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Paleoenvironmental implications and drainage adjustment in the middle reaches of the Sabarmati river, Gujarat: Implications towards hydrological variability

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ABSTRACT

The dryland fluvial sequences exposed in the lower part of the Gujarat alluvial plain are investigated for palaeohydrological/palaeoclimatic reconstruction using conventional sedimentology, grain size analyses supported by optical chronology. Considering that the study area is cradling large-scale constructional activities, an attempt has also been made to assess the geotechnical properties of the sediments.

It has been observed that the lower reaches of the Sabarmati valley have preserved record of fluvial aggradation since MIS-5 (90 ka) to MIS-3 (47 ka) whereas the onset of aeolian processes began at around 12 ka. Based on the sediment texture, the alluvial sequences are divided into the lower and upper units. The lower fluvial sequence is dated to 90–63 ka whereas the upper fluvial sequence is dated to 47 ka. The stratigraphic marker red soil is dated to 63 ka. The study indicates that the terrain experienced tectonic perturbations after ~12 ka which was responsible for the shifting of the Sabarmati river from regional NE-SW to N-S which is more pronounced towards the upstream of the Sabarmati river basin while the landscape stability is observed towards the downstream consisting of the older alluvium dated to 90 ka. Geotechnical investigation reveals potentially liquefiable sand, which however have been compacted due to large scale calcretisation since their deposition.

1. Introduction

Dryland river systems owe their importance in geo-environmental studies as they cover huge part of the earth's landmass and support considerable percentage of world population. In such river systems, pronounced downstream changes have been reported in channel morphology (Thornes, 1976; Clark and Davies, 1988), sedimentary bedforms, sedimentary structures and bed material of the dryland rivers (Frostick and Reid, 1980; Rhoads, 1989). Therefore, it is pertinent to investigate the dryland rivers, at multiple locations in order to generate a near complete scenario of pattern of sediment aggradation and incision that in turn can be used to provide a basin wide picture of palaeohydrlogical/palaeoenvironmental and tectonic instability (Nanson et al., 2002). In view of this, to determine the fluvial response to external factors (climate and tectonics), we investigated the exposed alluvial sequence in the lower part of the middle alluvial plain (Fig. 1). The rationales behind selecting the study area are as follows: i) Sabarmati is a major drainage basin of the Gujarat alluvial plain that has preserved a relatively detailed sedimentological archive. Earlier studies indicated the potential of using the alluvial succession towards reconstructing late Quaternary climate and tectonic instability (Foote, 1898; Sankalia, 1945; Zeuner, 1950; Tandon et al., 1997; Jain et al., 2004a, 2004b; Srivastava et al., 2001; Juyal et al., 2000, 2006). However, the earlier studies were confined to the upper reaches, whereas the lower reaches remained largely unexplored. (ii) The study area is experiencing accelerated constructional activities; hence it is essential to evaluate the geotechnical status of the alluvium.

A systematic investigation of the alluvial sequences and their palaeoclimatic potential was suggested by Pant and Chamyal (1990) who demonstrated that the dryland fluvial systems in the Gujarat alluvial plain responded in tandem with the monsoon variability and hence can be used as a terrestrial archive for the Late Quaternary climate variability. According to Tandon et al. (1997), the stratigraphic studies of the Late Quaternary succession in the

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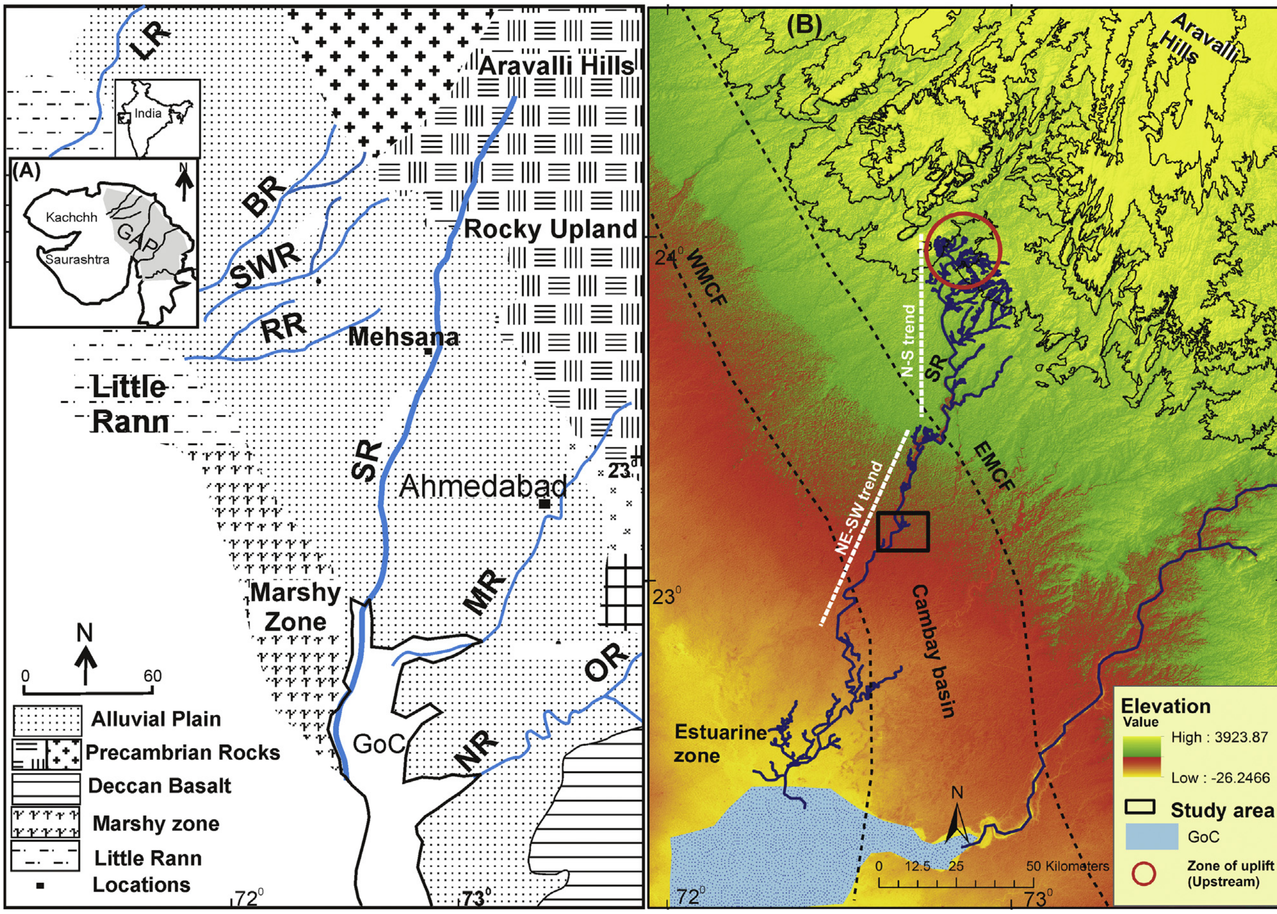

Fig. 1. (A) Map showing location of the Gujarat alluvial plain (GAP) and the major drainages flowing from the Aravalli hills towards the Gulf of Cambay (GoC). LR = Luni River, BR= Banas river, SWR= Saraswati river, RR = Rupen river, SR= Sabarmati river, MR = Mahi river, OR= Orsang river. (B) DEM showing the Sabarmati river (SR) flowing across the Cambay rift basin. EMCF = East Margin Cambay Fault, WMCF= West Margin Cambay Fault, black rectangle indicates the study area and the red circle indicates zone of uplift; Dharoi (discussed later). White dotted lines indicate river trend which shows N-S trend in the upstream part and NE-SW trend in the middle downstream part of the Sabarmati river. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Sabarmati basin can be divided into four major lithostratigraphic units: the *Waghpur Formation* (conglomeratic lower unit overlain by sandy unit); the *Mahesana Formation* (fine sand/silty sand/silty clay, caliche layers overlain by fine sand, silt/clay with subordinate pedogenic carbonates, and brown silty clay); the *Akhaj Formation* (dune sediments) and the *Sabarmati Formation* (unconsolidated alluvium). The dating of the oldest Quaternary deposits suggested to be of >300 ka. On the basis of optical dating (BLSL and IRSL), at Mahudi (upstream part of the Sabarmati river), Srivastava et al. (2001) suggested fluvial sedimentation between 54 and 30 ka and aeolian activities during 12 ka to 5 ka. The pedogenised horizon dated to 69 to 60 ka, known as red soil has been recognized as the intra-basinal stratigraphic marker (Juyal et al., 2006). The red soil overlain by pedogenised silty-sand is termed as upper fluvial sequence (Srivastava et al., 2001). In addition to paleoclimate, neotectonic activities in the Sabarmati basin has also been determined which suggested regional slope-deviatory nature of the river (Sareen et al., 1993; Maurya et al., 1995; Merh and Chamyal, 1997; Tandon et al., 1997; Rachna et al., 1999; Srivastava et al., 2001; Chamyal et al., 2003; Jain et al., 2004a, 2004b; Juyal et al., 2006). In south Gujarat alluvial plain, the neotectonic activities are documented along the lower Narmada river basin (; Sant and Karanth, 1993; Chamyal et al., 2003) and also in the Orsang and Mahi river basin (Maurya et al., 1997; Juyal et al., 2000, 2006). Based on the IRSL dates, Tandon et al. (1997) suggested that the neotectonic adjustment of the Sabarmati river occurred possibly within the past 39 ka. Earlier studies indicated large variations in the Quaternary deposition from upstream (80 m) to downstream (300 m) (Chandra and Chaudhary, 1969). However, a large hiatus has been observed during the Quaternary (Jain et al., 2004a, 2004b). Those studies were based on IRSL ages and were mostly confined to only the upstream part of the Sabarmati river. However, the basinwide descriptions, particularly the investigations along the downstream part have not been carried out so far. In addition to this, ages obtained with IRSL techniques have their own limitations over those obtained by coarse-grained quartz. Therefore, in the present study, we attempt to investigate the alluvial deposits in the lower part of the Gujarat alluvial plain with the help of geomorphology, sedimentology, optical dating (with quartz) and geotechnical methods. This study will help us better understand the palaeoclimatic and neotectonic scenario along the Sabarmati river basin flowing through the Gujarat Alluvial Plain. More specifically, the objectives are to (i) reconstruct the alluvium stratigraphy in the middle reaches of the Sabarmati basin (ii) ascertain the timing of various lithofacies deposition and the climatic significance (iii) constrain the timing and causes of river adjustment and incision and (iv) ascertain the geotechnical property of the sediment succession as a function of lithofacies and sediment ageing. Towards this, two stratigraphic sections exposed along the east and west flanks have been documented for detailed field stratigraphy (Figs. 2–4).

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