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Climate variation in the Thar Desert since the Last Glacial Maximum and evaluation of the Indian Monsoon

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Abstract

Thar Desert is a rainfall deficient (~500-100 mm/year) region in the northwestern India. Previously published information on sediment facies, mineralogy, and radiocarbon chronology helped to reconstruct orbital-scale lake stands and variations in water column salinity of five different lacustrine basins in the desert. We evaluated the hydrological conditions with respect to strength (i.e., amount and geographic coverage) of the southwest summer monsoon since the last glacial maximum (LGM). Between LGM and c.15 cal. ka BP, the eastern basins hosted saline and hypersaline playa lakes and the western part had an intermittent variable lake. A shift from saline-hypersaline playa lakes to perennial deep lakes occurred in the eastern margin at c.15 cal. ka BP as more summer insolation increased sea surface temperature (SST) of the Indian Ocean and strengthened the southwest summer monsoon. During the Pleistocene-Holocene transition, the highest summer insolation as well as warmer SST of the Indian Ocean increased the amount of summer precipitation and expanded the southwest monsoon over the entire desert. However, more winter precipitation and minimal summer rainfall maintained perennial lakes across the desert during the early and middle Holocene. Over the middle-late Holocene, the regional arid conditions were contemporary to intervals of reduced summer insolation, southerly located Inter-Tropical Convergence Zone and frequent El-Niño Southern Oscillation.

Key Words: Forcing, Indian Monsoon, Orbital-scale, Paleoclimate, Pleistocene-Holocene, Thar Desert.

Variación climática en el desierto de Thar desde el Último Máximo Glacial y evaluación del Monzón de la India

Resumen

El desierto de Thar está ubicado en la parte noroccidental de la India y es una región con escasez de lluvia (~500-100 mm/año). Los datos previamente publicados sobre la mineralogía, facies sedimentarias y cronología de radiocarbono han ayudado a reconstruir los cambios en el nivel lacustre y la salinidad de los cuerpos de agua en la escala orbital en cinco diferentes cuencas lacustres del desierto. Se evaluaron las condiciones hidrológicas en términos de la variación en la fuerza (cantidad y cobertura geográfica) del monzón del suroeste desde el último máximo glacial (UMG). Entre el UMG y aproximadamente 15 ka cal AP, las cuencas de la parte oriental mantuvieron lagos salinos e hipersalinos y la parte occidental tuvo un lago intermitente. El cambio de una playa salina-hipersalina a un lago perenne con condiciones profundas ocurrió en la margen oriental alrededor de los 15 ka cal AP a medida que la insolación de verano aumentó tanto la temperatura superficial del mar (TSM) del Océano Índico como la fuerza del monzón del suroeste. Durante la transición del Pleistoceno al Holoceno, la mayor insolación de verano y la alta TSM del Océano Índico aumentaron la cantidad de lluvia de verano y facilitaron la expansión del monzón a todo el desierto. Sin embargo, el predominio de las precipitaciones de invierno sobre las lluvias de verano durante el Holoceno temprano y medio mantuvieron lagos perennes a lo largo del desierto. Durante el Holoceno medio y tardío, las condiciones más secas en la región fueron contemporáneas a los intervalos de reducción en la insolación de verano, la ubicación de la Zona de Convergencia Intertropical en una latitud sureña y el aumento en la actividad de El Niño-Oscilación del Sur.

Palabras Clave: Forzamiento, Monzón de la India, Escala orbital, Paleoclimatología, Pleistoceno-Holoceno, Desierto de Thar.

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Introduction

The southwest summer monsoon is one of the principal global meteorological systems and it contributes dominantly to hydrological budget of India[1]. It begins from southern margins of the country in the earliest stage and reaches the northwestern part at an advanced stage (Figure 1). Modelling studies suggest a strong link between strength of the monsoon system and summer insolation[2-3]. Insolation modulated sea surface temperature (SST) of the tropical Indian Ocean and associated evaporation provide most of the water vapour for precipitation[4-5]. More summer precipitation is related to warmer conditions in the Arabian Sea during the pre-monsoon months[6] and position of the Inter-Tropical Convergence Zone (ITCZ) at northern latitudes[7-8]. SST anomalies in the central-eastern Pacific Ocean associated with the El Niño-Southern Oscillation (ENSO) also have a teleconnection with the monsoon[9-10]. Below normal summer rainfall occurs during the El Niño years and the rainfall is above average in years with La Niña conditions[11-12]. Recently, Annamalai *et al.* (2013)[13] observed that amounts of modern era rainfall shows inverse relationship with concentrations of greenhouse gases in the atmosphere and SST of the western Pacific Ocean.

In geological registers, varying strengths of the summer monsoon was in phase with North Hemisphere insolation[14]. This relationship weakened with increasing influence of the glacial forcing. Influence of ITCZ on the Indian monsoon was evaluated in speleothem records from the Oman and Yemen for the Holocene[15] and in sediments of the Arabian Sea for the late Pleistocene[16]. Productivity of planktic foraminifera and

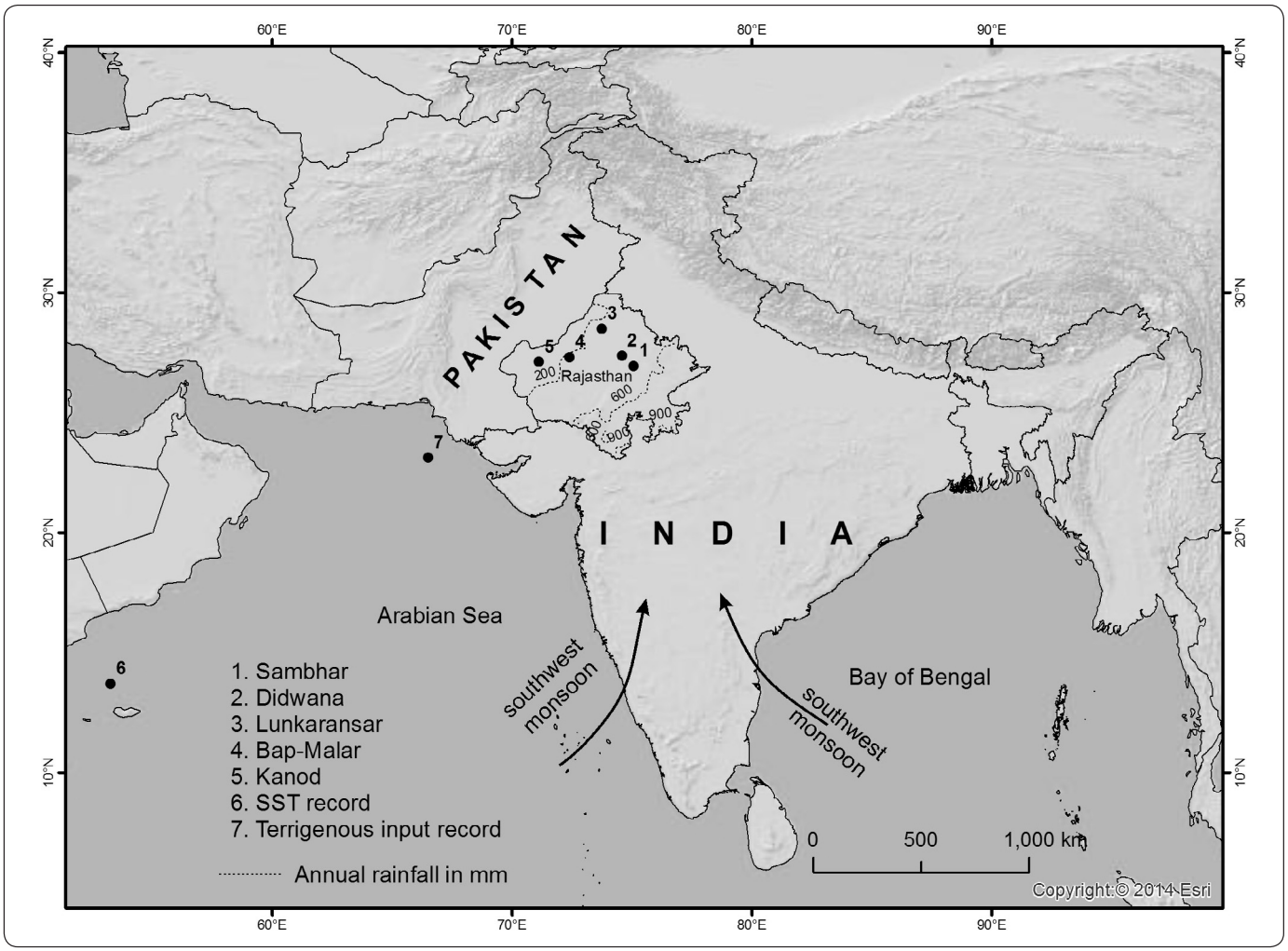

Figure 1. A large part of the Thar Desert is located in western part of the Rajasthan state of India. Reviewed lacustrine basins are present in an east-west transect. Terrigenous input into the eastern Arabian Sea[17] estimates summer precipitation associated with the southwest monsoon and alkenones from the western Arabian Sea[18] provide information about sea surface temperature (SST) of the Indian Ocean.