figure 4)).

The Narmada river basin lies within the tectonically active area as it astrides the active NSF. However, the basin is also dominated by the southwest monsoon with frequent flood producing storms[13]. The flood records and tectonic uplift during the historic times are considered responsible for the deposition and the present-day elevation of the late Holocene depositional surface in the lower Narmada basin. The historic earthquake data of western India date back to 500 yrs BP. We know little about Indian earthquakes earlier than 500 yrs BP, and records are close to complete only for earthquakes in the most recent 200 years[14]. Archaeological excavations at Sindh and Gujarat suggest that earthquakes were responsible for the abandonment of Harrappan cities[14]. A probable earthquake around AD 0 near the historical city of Dwarka[14] has been recorded as a zone of liquefaction in archeological excavations of the ancient city[15]. Trench investigations in various parts of western India indicate that the faults have been repeatedly active in the Indian subcontinent[16].

In the central Narmada basin geomorphic investigations have revealed evidence of a series of major floods[13]. Kale *et al.*[13] have assembled a 2000-year chronology of large floods on the Narmada. Two events of extreme floods date between ~1900 and 690 yrs BP. The large flooding episodes in central Narmada may have led to the deposition of fine silty-sand and clay at the sheltered locations in the lower reaches of the Narmada river. Sheltered, small tributary mouths and channel margins are common sites for the preservation of flood records[13]. The sheltered geomorphic situation for the deposition of large flood deposits in the backwater areas is ideally provided by the tributaries of lower Narmada river. These flood deposits presently occur as late Holocene depositional surfaces in all the three tributaries of the lower Narmada, i.e. Amravati, Kaveri and Madhumati rivers. These tributaries have small catchments and low water mass during large floods on the river Narmada.

The change in climate and sea level[12] from 1200 yrs BP to the present is not significant enough to incise this depositional surface to the order of 2–4 m. Ongoing tectonic activity within the vicinity of the NSF is well documented in various geomorphic studies of the area[4,10].

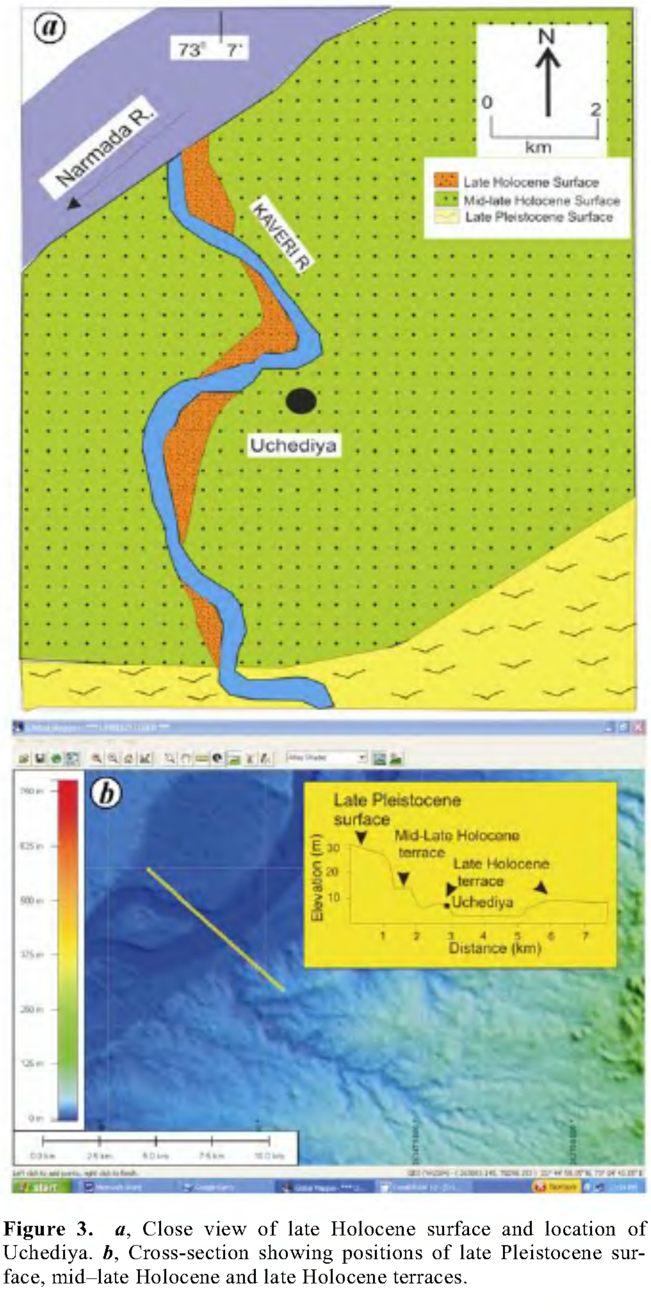

Figure 3. ***a***, Close view of late Holocene surface and location of Uchediya. ***b***, Cross-section showing positions of late Pleistocene surface, mid–late Holocene and late Holocene terraces.

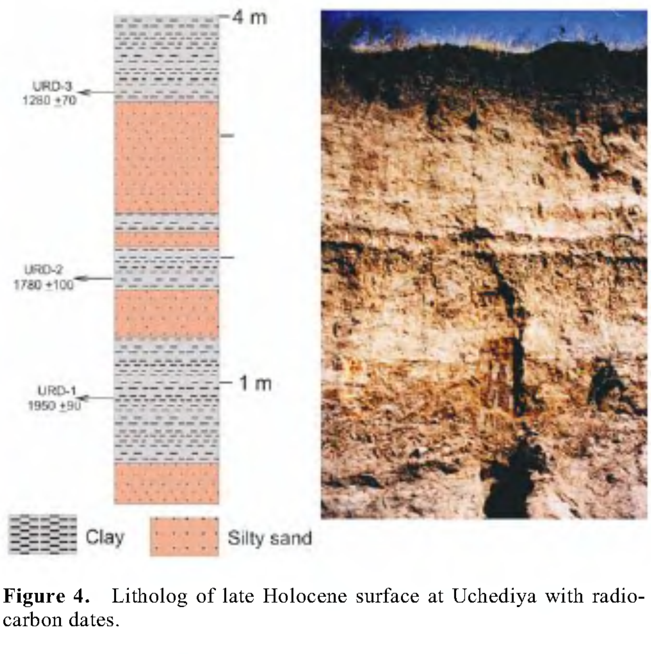

Figure 4. Litholog of late Holocene surface at Uchediya with radiocarbon dates.

The late Holocene phase of tectonic uplift in the study area corresponds well with the previous studies in the neighbouring area, where a general tectonic uplift between 2 Ka and the present is envisaged[4,5,17]. The present position of this surface as a 2–4 m high terraced surface within the valley of mid–late Holocene surface could be attributed to tectonic uplift in the area after 1200 yrs BP.

Two phases of tectonic uplift during the Holocene have been established in lower Narmada basin[4]. Early Holocene uplift resulted in the development of ravines and deeply incised fluvial valley. Second phase of uplift took place after the deposition of mid–late Holocene sediment surface and resulted in the uplift of this surface[4]. The present study indicates a third phase of uplift after 1200 yrs BP in the lower Narmada basin. Detailed trench studies across the active faults and liquefaction features are likely to generate more information useful for characterizing this latest uplift event in the lower Narmada basin.

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