Journal of Asian Earth Sciences 66 (2013) 240–248

Contents lists available at SciVerse ScienceDirect

Journal of Asian Earth Sciences

journal homepage: www.elsevier.com/locate/jseaes

Early Holocene fluvial activity from the sedimentology and palaeohydrology of gravel terrace in the semi arid Mahi River Basin, India

Alpa Sridhar [a,*], L.S. Chamyal [a], Falguni Bhattacharjee [b], A.K. Singhvi [c]

[a] Department of Geology, The M.S. University of Baroda, Vadodara 390 002, India
[b] Institute of Seismological Research, Raisen, Gandhinagar 382 009, India
[c] Physical Research Laboratory, Ahmedabad 380 009, India

ARTICLE INFO

Article history:
Received 4 August 2012
Received in revised form 26 December 2012
Accepted 19 January 2013
Available online 5 February 2013

Keywords:
Palaeohydrology
River terrace
Early Holocene
Climate change
Mahi River Basin

ABSTRACT

Palaeocompetence analysis and palaeodischarge estimation techniques are applied to a late Pleistocene–early Holocene gravel terrace in the Mahi River Basin, western India. Terrace sedimentology, comprising gravels overlain by sand lithofacies suggests a gradual change in palaeohydrological conditions marking a switch from braided to meandering fluvial styles. The discharge values for the gravel bedforms based on the clast size and the cross bed set thickness are estimated between ~150–180 $m^3 s^{-1}$ comparable with the present day observed values albeit with a much higher competence. Results indicate that fluvial aggradation occurred under low discharge conditions with intermittent high discharge events depositing longitudinal gravel bars. The incision of these gravel bars and the formation of terraces can be attributed to the higher discharge regime post 9.2 ka. The study further indicates that whereas the aggradation of the gravel terrace during the early Holocene was controlled by the large sediment influx, the incision that followed was in response to the increase in the discharge and competence of the river flow.

1. Introduction

The fluvial systems of South Asia have responded to the abrupt deglacial intensification of the monsoon (Goodbred and Kuehl, 2000). A broad link between monsoon strength and fluvio-sedimentary response (aggradation and incision events) in the Indian sub-continent has been envisaged based on the data from the alluvial sequences in various river basins (Kale, 2007; Chamyal and Juyal, 2008; Sinha and Sarkar, 2009). The influence of climatic fluctuations on fluvial activity can be understood by correlating these to sedimentation and erosion process (Baartman et al., 2011). In the Indian sub-continent, the continental and marine proxy records of the late Pleistocene–Holocene period indicate abrupt to gradual change in the monsoon over long as well as short time scales (Prell and Kutzbach, 1992; Sirocko et al., 1993; Enzel et al., 1996; Overpeck et al., 1996; Anderson et al., 2002; Gupta et al., 2003; Staubwasser, 2006; Rao et al., 2008). Therefore, the aggradation and incision events need to be evaluated on the basis of the regional dynamics encompassing climate change and related sediment supply.

Fluvial palaeohydrological techniques aid in interpreting indices of past hydrological processes (Baker, 1996). Sediment archives preserve the evidence of past flow regimes; sand-sized particles reflect the average flow conditions, whereas coarser sediments yield information on the maximum flow and the related stream competence (Wohl and Enzel, 1995). The river terrace sediments possess various grain sizes, sedimentary structures of varying dimensions and channel forms that can be effectively used as input data for flow competence and regime theory of palaeohydrological estimations (Stokes et al., 2012). Such palaeohydrological estimation methods are well established (Etheridge and Schumm, 1978; Williams, 1984). While all these calculations may provide only the estimates, it enables reliable approximation especially when used on a comparative basis (Miall, 1996). However, little research has been taken up using Quaternary river terraces and their sediment archives (Stokes et al., 2012 and references therein).

Here, we discuss the fluvial activity and pattern of sedimentation in the Mahi River Basin, western India during the late Pleistocene–early Holocene transition which is hitherto not described. Sediment attributes, regime-based palaeodischarge estimations and palaeocompetence analysis are employed to understand the processes of formation, aggradation and incision of the terrace in response to the change in the river flood regime, tectonic disturbances and related sediment supply during the Holocene. Mid to late Holocene fluvial sediment sequences are preserved in the alluvial reach of the river (Kusumgar et al., 1998; Sridhar, 2007a) however, no records of fluvial deposition during the early Holocene have been reported until now. The present study in the Mahi River

* Corresponding author. Tel.: +91 2652785560.
E-mail address: alpasridhar@rediffmail.com (A. Sridhar).

1367-9120/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jseaes.2013.01.017

Basin offers a link between the late Pleistocene sedimentation record and the early Holocene rejuvenation of the monsoon. An attempt has been made to comprehend the aggradation/incision behavior of the river in response to climatic variations and sediment supply during early Holocene.

2. The Mahi River

2.1. Geology and geomorphology

The Mahi River (583 km in length and 34,842 km^2 in drainage surface) drains the metamorphic basement of Proterozoic Aravalli Super Group, volcanics of the Cretaceous–Eocene Deccan Group, the vast Quaternary alluvial plains and joins the Arabian Sea (Fig. 1). The drainage is controlled by Aravalli trend (NW–SE) in the uplands whereas in the lower reaches the drainage network is mainly controlled by the Tertiary Cambay Basement Faults (ECBMF; Fig. 1) (Maurya et al., 1997). A southwestward palaeocourse of the Mahi River during late Pleistocene has been envisaged (Agarwal et al., 1996) and the present course of the Mahi River was probably occupied in the Holocene. The region experienced major tectonic activity in the early Holocene that not only shifted the Mahi River to its present course but also caused the incision of the older sediments (Merh and Chamyal, 1997). The evolution of the present landscape of the lower Mahi basin has been attributed to two phases of tectonic uplift during the Holocene, one during the early Holocene and the other during the late Holocene to recent times (Maurya et al., 1997). The climatic control on the geomorphic evolution of the basin however is not well understood.

Mahi Basin is divisible into four morphological zones: rocky upland (referred to here as the upland zone), piedmont, alluvial plain and estuarine zone (Fig. 1) (Raj et al., 1999). In the upland zone, the Mahi River occupies a ~10 m deep and 200 m wide valley developed into bedrock whereas in the piedmont zone, the channel is ~6 m in depth and up to 500 m wide characterized by a low flow channel, patches of bedrock and active floodplains, and terraces. In the alluvial zone, terraced surfaces and extensive badland topography are observed. The channel is incised into the alluvial plain surface forming alluvial cliffs up to 40 m high along both banks. The river is meandering and is characterized by the presence of point bars, channel bars and alluvial terraces. The estuarine zone is characterized by a wide estuarine river mouth with marine and estuarine valley fill deposits. Typically, these terraces are exposed along the river at lower elevations (5–12 m). Within the alluvial zone, exposures through the discontinuous terrace remnants exhibit typical gravel and sand point bar facies near the base, which in turn are overlain by silt and clay floodplain facies (Sridhar, 2007a). The gravel has been radiocarbon (C^{14}) dated to 6400 ± 120 yrs BP (Maurya et al., 1997), the oldest of the Holocene sediment to have been dated so far. Evidence of high magnitude floods in the alluvial zone has been documented in the form of slack water deposits dated by OSL to 4.6 ± 1 ka (Sridhar, 2007b). Also valley fill terraces in the estuarine zone have been radiocarbon (C^{14}) dated to 3660 ± 90 ^{14}C yr BP (Kusumgar et al., 1998). This implies that no record of fluvial sedimentation post 30 ka (phase of fluvial aggradation from 50 to 30 ka in the Mahi Basin according to Juyal et al. (2000)) until ~6 ka is available.

2.2. Climate and hydrology

The modern Mahi River is a monsoon dominated semi arid river where rainfall is typically between July and September. The mean annual rainfall decreases from 850 mm in the headwaters to 600 mm in the lower reaches and creates a mean annual discharge of 384 $m^3\ s^{-1}$. The flow is influenced by the construction of dams and weirs along the main channel and tributaries. Within the catchment the majority of rainfall occurs in association with the passage of monsoon depressions and low pressure systems, either

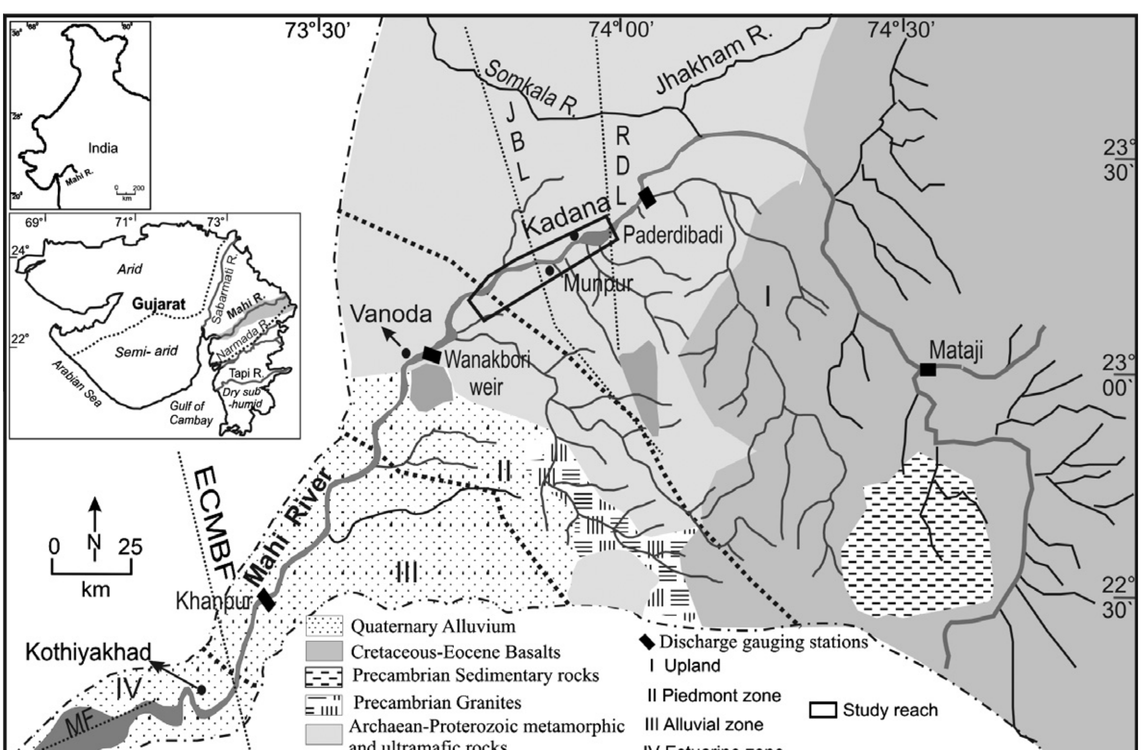

Fig. 1. Geological and geomorphological setting of the Mahi River (modified from Raj et al. (1999)). ECMBF – East Cambay Margin Basement Fault; JBL – Jaisalmer–Barwani Lineament; RDL – Rakhabdev Lineament; MF – Mahisagar Fault. Also note the location of the study area.