Available online at www.sciencedirect.com
ScienceDirect
Chemie der Erde 68 (2008) 313–322
CHEMIE der ERDE GEOCHEMISTRY
www.elsevier.de/chemer

Geochemical zones and reconstruction of late Holocene environments from shallow core sediments of the Pachapadra paleo-lake, Thar Desert, India

P.D. Roy[a,b,*], W. Smykatz-Kloss[a], O. Morton[c]

[a]*Institute of Mineralogy and Geochemistry, University of Karlsruhe, 76131 Karlsruhe, Germany*
[b]*Centro de Investigaciones en Ciencias de la Tierra, Universidad Autónoma del Estado de Hidalgo, carr-Pachuca-Tulancingo, Km. 4.5, 42184 Pachuca, México*
[c]*Instituto de Geofísica, Universidad Nacional Autónoma de México, Cuidad Universitaria, 04510 México, DF*

Received 11 November 2005; accepted 11 January 2006

Abstract

Lithostratigraphy, mineralogy, major and trace element concentrations, carbon and sulphur contents are investigated from a shallow depth profile from Pachapadra paleo-lake, Thar Desert, north-western India, to understand the phases of paleo-hydrology and paleo-limnology. Based on the geochemical proxies (Na/Al, Si/Al, Zr/Al and Ca/Mg) and evaporite mineralogy, the depth profile is divided into three geochemical zones of variable sediment–water interaction, evaporation and aeolian activity. The sub-recent zone (I) enriched in halite (NaCl) indicates low chemical weathering and higher aeolian input. The intermediate relatively humid zone II is enriched in major elements, trace elements and calcite ($CaCO_3$) and reflects higher chemical weathering in the catchments. Zone III is enriched in gypsum ($CaSO_4 \cdot 2H_2O$) and characterised by lower chemical weathering, higher aeolian activity and evaporation.

Keywords: Evaporite mineralogy; Paleo-hydrology; Holocene; Geochemical zones; Paleo-lake; Thar Desert; India

1. Introduction

Deserts all over the world have formed as a result of changes in atmospheric circulation pattern and, hence, distribution of rainfall (Dawson, 1992). These are the regions which witness the interplay of climate on geology with minimum interference from biology. So the geological and stratigraphical records from different archives, e.g., lacustrine, fluvial and aeolian, from the desert margins or arid–semi-arid climatic transitions are pristine and are studied to understand the paleo-hydrology, paleo-climatology and, hence, changes in past atmospheric circulation pattern.

The geographical location of the Thar Desert in a transitional monsoon regime that is typical of general mid-latitudinal atmospheric circulation implies that minor perturbation in this pattern affects the hydrology and influences the geomorphology of the region in an amplified scale. A very systematic spatial climatic shift in the entire region has been documented by the deposits of loess and fossil sand dunes (Wasson et al., 1983; Dhir et al., 1992; Tripathi and Rajamani, 1999) in the

*Corresponding author. Centro de Investigaciones en Ciencias de la Tierra, Universidad Autónoma del Estado de Hidalgo, carr-Pachuca-Tulancingo, Km. 4.5, 42184, Pachuca, México.
Tel.: +52 017717172000x6621/6622.
E-mail address: priyadarsi@lycos.com (P.D. Roy).

0009-2819/$ - see front matter © 2006 Elsevier GmbH. All rights reserved.
doi:10.1016/j.chemer.2006.01.006

present-day relatively humid eastern margins and the presence of calcretes (Dhir, 1995) and paleo-streams (Bakliwal and Grover, 1999) in the dune dominated arid western region. The lacustrine records show large amplitudes of paleo-hydrological and paleo-limnological variations of the region in the time span of $\leqslant 30$ ka (Wasson et al., 1984; Enzel et al., 1999; Deotare et al., 2004; Sinha and Raymahashay, 2004).

The paleo-lakes or playas of the Thar Desert are saline and shallow. These hydrologically closed lakes have their antiquity in the fluvial regimes. The tectono-geomorphic evolution of these lakes has been related to excessive siltation at the river confluence, dune segmentation of former streams during the late Pleistocene climatic transition (Agarwal, 1957; Ghose, 1964; Ghose et al., 1977; Kar, 1990; Singhvi and Kar, 1992) and tectonic movements along the lineaments that caused formation of horst and graben structures (Sinha-Roy, 1986; Dassarma, 1988; Roy, 1999). These paleo-lakes are replenished by surface runoff during the months of south-west monsoon and deposit allochthonous detritals and authigenic evaporites depending on the inflow quality (salinity, composition), quantity (inflow strength) and aeolian activity. In the recent years, a number of studies were aimed at reconstructing the paleo-hydrological changes using the sedimentary archives preserved in these shallow lakes of the Thar Desert (Wasson et al., 1984; Singh et al., 1990; Enzel et al., 1999; Deotare et al., 2004; Sinha and Raymahashay, 2004; Roy et al., 2006). The available paleo-hydrological and paleo-climatological information suggests that the region experienced enhanced aridity during last glacial maximum (LGM), fluctuating condition till 7–8 ka and improved perennial condition till 5–6 ka. The lakes from the eastern margin are experiencing ephemeral conditions since the last 3.5 ka, whereas the lakes from the north-western and western margin are ephemeral since the last 5 and 6 ka, respectively.

In this paper, we attempt to understand the paleo-hydrological and paleo-limnological conditions documented in a shallow sediment core from Pachapadra paleo-lake situated in the south-central Thar Desert. The geochemical zones supported by elemental concentrations and evaporite mineralogy delineate three phases of varying chemical weathering, evaporation and aeolian activity.

2. Climate and geography

The Thar Desert extends from the Archean/Proterozoic Aravalli mountain range (India) in the east to the perennial Indus river (Pakistan) in the west. A major part of it is located in the western part of Rajasthan state of India (Fig. 1). The instrumental record of the last 130 yr (source: Indian Institute of Tropical Meteorology, Pune) suggests that like the rest of India, the Thar experiences similar fluctuating south-west monsoon, which has been related to the land–sea temperature contrast and Eurasian/Tibetan snow cover (Dickson, 1984; Meehl, 1994). The region shows a decreasing average annual rainfall gradient (500–100 mm) from east to west, which has been related to the subsidence of air mass and large quantity of aerosols in the atmosphere (Das, 1962; Datta and George, 1964; Bryson and Baerreis, 1967). The drainage networks of the Luni river, which carries water from the western slopes of the Aravalli mountains to the Rann of Kutchh in the Arabian Sea, indicate a south-western regional slope (Fig. 1).

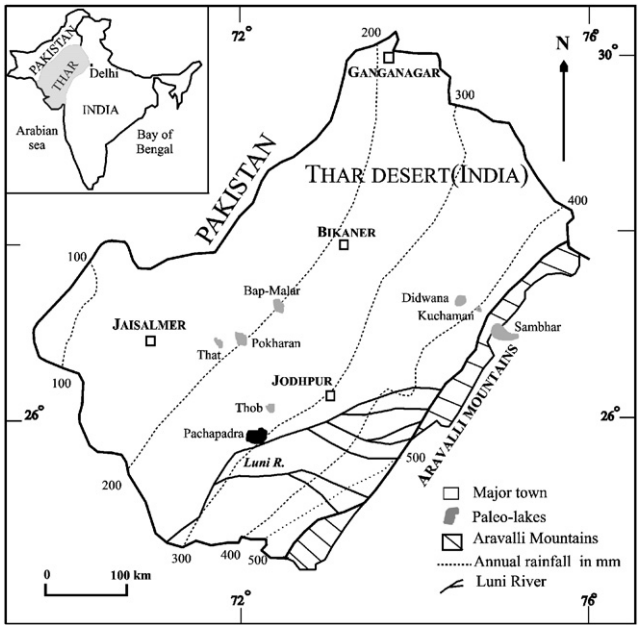

Fig. 1. Location map of different saline paleo-lakes located in the Thar Desert, north-west India. The region shows a gradual increasing aridity from east to west. Pachapadra paleo-lake (shown in dark grey colour) is located in the south-central Thar Desert.

The higher average annual temperature ranges between 45 and 50 °C and hence the annual evapo-transpiration in the region varies between 1500 and 2000 mm. Across this rainfall and evapo-transpiration gradient, a number of saline, shallow paleo-lakes are present, which receive rainfall for few days and remain dry for the rest of the year. Most of these lakes receive soluble ions and sediments from the chemical weathering of the igneous and metamorphic rocks (quartzite, mica-schist, granite, marble, granitic pegmatites and gneisses) exposed along the Aravalli mountains (Sinha and Raymahashay, 2004; Roy and Smykatz-Kloss, 2005).