Palaeogeography, Palaeoclimatology, Palaeoecology 421 (2015) 60–74

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

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

Holocene climatic fluctuations in the Gujarat Alluvial Plains based on a multiproxy study of the Pariyaj Lake archive, western India

Rachna Raj [a,*], L.S. Chamyal [a], Vandana Prasad [b], Anupam Sharma [b], Jayant K. Tripathi [c], Poonam Verma [b]

[a] Department of Geology, Faculty of Science, The M.S. University of Baroda, Vadodara 390 002, India
[b] The Birbal Sahni Institute of Palaeobotany, 52 University Road, Lucknow 226 007, India
[c] School of Environmental Sciences, Jawaharlal Nehru University, New Delhi 110067, India

ARTICLE INFO

Article history:
Received 2 January 2014
Received in revised form 8 December 2014
Accepted 6 January 2015
Available online 10 January 2015

Keywords:
Holocene
Palaeoclimate
Lakes
Gujarat Alluvial Plains
Western India

ABSTRACT

A sediment core from Pariyaj Lake, from the Vatrak River basin, located at the desert margin in the Gujarat Alluvial Plains of western India, was investigated in a multidisciplinary aspect. The goal was to reconstruct the palaeoclimate, palaeoenvironment and tectonic history and to understand the role these factors played in the geomorphological evolution of the area during the Holocene. Palaeoclimatic interpretations also shed light on the factors responsible for the rise and fall of the Harappan civilisation. The results obtained based on multiproxy studies show five climatic phases during the last 11,000 yr BP. Phase 1 (~11,000 cal yr BP) represents a very humid climate and high precipitation/discharge leading to high lake stand as attested by the high pollen concentration of semi-evergreen tree taxa, phytoliths belonging to cool and moist grasses, and large proportion of algae, marking the onset of Holocene. In phase 2 (~8000 to 9000 cal yr BP) a significantly reduced yield of pollen, phytoliths and aquatic algae indicates shrinkage of the lake. Phase 3 (~7630 cal yr BP) shows moderate yield of pollen and phytolith pointing towards fluctuating precipitation conditions. Phase 4 (~5864 to 4680 cal yr BP) shows very low pollen and phytolith counts, indicating a very dry spell. Finally, phase 5 (~4680 to 3500 cal yr BP) shows a good density and diversity of flora. The wet climate and high lake stand ~11,000 cal yr BP, 7630 cal yr BP and after ~4680 cal yr BP are synchronous with the lacustrine, marine and aeolian records of western India. The contribution of winter precipitation at 7630 cal yr BP and after ~4680 cal yr BP can be correlated with similar records from Rajasthan Lake. Decrease in the precipitation activity, the low lake stand and the onset of dry climatic condition between 8000 and 9000 cal yr BP corresponds to a near global anomaly of this period. Another dry event between ~5864 and 4680 cal yr BP documented in Pariyaj Lake record is synchronous with various proxy records of the mid–late Holocene Afro-Asiatic monsoonal belt.

1. Introduction

The Holocene spans the time period of the last 11.6 ka (Walker et al., 2009). In recent studies (Bond et al., 2001; Mayewski et al., 2004; Prasad and Enzel, 2006; Staubwasser and Weiss, 2006; Prasad et al., 2007, 2014a; Fletcher et al., 2013) it has been established that during the Holocene, which was traditionally considered a climatically more stable period than the Late Pleistocene, the climate varied significantly. Abrupt climate change during the early Holocene is also documented by various workers in Asia (Enzel et al., 1999, 2003; Weiss and Bradley, 2001; Parker et al., 2004; Migowski et al., 2006; Staubwasser and Weiss, 2006). During the first 5 ka of the early Holocene, a reorganisation of the hydrographical system due to the melting of the large ice-sheets took place (Carlson et al., 2008; Renssen et al., 2009) whereas the period of the last 7 ka was dominated by the decrease in solar insolation in the northern hemisphere during boreal summer (Berger, 1978; Wanner et al., 2008). Recent decades have been influenced by climate change due to anthropogenic forcing. Due to this redistribution of solar energy the global climatic system experienced a rearrangement that is classified in two main Holocene climate patterns, i.e. Holocene Thermal Maximum (HTM between ~7 and 4.5 ka BP) and the Neoglacial, which started around 4.2 ka BP and ended with the modern industrialisation in the 19th century (Wanner et al., 2008; Wanner and Bronnimann, 2012). The HTM witnessed enhanced heating of the northern hemisphere during the boreal summer leading to warming, generating intensified heat lows, and higher activity of the Afro-Asian summer monsoon system, thus transporting more moisture to the corresponding continental areas. An almost opposite pattern existed during the Neoglacial when summer monsoons were less active and the corresponding continental areas were exposed to an increased dryness (Gasse, 2000; Wang et al., 2005). With the better understanding of Holocene climatic fluctuations and rapid oscillations (Mayewski et al., 2004; Duplessy et al., 2005) multidisciplinary studies for this period are gaining importance. The period has widespread socio-economic impacts on human activities and defines the period during which civilisation developed.

* Corresponding author. Tel.: +91 9376220681 (mobile).
E-mail address: naveenrachna@gmail.com (R. Raj).

http://dx.doi.org/10.1016/j.palaeo.2015.01.004
0031-0182/

According to Force and McFadgen (2012) the effect of tectonic activity should be considered along with other factors such as climate change in evaluating human activity and development. The Holocene of Gujarat Alluvial Plains of western India has captured the interest of earth scientists due to several factors as, the area is very sensitive to climate change, a great part of it falls in the tectonically active Cambay basin and it has also witnessed strong human influence during this time (Hegde, 1995; Gaur and Vora, 1999). The area is presently undergoing various forms of stresses due to increased climatic variability and tectonic activity, so understanding the interactions between past climates versus palaeoenvironmental response and the geomorphic evolution of land, and relating these to rise and fall of agriculture-based societies is important in today's context. There is also a special interest attached to climate change as it relates to Indian agriculture since it affects the livelihood of over one billion people. These studies also help in developing an understanding of present day local climatic responses to regional and global climatic changes.

Tectonism has been evoked by previous workers (Raj et al., 1999a,b; Chamyal et al., 2002, 2003; Raj, 2004, 2007, 2012; Raj and Yadav, 2009) in studies of the early Holocene of western India to explain the regional uplift of Gujarat Alluvial Plains. A study of the Mahi River (Maurya et al., 1998) also suggests that seismic event that took place between 3320 ± 90 and 2850 ± 90 yr BP may have played a major role in shaping the Gujarat Alluvial Plains in general. A recent study in the Vatrak River basin in the northwest part of Gujarat Alluvial Plains (Raj, 2012) has established an eastward tilting of the Vatrak and its tributaries, a relatively rapid uplift of the basin, and a strong role of tectonic elements in the overall landscape evolution of the area. For the climatic change studies, within the terrestrial archives, lacustrine sediments provide the best record of Holocene climatic fluctuations and their potential links with rise and collapse of Indus Valley civilisation (Singh, 1971; Singh et al., 1974, 1990, 2007; Prasad et al., 1997, 2014a). In a recent study by Prasad et al. (2014a) of a lake in the central part of Gujarat Alluvial Plains, a number of arid and humid phases during the Holocene were linked with the rise and fall of Harappan civilisation using multi-proxy approach.

To gain a better understanding of the Holocene climatic fluctuations of the Gujarat Alluvial Plains, a multiproxy record was generated from the Pariyaj Lake, a large natural lake in the area. The primary aim of this study is to understand the palaeoclimatic fluctuations during the Holocene and to offer a regional correlation of the data generated by this study with that of the marine, lacustrine, aeolian and cultural records of West Asia. The role of climate in the rise and fall of the Harappan civilisation is also critically assessed.

1.1. Regional setting

1.1.1. Geology and tectonics

The Vatrak River basin, in the lower part of which Pariyaj Lake is situated, is bordered by the Thar Desert in the northwest, the Gulf of Cambay in the south and the Deccan Trap highland in the east, making it suitable for the palaeoclimatic studies (Fig. 1A–D). The river originates in the Aravalli upland and flows through a constricted course in the upper reaches of the Aravalli terrain. In the middle and lower reaches

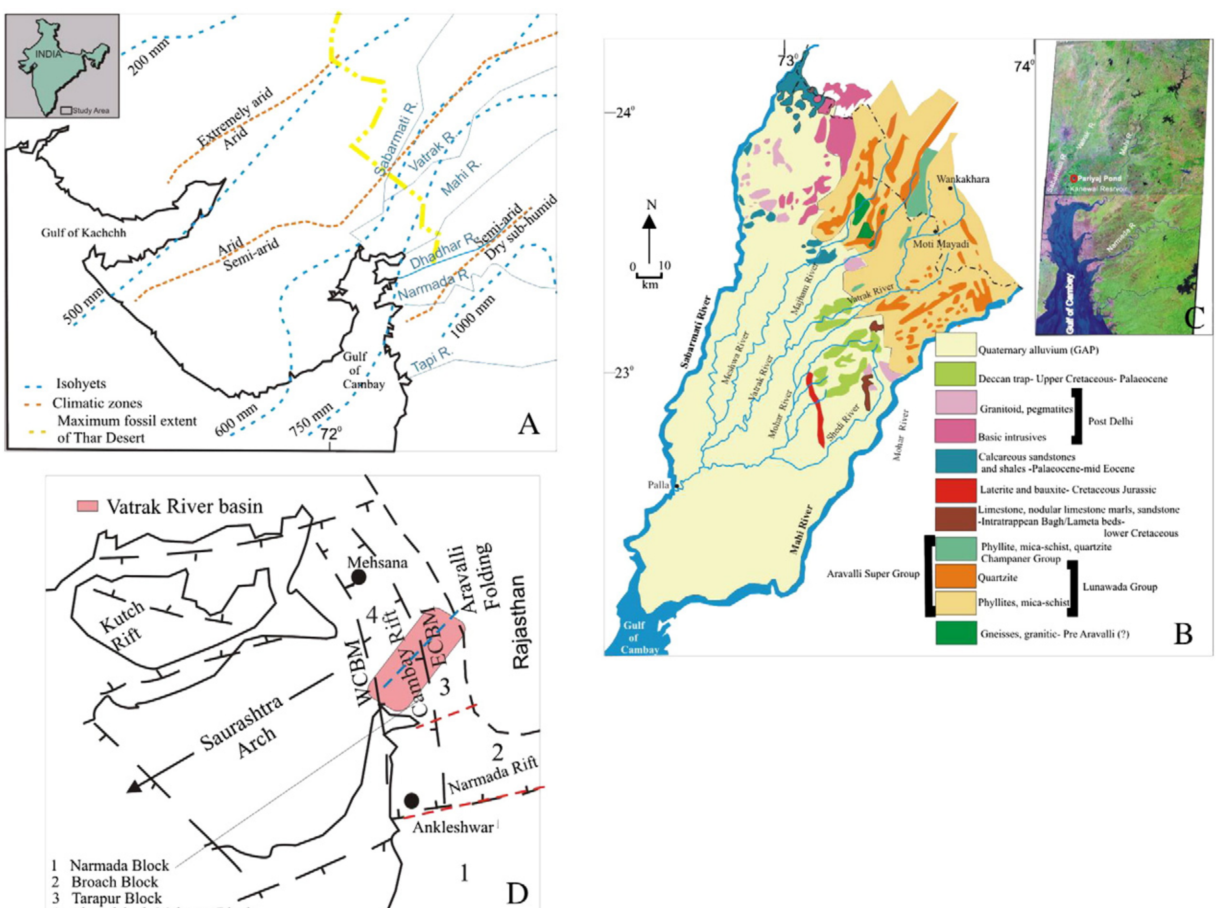

Fig. 1. A. Map of NW India showing climatic zones (indicated as brown lines), isohyets (indicated as blue lines) and the maximum fossil extent of the Thar Desert (after Juyal et al., 2003, indicated as yellow line). B. Geological map of the Vatrak River basin (Raj, 2012) showing vast stretch of Gujarat Alluvial Plains in the lower reaches where lake Pariyaj is located (see inset C). D. Structural map of NW India showing the extent of Cambay basin and its various blocks (modified after Biswas, 1982). Blue dashed line is Vatrak Fault which controls the drainage in the lower reaches of the River.