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Palaeoecology and the Harappan Civilisation of South Asia: a reconsideration

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Abstract

Climatic change has often been cited as a determining factor in cultural changes in the context of the Harappan Civilisation of northwestern South Asia, 2500–1900 BC. While these claims have been critiqued by archaeologists they continue to be accepted by non-archaeologists, including Quaternary scientists. The purpose of this paper is to assess the available evidence and published arguments and to provide a constructive working synthesis of evidence for the palaeoenvironmental setting of northwestern South Asia for the mid- to late Holocene, especially ca 4000–1000 cal BC, and its possible connection to important cultural changes. We conclude that Harappan urbanism emerged on the face of a prolonged trend towards declining rainfall. No climatic event can be blamed for a precipitous end of this civilisation, although strategic local shifts in agriculture that may have begun in response to prolonged droughts at ca 2200 BC may have contributed to the de-urbanisation process and the restructuring of human communities over the following 200–300 yr.

1. Introduction

There is evidence that recent extreme climatic events, which caused severe and prolonged drought, have had an impact on human populations. Especially important was the probable loss of crop production associated with these events, which caused famine and human displacements (Bourke, 2000). Even if with respect to the glacial–interglacial cycles the Holocene is considered stable, smaller-scale climatic variability has characterised the entire Holocene. Recently, several studies have explored past cultural adaptations to persistent or rapid climate change (see, e.g., de Menocal, 2001; Weiss and Bradley, 2001; Haberle and David, 2004; Wengxiang and Tungsheng, 2004). Climatic change has often been cited as a determining factor in cultural changes in the context of the Harappan Civilisation of northwestern South Asia, 2500–1900 BC (Fig. 1). This was first clearly articulated in the 'culture–climate' hypothesis of Singh (1971; Singh et al., 1974), who attributed the flourishing of the Harappan Civilisation to a period of higher rainfall during the third millennium BC and its fall to a drop in rainfall that was identified on the basis of pollen sequences from the salt lakes of Rajasthan at ca 3700 BP (ca 2100 cal BC; see also Bryson and Swain, 1981; Agrawal, 1982a; Swain et al., 1983). While these claims have been critiqued by archaeologists (e.g., Misra, 1984; Ratnagar, 1987, 2000; Shaffer and Liechtenstein, 1989; Paddaya, 1994; Possehl, 1997a, b, 1999, pp. 257–268; Fuller and Madella, 2001), they continue to be uncritically accepted by non-archaeologists including some Quaternary scientists (e.g., Naidu, 1996; Bentaleb et al., 1997; von Rad et al., 1999; Staubwasser et al., 2003). By contrast some archaeologists (e.g., Possehl, 1999, p. 268) consider climate change over the past 7000 yr to have been negligible or irrelevant for understanding past economies and social change. Arguments from both sides (Archaeology and Quaternary science) often tend to uncritically and unsystematically cite the relevant literature of the other discipline. The purpose of this paper is to critically assess the available evidence and published arguments and to provide a

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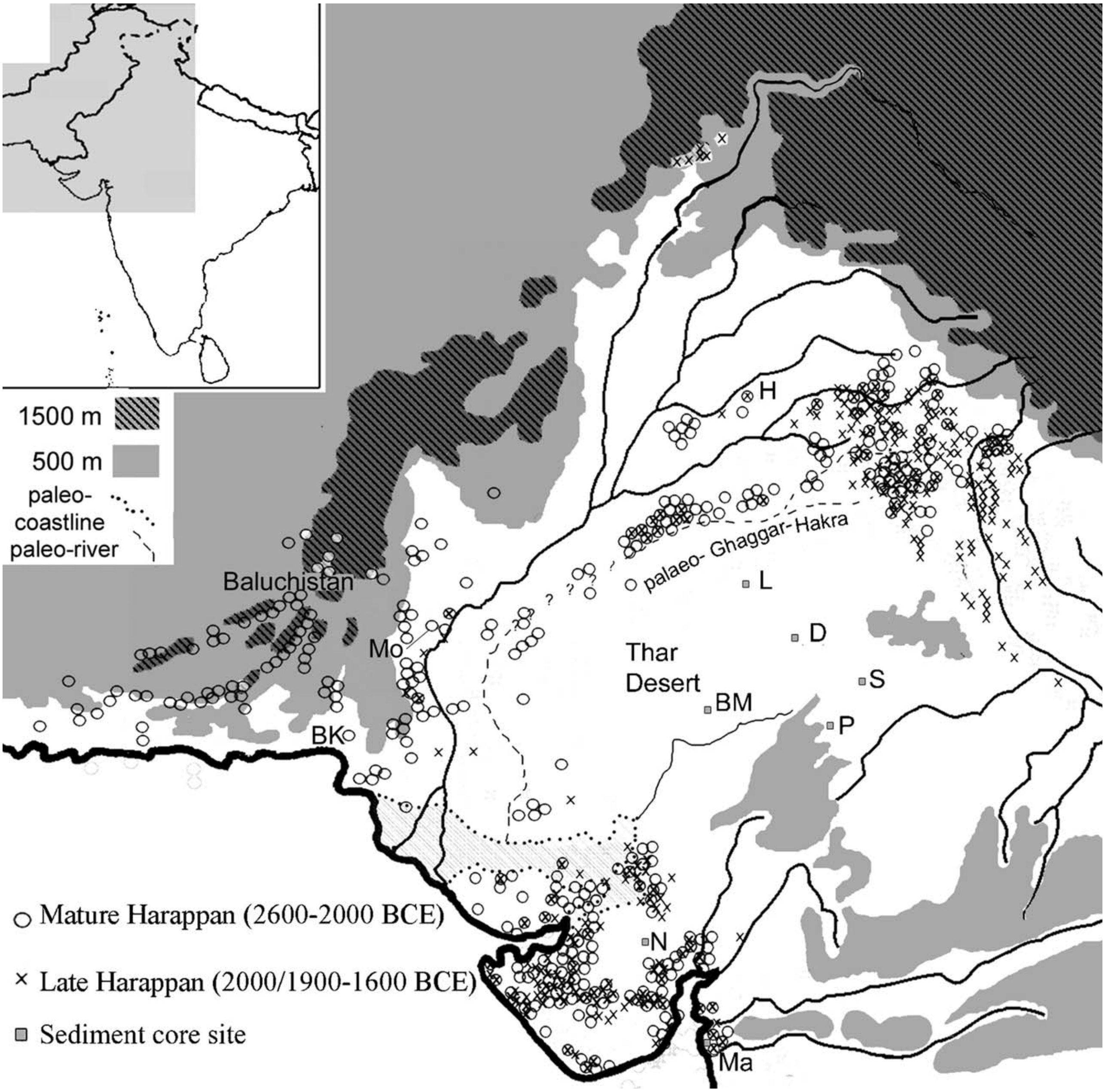


Fig. 1. Map of northwest Indian sub-continent with the archaeological sites of the Harappan Civilisation (circles identify Mature Harappan sites while crosses identify Late Harappan sites; for chronology see Table 1) and palaeoenvironmental records for the region (indicated by squares). Sites discussed in paper are identified by the following abbreviations: BK, Balakot; BM, Bap-Malar playa; D, Didwana Lake; H, Harappa; L, Lunkaransar Lake; Ma, Malvan; Mo, Mohenjo-daro; N, Nal Sarovar; P, Pushkar Lake; S, Sambhar Lake.

constructive synthesis of evidence for the palaeoenvironmental setting of northwestern South Asia for the mid- to late Holocene, especially at ca 4000–1000 cal BC.

2. The Indus or Harappan Civilisation

The Harappan Civilisation in what is modern-day Pakistan and India (Fig. 1) was the apex of a long cultural trajectory that started on the western highlands of Baluchistan and then moved into the greater Indus Valley. The greater Indus Valley is centred on the hydrological basin of the Indus River and its tributaries (the Jhelum, Chenab, Ravi and Sutlej rivers).

The early food-producing communities (7000–4300 BC, see Table 1) are found on the hills of Baluchistan, Northwestern Frontiers and Sindh (however, early sites in the plains of the Indus might be covered by thick alluvium). These are agricultural and pastoral villages. There is subsequently (4300–3200 BC) a consolidation of the early communities with a continuous growth in settled life as well as geographical expansion further into the plains. These communities have a clear cultural continuity

Table 1
Two major variants of archaeological chronology and terminology for northwestern South Asia

Chronology of the Indus Age according to Kenoyer (1998) and based on the stratigraphy at Harappa (Punjab, Pakistan)			Chronology of the Indus Age according to Possehl (2002)		
Period	Phase	Years BC	Years BC	Stage	
1A/B	Early Harappan/Ravi Phase	ca 3300–2800	7000–5000 and 5000–4300	Beginning of village farming communities and pastoral societies (two non-contemporaneous phases)	1
2	Early Harappan/Kot Diji Phase	ca 2800–2600	4300–3800 and 3800–3200	Developed village farming communities and pastoral societies (two non-contemporaneous phases)	2
3A	Harappan Phase	ca 2600–2450	3200–2600	Early Harappan (four contemporaneous phases)	3
3B	Harappan Phase	ca 2450–2200	2600–2500	Early Harappan/Mature Harappan Transition	4
3C	Harappan Phase	ca 2200–1900	2500–1900	Mature Harappan (five contemporaneous phases)	5
4	Harappan/Late Harappan Transitional	1900–?1700	1900–1000	Post-urban Harappan (several non-contemporaneous phases)	6
5	Late Harappan (Cemetery H)	?1700–1300	1000–500	Early Iron Age of N. India and Pakistan Painted Grey Ware	7

At the left is the chronology proposed by Kenoyer (1998), while that on the right is from Possehl (2002).

with the earlier ones accompanied by technological developments with, e.g., the introduction of the potter's wheel (Possehl, 2002). The Early Harappan (3200–2600 BC) is characterised by incipient urbanism, growth and further expansion of the farming communities into new territories. The transition between the Early and Mature Harappan (2600–2500 BC) see the appearance of the cultural innovations and the unifying attributes that will typify the Mature Harappan. During the Mature Harappan (2500–1900 BC) the Harappan Civilisation covers an enormous region with evidence for an elaborated and stratified society, the presence of complex architecture, a sophisticated material culture and an overarching ideology (Kenoyer, 1998, Possehl, 2002). It is during the Mature Harappan that there is the setting of urbanisation and a rapid growth of cities like Harappa and Mohenjo-daro. The Post-urban Harappan sees a demise of the urban character of this civilisation with many areas abandoned or more sparingly occupied and a proliferation of smaller, village-like, settlements.

3. Holocene climatic sequences and archaeology in South Asia

The problems of chronological correlation and causal linking in the archaeology and climatology of South Asia remain both acute. The use by some researchers of uncalibrated and by others of calibrate radiocarbon dates (radiocarbon dates in the present paper were calibrated according to OxCal version 3.3, Bronk Ramsey, 1995, 2001), even in comparisons between marine and terrestrial data sets (cf. Stuiver and Braziunas, 1993; Stuiver et al., 1998), creates difficulties for accurate correlation. In addition, within South Asia, some archaeological and Quaternary palaeoecological studies have used the 5730 yr half-life rather that the Libby half-life of 5568 yr that is the accepted standard elsewhere (e.g., Agrawal, 1982b; Singh et al., 1990). Previous discussions of radiocarbon calibration for pollen sequences and archaeology of northwestern Indian deposits suggested that the Rajasthan pollen evidence indicates the exact opposite of what Singh had argued, namely the rise of Harappan Civilisation during increasing aridity (e.g., Shaffer and Liechtenstein, 1989; Fuller and Madella, 2001, pp. 362–363). Enzel et al. (1999), on the basis of sedimentary evidence from the Lunkaransar playa, also contradict the culture–climate hypothesis. In addition, as discussed by a number of archaeologists, arguments linking climatic changes with archaeologically documented cultural changes have rarely been explicitly laid out (see, e.g., Paddaya, 1994; Possehl, 1997a, b).

Another factor in the Holocene environmental history of the northwestern sub-continent, overlooked in some discussions of Quaternary palaeoecology, is the changes in the river drainage system, especially the Ghaggar-Hakra system (see Fig. 1) flowing roughly parallel but separate to the Indus (Agrawal and Sood, 1982; Misra, 1984; Courty and Federoff, 1985; Courty et al., 1989; Agrawal, 1992, pp. 237–242; Possehl, 1997b, 1998; Kenoyer, 1998, p. 173; Schuldenrein et al., 2004). Archaeological research in Cholistan has led to the discovery of a large number of sites along the dry channels of the Ghaggar-Hakra river (often identified with the lost Sarasvati and Drishadvati rivers of Sanskrit traditions) (e.g., Mughal, 1982, 1997; Dikshit, 1984; Misra, 1984; Flam, 1986; Possehl, 1997a, 1999). Along the Ghaggar-Hakra there is a relatively high frequency of settlements during the Mature Harappan (2600–2000 cal BC), which suggests a well-watered region that could support agriculture. This may be interpreted either as a river or an inland delta in the area around Derawar (see Fig. 1). By the time of the Painted Grey Ware period (ca 1200–500 cal BC) the river must have been dry, because several sites of this period are found in river bed contexts. This change, thought to have been brought on by tectonic uplift and the capture of the Ghaggar-Hakra headwaters by the Yamuna watershed (Agrawal and Sood, 1982; Agrawal, 1992, pp. 237–242), led to gradual desiccation during the Holocene, which was well underway by the period of the Harappan Civilisation (Courty and Federoff, 1985; Courty et al., 1989). The final desiccation of some of these channels may have had major repercussions for the Harappan Civilisation and is considered a major factor in the de-centralisation and de-urbanisation of the Late Harappan period (Misra, 1984; Chakrabarti, 1995, p. 274; Allchin and Allchin, 1997; Mughal, 1997; Fuller and Madella, 2001). The capture of the Ghaggar-Hakra waters by the Yamuna would have also decreased the water outflow into the Gulf of Kutch, and thus offers an alternative, non-climatic explanation to changes in the sedimentation rate of varve-like sediments off the Karachi coast (cf. von Rad et al., 1999). Although, it is not clear how this would have affected $\delta^{18}O$ records, the palaeo-Ghaggar-Hakra with more easterly headwaters might be expected to have carried a higher proportion of monsoon derived water, heavier in $\delta^{18}O$ (cf. Staubwasser et al., 2003).

4. The salt lakes of Rajasthan as palaeoclimatic records of South Asia

The Thar Desert of western Rajasthan and adjacent parts of Gujarat to the south include numerous lakes and playas that have provided sampling sites for several palaeoenvironmental studies (Fig. 1). These lakes served as pollen traps from the late Pleistocene until the later mid-Holocene, and the implications of their vegetational record are discussed below. These lakes, however, have also provided climatic data from their sedimentology and geochemistry (e.g., Wasson et al., 1984; Enzel et al., 1999) and some workers have questioned whether salinity and lake levels are linked to climatic conditions (Vishnu-Mittre, 1976, p. 554; Possehl, 1997b). Globally, saline lakes and playas are associated with arid regions of high evaporation and during particularly dry periods, lower water levels are recorded as halites (Watson, 1983; Williams et al., 1993). There may be, however, numerous local factors affecting the condition of individual lakes, as is the case of Rajasthan. The origins of the salt lakes of Rajasthan have long spurred controversy (reviewed by Possehl, 1997b), but there appear to be a few interrelated processes that account for most, if not all, of these lakes. Roy (1999) suggests that most of these lakes derive from segmented palaeochannels, while a few have developed from streams trapped between a succession of longitudinal dunes (e.g., Didwana). The location of these lakes and at least some of the stream segmentation processes appears to be related to neotectonic action. Increasing evidence indicates that Rajasthan is cross-cut by northeast–southwest and southwest–southeast faults, and the intersections of these have served as the basins for many lakes (Roy, 1999). In the case of Lake Sambhar, e.g., the structural depression appears to be where two tectonic blocks have pulled apart. The suggestion by some authors (e.g., Vishnu-Mittre, 1976; Possehl, 1997b, p. 205) that the salt lakes derive from brine springs does not fit with the available evidence. Nevertheless, as the case of the freshwater lake at Pushkar or the Lunkaransar playa, sub-surface drainage may have played an important role in these anomalous cases (Possehl, 1997b; Enzel et al., 1999). This evidence raises the possibility that changes in sub-surface drainage, connected to regional precipitation and perhaps tectonic events, may have affected salinity levels. While the drying up of several of these lakes in the late third millennium BC could be connected to such changes in sub-surface hydrology, it is notable that the anomalous freshwater Pushkar Lake does not dry up. Recent environmental work on three more playas of western Rajasthan (Pushpendra, Thob and Bap-Malar) has been argued to indicate some effects of local hydrological conditions on plant assemblages (Deotare and Kajale, 1996; Kajale and Deotare, 1997; Deotare et al., 1998, 2004a, b). Nevertheless, the broader patterns in the pollen assemblages should represent regional vegetation, and the correlation between sequences, as well as with other palaeoclimatic proxy records, indicate that these lakes provide useful palaeoenvironmental data.

The drying of particular lakes and movement of sand dunes may also be connected to climatic aridification, though these proxies show a greater degree of distinct local patterns. For example, the litho-stratigraphic column at Bap-Malar playa (Jodhpur district) suggests that the lake had already dried up by around 6000 BP (ca 4850 cal BC) (Deotare et al., 1998, 2004a). If extrapolated, this would imply relative stability of the locally low level of precipitation since well before the Early Harappan period. Indeed, thermoluminescence dating of sand profiles from three other sites in Rajasthan indicates that accretion of wind-blown sands (due to a drier climate) recommenced between ca 6400 and 5500 BP (ca 5930 and 4345 cal BC), after a hiatus throughout the terminal Pleistocene and the earlier Holocene (Chawla et al., 1992). Other sand stabilisation data sets from northwest India differ, however. For example, the final activity of the now stabilised dunes around the Bap-Malar playa appears to predate the lake's desiccation at ca 7000 BP (ca 5860 cal BC) (Deotare et al., 1998, 2004a, b). Further east, a profile at Manawara, south of the Luni river bend, suggests stabilised dunes during the mid-second millennium BC but drier conditions and sand movement in the first millennium BC (Mishra et al., 1999). The growing evidence for local variation in conditions affecting dune stabilisation, sand movement and lake water levels warns against extrapolation from single sequences to macro-regional climatic patterns.

Despite local effects, there remain large-scale patterns of vegetational and sedimentary change that can be correlated between sites and related to more global climatic patterns. During the preceding early and middle Holocene, the respective broad phases of high and low lake stands appear well correlated between lakes and agree with the palynological evidence for past rainfall regimes (see Table 1 and discussion below). The numerous short-term fluctuations in the inferred lake levels cannot be established as relating to short-duration climatic events due to lack of dating precision that might allow correlation between sites. The broad patterns are congruent with mid-Holocene changes in precipitation, however, and recent research on planktonic oxygen isotope ratios off the Indus delta suggests a link between solar variability and the South Asian climatic change (Staubwasser et al., 2002, 2003). Indeed, the high-resolution data available from the Karachi Delta $\delta^{18}O$ record provides a good overall match to global patterns mapped in the Greenland GISP methane curve as well as several lake level fluctuations in the Thar Desert lakes (Fig. 2). These patterns, therefore, allow us to reconstruct the climatic variability during the period encompassing the Harappan Civilisation.

5. Palynology and vegetational change in the Thar Desert

Aridity in northwest South Asia is centerd on the Thar Desert, where mean annual rainfall is less than 100 mm. Around this very arid core are more or less concentric belts of increasing rainfall, from arid (100–250 mm) to semi-arid (250–500 mm) and to semi-humid (500–600 mm), which mirror the distribution of plant species (Singh et al., 1973; Meher-Homji, 2001). The southwest monsoon of the summer months is the origin of most of the rain for the semi-arid and arid regions of Rajasthan. The air circulation in winter is characterised by winds of continental origin from the northwest. The resulting winter rainfall is primarily restricted to the area north and northwest of Delhi and gradually decreases towards the Thar Desert. The very dry and dry areas of the Thar are distinguished by thorny vegetation characterised by plants of the ‘‘sand formation’’ (Blatter and Hallberg, 1918–21) dominated by *Calligonum polygonoides*, *Aerva* sp. and other taxa adapted to live on sandy, non-stabilised sediments. Gravel and rocks are colonised by scattered trees and shrubs like *Zizyphus nummularia*, *Prosopis cineraria*, *Salvadora oleoides* and *Capparis decidua*. The semi-arid zone has a relatively higher rainfall and often impeded drainage caused by sand dunes. The playa lake basins in the region sustain halophytic and more water-demanding taxa like *Tamarix* sp., *Sueda fruticosa*, *Salsola foetida* and *Chenopodium* sp. The primary difference between this zone and the more arid areas is the greater abundance in trees, which creates a grass savannah covering much of this territory. The semi-humid area, running along the Aravalli Hills and north of Delhi in Haryana and Punjab, is associated with a denser presence of trees with many species of *Acacia*.

The interpretation of some pollen indicators and their relationship to rainfall has been disputed, but a number of changes in the pollen sequences are clearly indicated. Anthropogenic factors also had an important role to play in changing the vegetation (Vishnu-Mittre, 1974, 1976, 1978, 1981, 1982; Meher-Homji, 1980, 1994a, b, 1996a, b). Vishnu-Mittre (1981) highlighted the problems of extrapolation from incompletely known modern plant ecologies to past environments. Nevertheless, these data were used to infer quite precise changes in summer and winter precipitation over northwestern India (Bryson and Swain, 1981; Swain et al., 1983). As we claim below, the large-scale correlations between sequences and with those across the Indian Ocean area argue for climatic changes, although local discrepancies suggest that these data are not robust enough to sustain the use for precise calculations of rainfall variations.

The most comprehensive palynological evidence from lakes in the Thar Desert is that of Singh et al. (1974) from four lakes in Rajasthan (Fig. 1), which has served as the basis of interpretation by numerous authors (e.g., Singh, 1971; Bryson and Swain, 1981; Swain et al., 1983; Sharma and Chahuan, 1991). In the original publication, the best-dated sequence was that from Sambhar Lake, which served as the type sequence to which the others were related, although the age of one of the key changes towards the top of the sequence had to be extrapolated. Unfortunately, the assumption of constant sedimentation rates is problematic on account of inferred changes in rainfall levels and probable local cultivation that could have affected erosion rates. Additional, and better-dated, sequences have been studied subsequently, using sedimentology, geochemistry and pollen analyses at Didwana (Wasson et al., 1984; Singh et al., 1990), and sedimentology and geochemistry at Lunkaransar (Enzel et al., 1999) (Table 2).

Linked changes in the Didwana (Fig. 3) and Lunkaransar (Fig. 4) sequences can be traced from an arid phase of the late Pleistocene (Table 2). After the Last Glacial Maximum (LGM), the Lunkaransar basin was dry (Fig. 4) and Didwana (Fig. 3) shows evidence for frequent evaporation (arid plant taxa) suggesting that the pre-LGM arid conditions continued, albeit at reduced levels. The Didwana assemblage is rich in the pollen of grasses, sedges, *Chenopodiaceae/Amaranthaceae* and *Artemisia*, and it is interpreted as reflecting the development of grass-steppe vegetation following a period of extreme aridity (Singh et al., 1974, 1990). In general, the early Holocene was wetter, with rises in marsh plants including sedges (which could include those growing in saline conditions) and *Typha* (suggesting freshwater conditions only). This long early Holocene wet phase was punctuated by brief, more arid intervals (see Fig. 2). These are indicated by gypsum evaporite layers in Lunkaransar Zones 1 and 2 (Enzel et al., 1999), as well as in the fluctuating frequencies of some of the plant taxa, shown most clearly in the Didwana sequence (Singh et al., 1990). Similarly brief episodic fluctuations between wetter and drier conditions are indicated in marine isotopic records (Staubwasser et al., 2002, 2003).

Another wet phase began after 5000 cal BC, indicated by high and continuous lake levels at Lunkaransar Zone 3 and

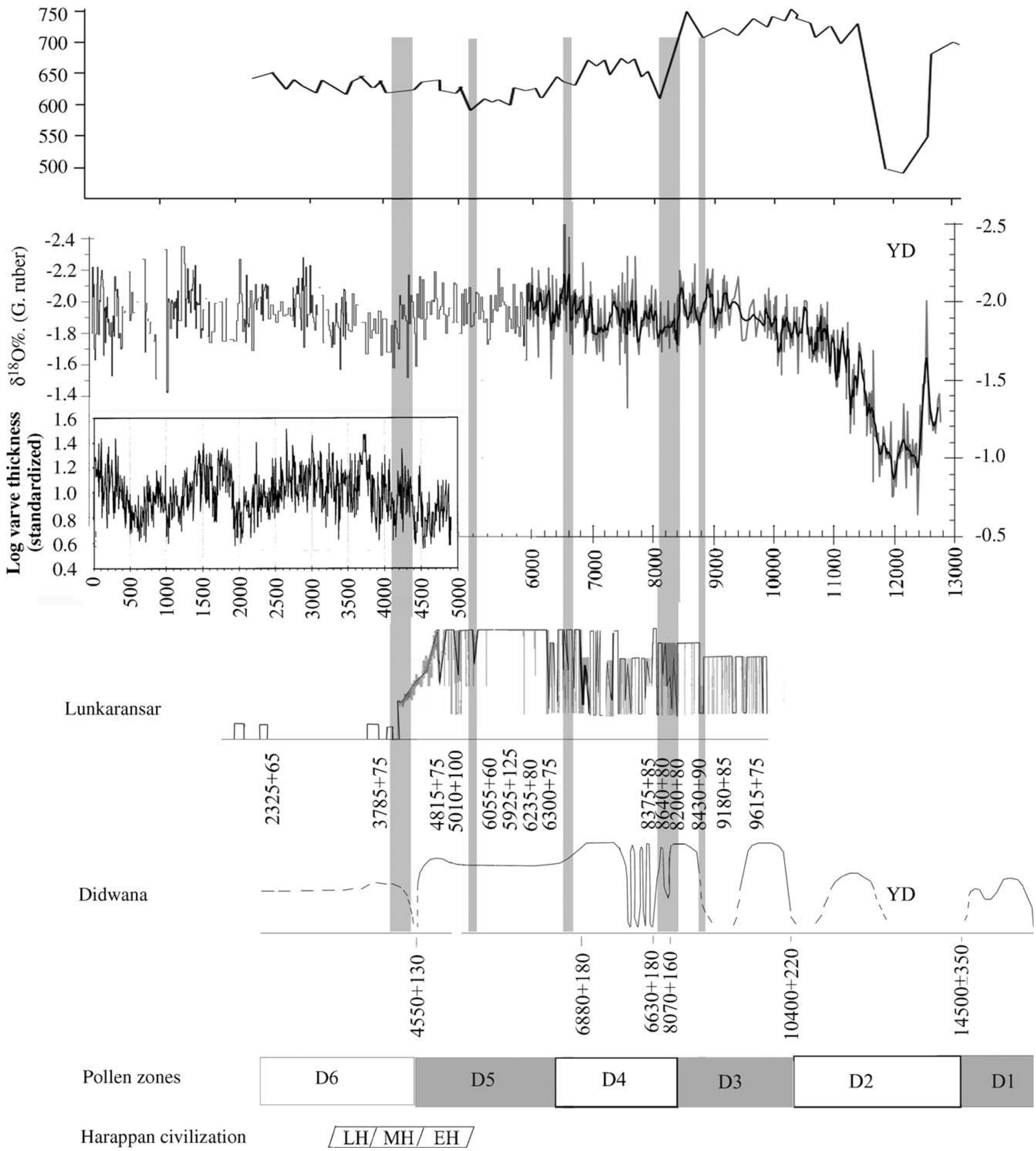


Fig. 2. Correlation between various palaeoclimatic proxies from northwestern South Asia and global climate change. From top to bottom: global atmospheric methane as measured in the Greenland GISP core (after Blunier et al., 1995); $\delta^{18}O$ isotopic variation from Pakistan continental margin (after Staubwasser et al., 2002, 2003); 5000 yr of Indus discharge inferred from the Karachi Delta varve thickness level (after von Rad et al., 1999); lake level data from Lunkaransar Lake, major trends in black (after Enzel et al., 1999); lake level data from the Didwana Lake (after Wasson et al., 1984); the Didwana pollen zones (after Singh et al., 1990), and the main phases of Harappan Civilisation (simplified from Table 1). Some major correlated events are indicated in grey, while the Younger Dryas (YD) is also indicated.

Didwana Zone D5 (Table 2). This mid-Holocene wet period appears to have been wetter than the early Holocene "wet phase" in Rajasthan. However, it is likely that the additional moisture available was connected with more intrusive winter rains from the northwest (see Bryson and Swain, 1981, p. 137; Singh et al., 1990; Phillips et al., 2000; Staubwasser et al., 2003). This wet phase was followed by a drier period. In both sequences, this aridity had fully set in before 4000 BP (2900–2700 cal BC in Lunkaransar and 2850–2450 cal BC for Didwana). A similar trend can be

Table 2
Tabular summary of palaeoenvironmental phases of Didwana Lake sediments (locus DIA1, based on Singh et al., 1990) and of Lunkaransar Lake sediments (based on dated stratigraphy from Enzel et al., 1999 and correlated with palynology from Singh et al., 1974)

Pollen zone	Sedimentology in relation to lake level (also Wasson et al., 1984)	Climatic interpretations	Chronological synthesis (calendrical period)	Pollen zone (Singh et al., 1974)	Sedimentology in relation to lake level (Enzel et al., 1999)	Climatic interpretations (cf. Bryson and Swain, 1981)	Chronological synthesis (calendrical period)
D6	Poorly laminated, silty clays, ephemeral lake	Arid, low rainfall as present day	Post-2800 BC	LK-4 post-pollen hiatus	(Zone 4) Drying playa and episodic lakes, saline	Declining rainfall to modern levels of aridity	Post-2800 BC
D5	Laminated clays: moderately deep fresh water	Wet but with declining rains	5200–2800 BC	LK-3	(Zone 3) Maximum lake depth, no gypsum, d 13C increase suggests algae in deep water	Consistently high rainfall levels, including maximal winter rains	5200–2800 BC, drying begins between 3950 and 3700 BC, equivalent to start of pollen Zone 3
D4	Laminated clays: deep, permanent fresh water, but with fluctuations to dry, evaporite conditions during early part of phase	High rainfall (including peak winter rains): local savannah grasslands	7000–5200 BC	LK-2b (possibly continuing into sedimentary Zone 3)	(Zone 2) Laminated clay silt alternating with gypsum rich layers, C-13 suggests algal mat in shallow water: fluctuating shallow lake to saline playa, with extremes	High rainfall (with winter rains), alternating with more frequent/severe arid episodes	7000–5200 BC
D3	Laminated clay	Shrub savannah grassland	8500–7000 BC	LK-2a	(Zone 1) Laminated clay silts with some gypsum evaporite layers: fluctuating shallow lake, fewer extremes	High rainfall, with anthropogenic(?) burning	Pre-7000 BC. Arid spells ca 9200–8800, 8500–8300 and 7300–7050 BC
D2	Laminated and unlaminated clays alternate: intermittent filling with freshwater and saline shallow water, rainfall fluctuations	Shrub savannah grassland	12500–8500 BC	LK-1		Higher rainfall, including winter rains, with arid episodes	
D1	Halite: evaporating lake: hyperarid	Arid steppe/desert	19,500 BC?–12,500	Loose, sterile sand		Hyperarid	Last Glacial/Younger Dryas

Note that the two ages for the LK-2b and LK-3 transition appear to be too young and should probably be disregarded in favour of the more numerous and consistent AMS dates of Enzel et al. (1999).

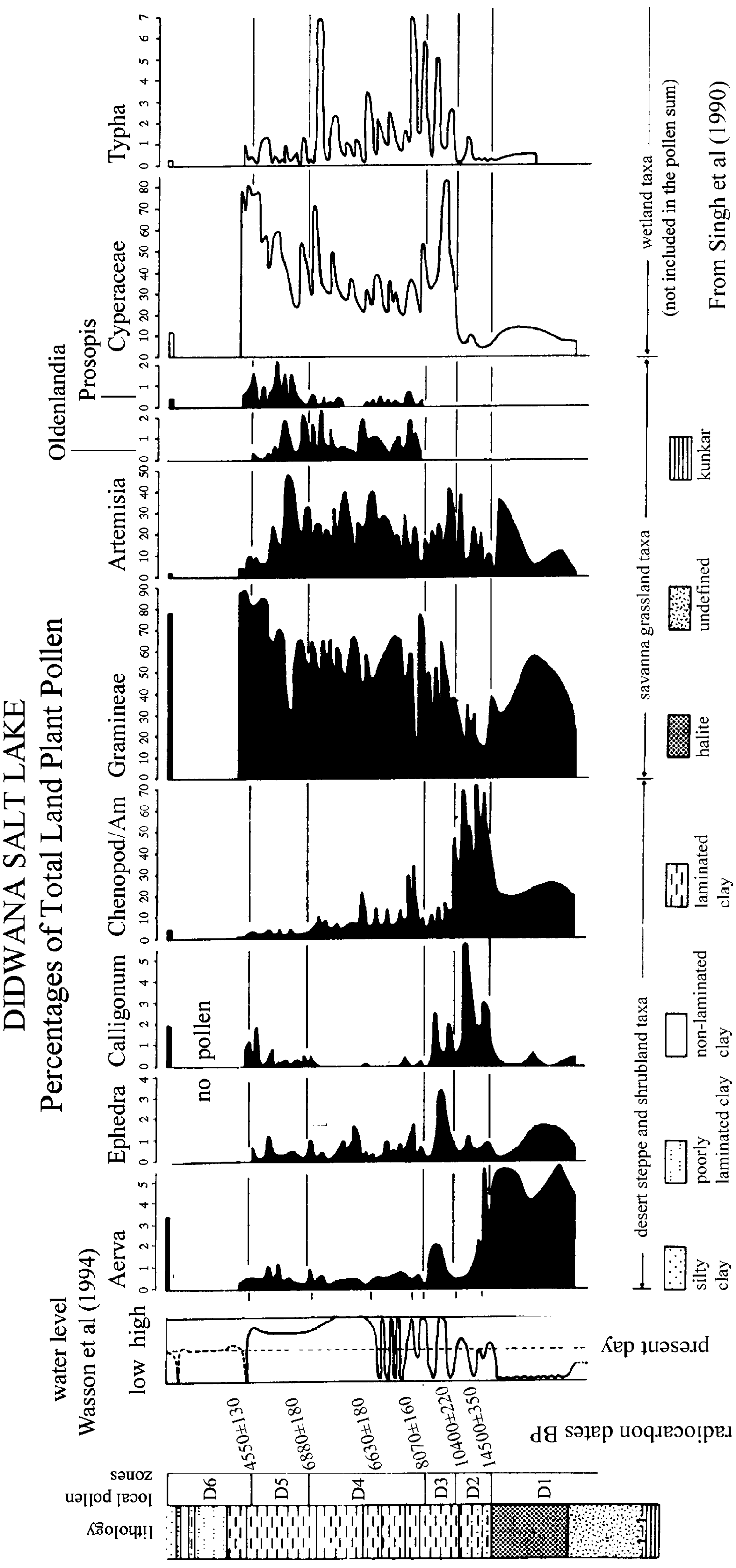


Fig. 3. Pollen diagram of Didwana salt lake (Rajasthan, India).

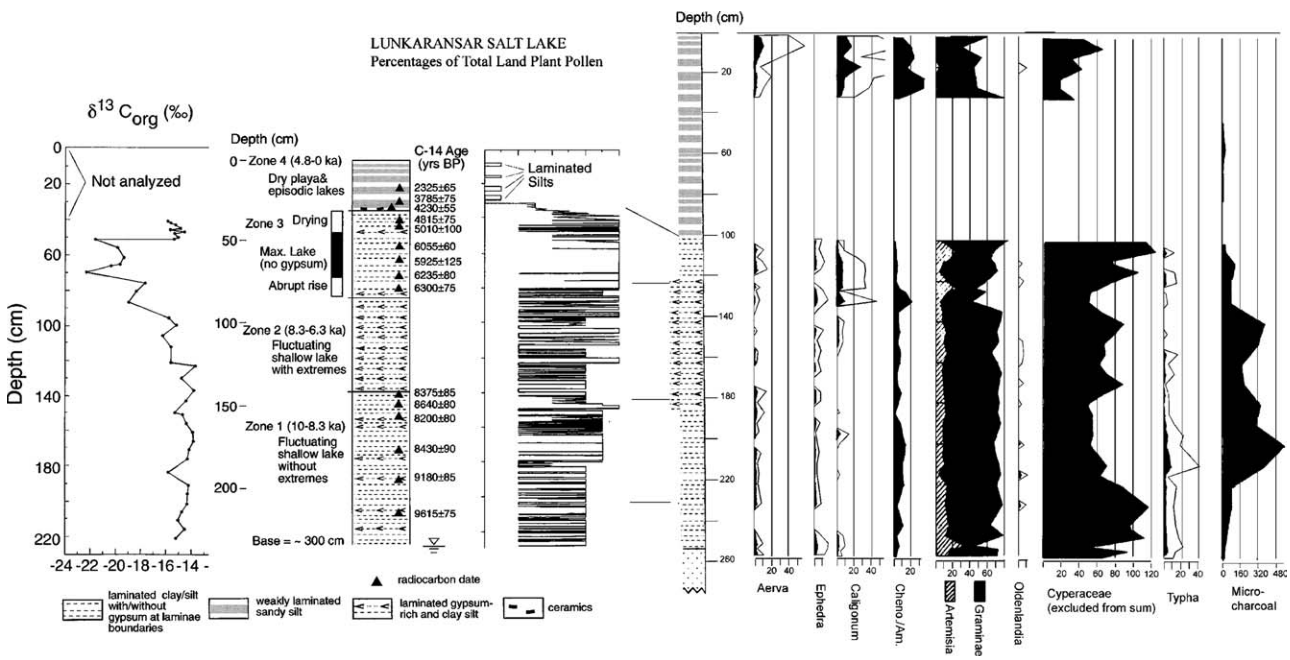


Fig. 4. Pollen diagram of Lunkaransar salt lake (Rajasthan, India).

seen in the Sambhar Lake sequence where a decrease in *Artemisia* and *Oldenlandia* has been dated by two radiocarbon dates at 4665 ± 115 BP (3640–3340 cal BC) and 4510 ± 110 BP (3370–3020 cal BC) (Singh et al., 1974). This drying out was probably a drawn out trend that began by the mid-fourth millennium BC, as indicated by the first dated gypsum level at Lunkaransar above the high lake stand.

Additional evidence comes from lakes to the south in Gujarat. These include Nal Sarovar (Fig. 1) near the southern periphery of the Thar Desert, which has seen both palynological work (Vishnu-Mittre, 1979; Vishnu-Mittre and Sharma, 1979) and a more recent geochemical study (Prasad et al., 1997), and Malvan Lake (Fig. 1) in southeastern Gujarat where a short sequence was investigated in conjunction with an adjacent Chalcolithic site (ca 4500–3000 BC), which provides a general age for the period of the lake (Vishnu-Mittre and Sharma, 1973; Vishnu-Mittre, 1990). Both pollen data sets for the middle Holocene wet phase show that a grassland-chenopod savannah, with very low frequencies of *Artemisia*, was in place together with a dry-deciduous riverine forest (e.g., *Holoptelea*) (Fig. 5). The plant associations of Gujarat indicate that winter–spring precipitation from the northwest was of minimal impact in this region, and the major source of precipitation was summer monsoon. From the mid-Holocene there is a gradual weakening of the rains with a decline of the dry-deciduous forest, which disappears after 4000 BP (2400 cal BC), in line with the evidence from Rajasthan. The chemical indicators from Nal also denote declining lake levels, although these appear to be delayed until the second millennium BC (Prasad et al., 1997). The signal of low lake levels in the fifth millennium BC, which should be the mid-Holocene wet phase, however, indicates that some local hydrological effects are obscuring climatic patterns in the chemical profile (for mechanisms that can alter chemical signatures see also Enzel et al., 1999).

Further east in central India (Madhya Pradesh), recent palynological data can be interpreted as signifying higher winter precipitation, with stabilisation towards modern monsoonal conditions only towards the end of the third millennium BC. Pollen sequences from five sites in eastern Madhya Pradesh (Chahuan, 1996, 2000, 2002; Fig. 6) indicate that the modern climax vegetation of dry-deciduous sal (*Shorea robusta*) forests and savannah grasslands only emerged after the middle third millennium BC (e.g., pollen zones DS-IV, BS-V, JS-III and JS-IV, Chahuan, 1996, 2000). Earlier pollen zones have a notable lack of these modern dominant monsoon deciduous forest trees, while fern spore counts are especially high, and *Artemisia* and Caryophyllaceae are notably present. This may indicate higher rainfall during the cooler winter, as well as a monsoon that was weaker or of different timing. Interestingly, large grass pollen (which could include cereals) and plausible winter-crop weeds (e.g., *Justicia* sp., *Polygonum* sp.) appear in these sequences shortly before ca 2500 cal BC, just as the major vegetation transition is setting in. Although archaeobotanical evidence for this region is weak, it is clear that winter crops spread to the northern Peninsula by the Chalcolithic, a likely continuation of the earlier dispersal marked by Balathal in Rajasthan (Fuller, 2002, 2003). It is plausible that human interference aided the spread and dominance of both *Madhuca* and *Shorea* trees, economically useful species that respond well to human management such as coppicing.

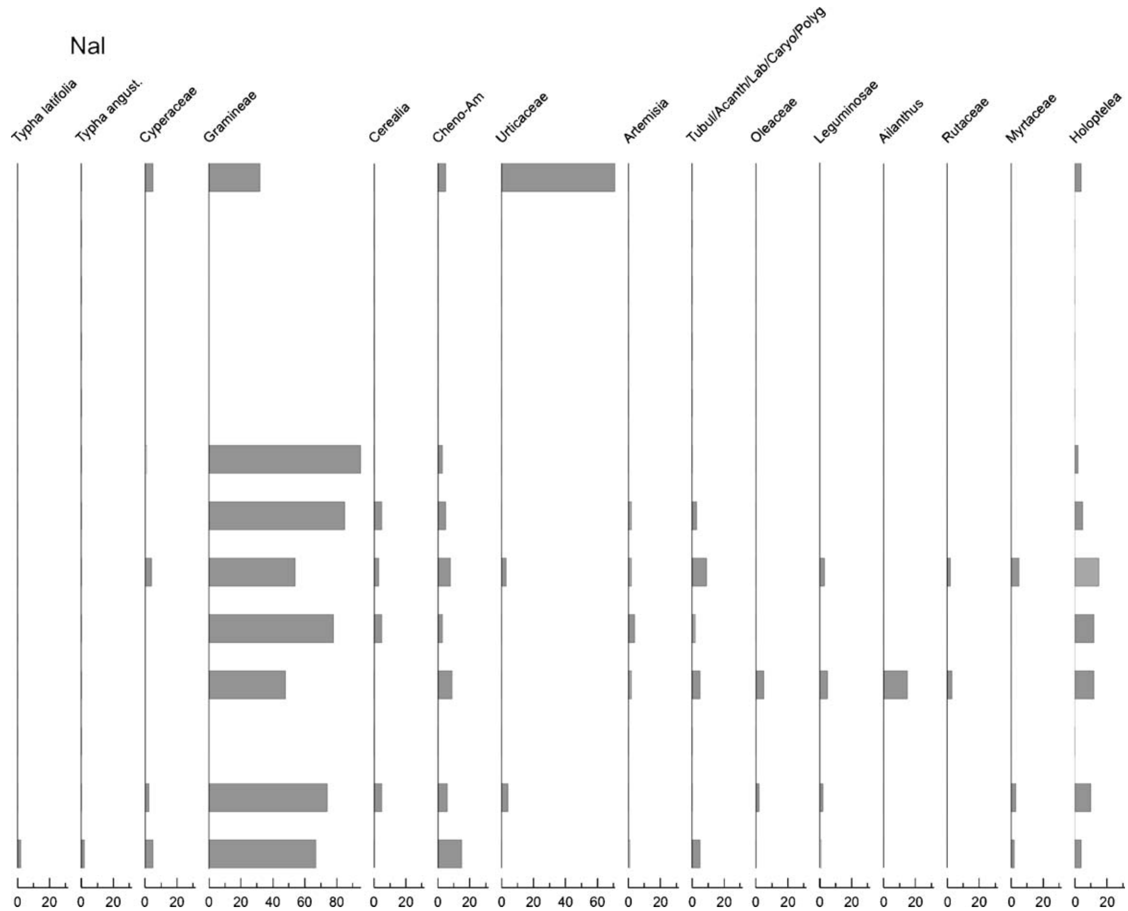


Fig. 5. Nal Sarovar pollen sequence (data from Vishnu-Mittre, 1978, 1979).

The mid-third millennium transition marks the onset of modern monsoonal conditions and seasonality in central India, with no evidence for a subsequent marked aridity.

Another pollen sequence from the Harappan region is from the archaeological site of Balakot (Fig. 1), northwest of Karachi near the Arabian Sea coast (McKean, 1983, synopsis in Dales, 1986), where sediments dated between 5500 (4300–4100 cal BC) and 3500 BP (ca 1900 cal BC) were analysed (Fig. 7). The interpretation of pollen from anthropic sediments in terms of climatic characteristics is never safe. Indeed, several variables, related to human occupation, can influence the pollen rain and make the data set unsound as a source for reconstructing natural vegetation (and therefore climate). In addition, there are serious taphonomic and preservation concerns, as archaeological pollen is prone to mixing and contamination by intrusive pollen from insect-pollinated plants (Bottema, 1975). Nevertheless, it is worth noting the conclusion of McKean (1983) that: "there is nothing in the Balakot pollen data, which might suggest that the climate during the protohistoric period in Las Bela was decidedly wetter than at present". This evidence therefore does not contradict the evidence from Rajasthan when dates are calibrated, indicating that the mid-Holocene wet phase was more or less over by the time of the establishment of the Mature Harappan Civilisation of the second half of the third millennium cal BC.

6. The Indian Ocean monsoon and transoceanic correlations

Indian rainfall patterns are part of the wider Asian monsoon system, which also brings precipitation to the Arabian Peninsula, East Africa and the Tibetan Plateau. Thus, evidence from these regions as well as the Indian Ocean and Arabian Sea provide additional data sets for assessing non-local processes in northwestern India (Figs. 6 and 8). In general terms, the monsoon climatic pattern can be discussed in terms of an early Holocene wet phase, a mid-Holocene dry phase, a mid-Holocene wet phase and then a late Holocene establishment of the modern climatic pattern. These broad divisions mask much inter-regional and local variation, but nevertheless provide a context in which to understand the climatic patterns in northwestern South Asia.

As is evident from Fig. 8, before the end of the Pleistocene and certainly by the beginning of the Holocene, regions from China to Africa experienced higher rainfall. This wet period is also evident in high water levels in parts of Australia (Bowler et al., 1995). Higher rainfall is well documented for Africa in lake levels (Hassan, 1997a;

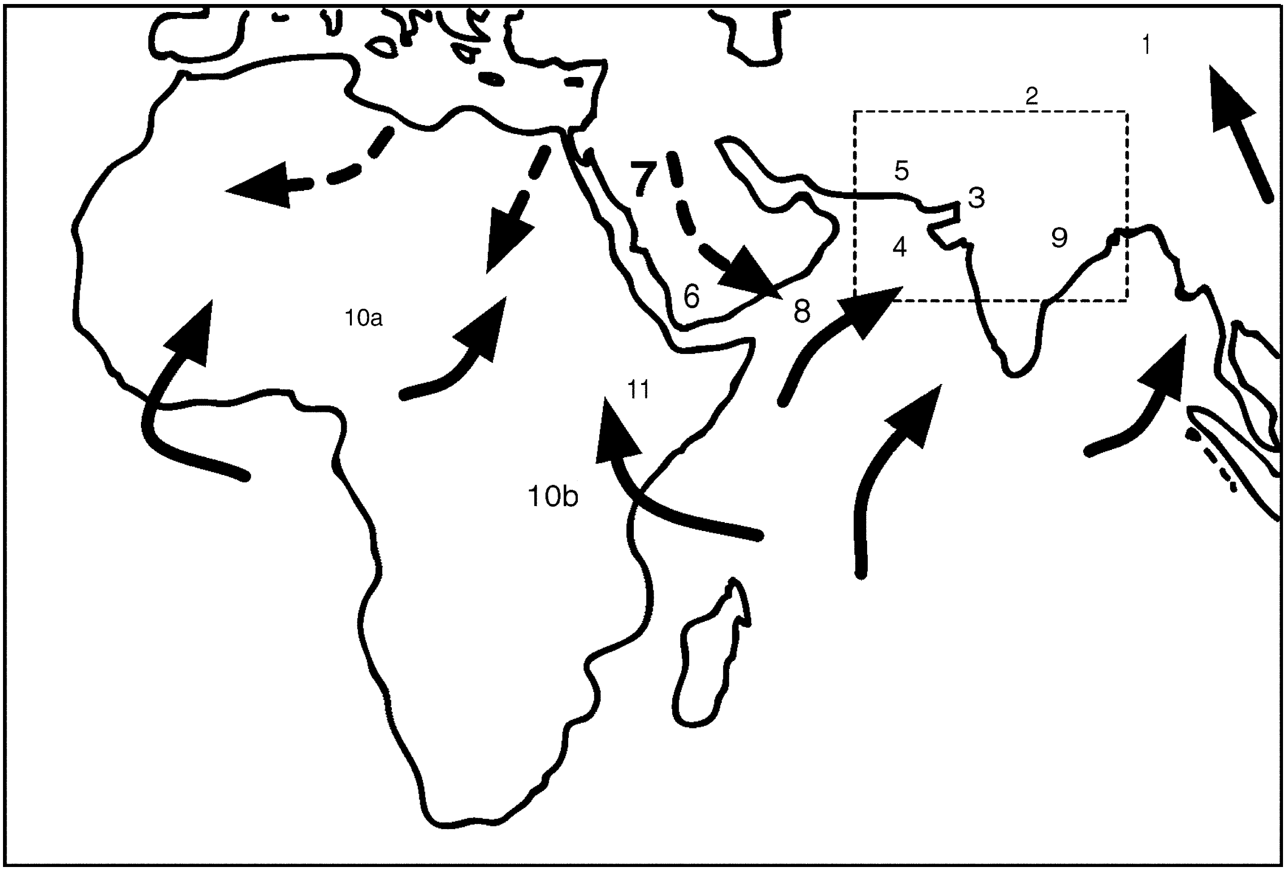


Fig. 6. Map showing major palaeoecological data sets for Holocene climate change in the Indian Ocean region discussed in this paper. The focal region of discussion is boxed, see detailed map in Fig. 1. Also showing are the major air currents of the summer monsoon period: solid arrows represent the major moisture laden currents while dashed arrows are the dry desert winds. Regional data sets numbered as follows, for references see text: (1) Selin and Qinghai (Central Tibet and Qinghai Plateau); (2) Bangong and Sumxi (Western Tibet); (3) Thar Desert sites (see also Fig. 1); (4) Makran and Sindh/Indus fan; (5) Balakot (see also Fig. 1); (6) Ramlat as-Sab'atayn (Yemen); (7) an-Nafud lakes (Saudi Arabia); (8) Arabian Sea core; (9) eastern Madhya Pradesh pollen cores; (10a) and (10b) African lakes (major clusters), for a detailed distribution map of these sites see Fig. 3 in Gasse (2000); (11) Abhe Lake (Ethiopia).

Gasse, 2000) as well as palynological, archaeobotanical and faunal data sets that indicate higher rainfall and a northwards shift in the savannah belt which infringed upon a greener Sahara (Haynes and Mead, 1987; Pachur and Kropelin, 1987; Haynes et al., 1989; Neumann, 1989; Wendorf and Schild, 1994; Fuller, 1998; Jolley et al., 1998). This wet period had begun by 9000–8500 cal BC, with peaks in moisture placed at ca 7000 and 6000 cal BC (Grove, 1993; Muzzolini, 1993; Hassan, 1997a). Dates for evidence of high lake levels in Saudi Arabia and Yemen indicate a period of higher rainfall correlating with the early Holocene wet phase, ca 8000–5500 cal BC, including two supposed peaks (McClure, 1976; Lézine et al., 1998). Higher rainfall is also clearly indicated in general for the early Holocene in the Tibetan and Qinghai Plateau regions of China (Bowler et al., 1995; Wei and Gasse, 1999), although the two previously mentioned peaks are not evident, with the exception of a peak in rainfall around 7000 cal BC in the Bangong data. The onset of this monsoonal wet phase by ca 8500 cal BC correlates well with the Didwana (D3) and Lunkaransar (L-2a) sequences (see Table 2). The start of this wet phase is not precisely correlated across all regions but potentially reflects a global stepwise onset of post-glacial conditions, as discussed by Gasse (2000).

Within the early Holocene wet phase were evident climatic fluctuations with short intervals of aridity. Hassan (1988, 1997a) has attempted to correlate periods of a few centuries to recognised arid spells in the Eastern Sahara. In general, similar short-term climatic fluctuations seem to be observed also in other regions, although it remains problematic whether these events can be correlated and should be seen as global or multi-regional in scale. The first of the dated gypsum layers from Lunkaransar Zone 1, ca 9200–8800 cal BC (Enzel et al., 1999), corresponds well with the first dry spell noted for early Holocene Africa by Hassan (1997a). The other dated Zone 1 gypsum layers, however, do not have clear correlations with the dated aridifications of Hassan; thus, it is unclear whether to regard them as peculiar to Rajasthan or of wider geographical scope. As comparisons between the African lake data sets (Gasse, 2000) and between the various Chinese data sets (Wei and Gasse, 1999) indicate, there appear to be either more local factors in operation during

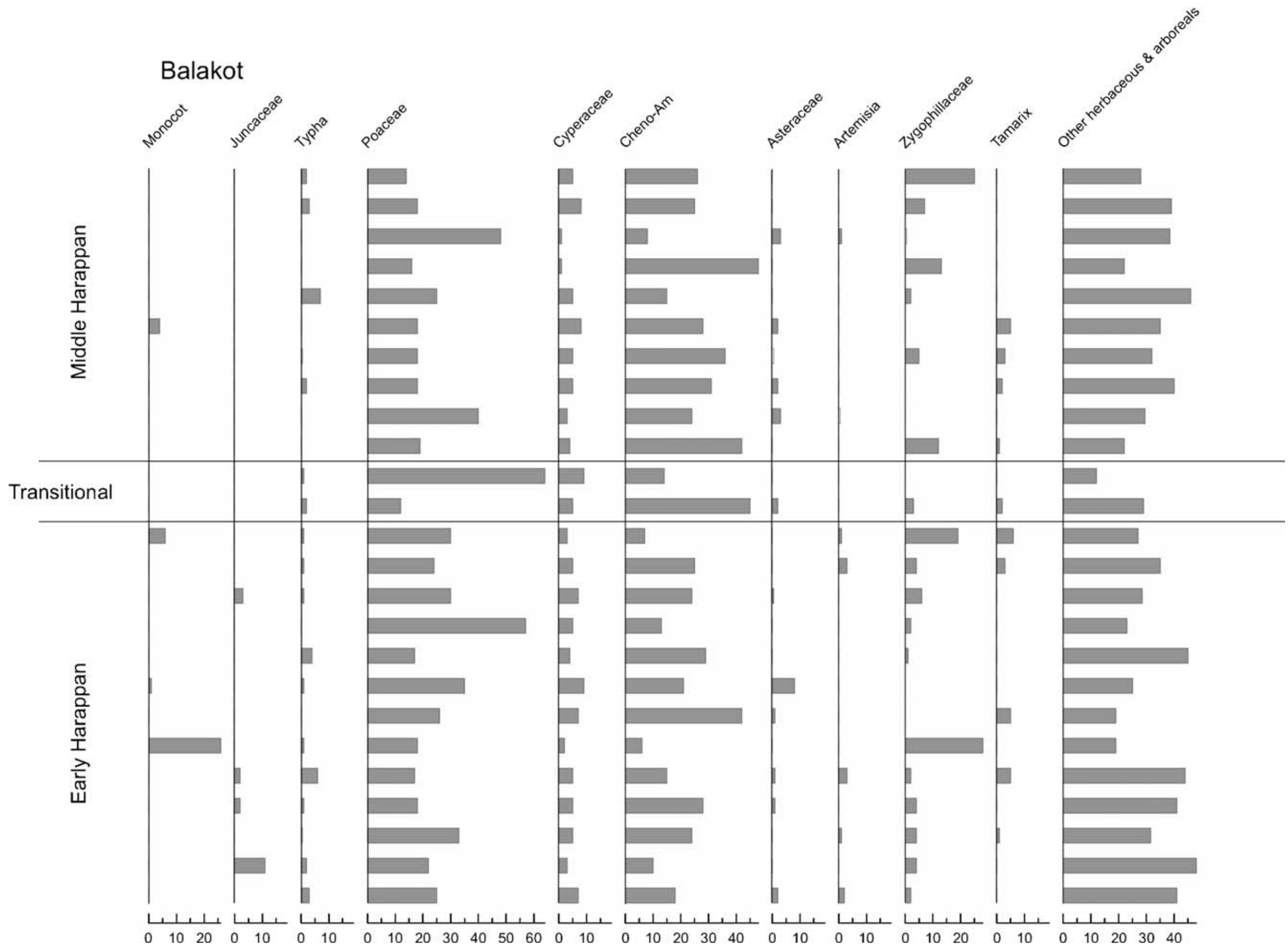


Fig. 7. Balakot pollen sequence (data from McKean, 1983).

these short-duration arid spells or else problems with the precision of the dating. A real challenge to decoding these short-duration events remains the provision of accurate chronological frameworks of adequate resolution. Establishment of such frameworks requires far more radiometric dates than are generally reported with South Asian palaeoenvironmental data sets. An exception to this dearth of dates is the work of Staubwasser et al. (2003) where a laminated sediments core was recovered from the formerly active Indus delta, off the coasts of Pakistan, and tied down with 36 ^{14}C dates. The dates were calibrated considering the potential effect of the upwelling and convection on ^{14}C reservoir ages of the sea surface (Staubwasser et al., 2002). This data set, therefore, provides a chronologically robust picture, and indicates clear overall correlation with other northwest South Asian and inter-regional data sets (Figs. 2 and 8).

In some summaries of the African data, there is a trans-regional dry period in the middle Holocene during the late seventh to early sixth millennium cal BC, perhaps centred on ca 6200 cal BC (Gasse, 2000, e.g., Fig. 9; also, Hassan, 1988, 1997b; Grove, 1993; Muzzolini, 1993). This event may be part of global climatic change, correlated with an ^{18}O shift and a decrease in methane recorded from Greenland ice cores (Alley et al., 1997; Gasse, 2000) and South Arabian Sea core (Staubwasser et al., 2002). In the Rajasthan data, there is no phase clearly equivalent to the mid-Holocene arid spell of northern Africa. Although some of the fluctuations in both Lunkaransar and Didwana can be interpreted as muted signals of this phase, e.g., at the end of Zone D3 and the middle of Lunkaransar Zone 2, indicated by pollen fluctuations in the middle of LK-2b (around 150 cm). It may be that finer sampling intervals would have picked this event up more clearly; however, the published samples examined provide clear indications of high rainfall for the period before and after this event. In addition, for these periods in Rajasthan a potentially mitigating factor involves anthropogenic fires which could have maintained early successional plant communities and thus muted the fluctuations in woody indicator taxa. As is clear from Lunkaransar, and from the early pollen profile of Didwana (Singh et al., 1974), much of this period, beginning between 8600 and 8200 cal BC, was marked by a dramatic rise in micro-charcoal. While it is extremely unlikely that the few large grass pollen grains ('cerealia') indicate cultivation (cf. Vishnu-Mittre, 1978, 1981; Fuller, 2002), it is possible that the Mesolithic populations that came to inhabit the Thar Desert region

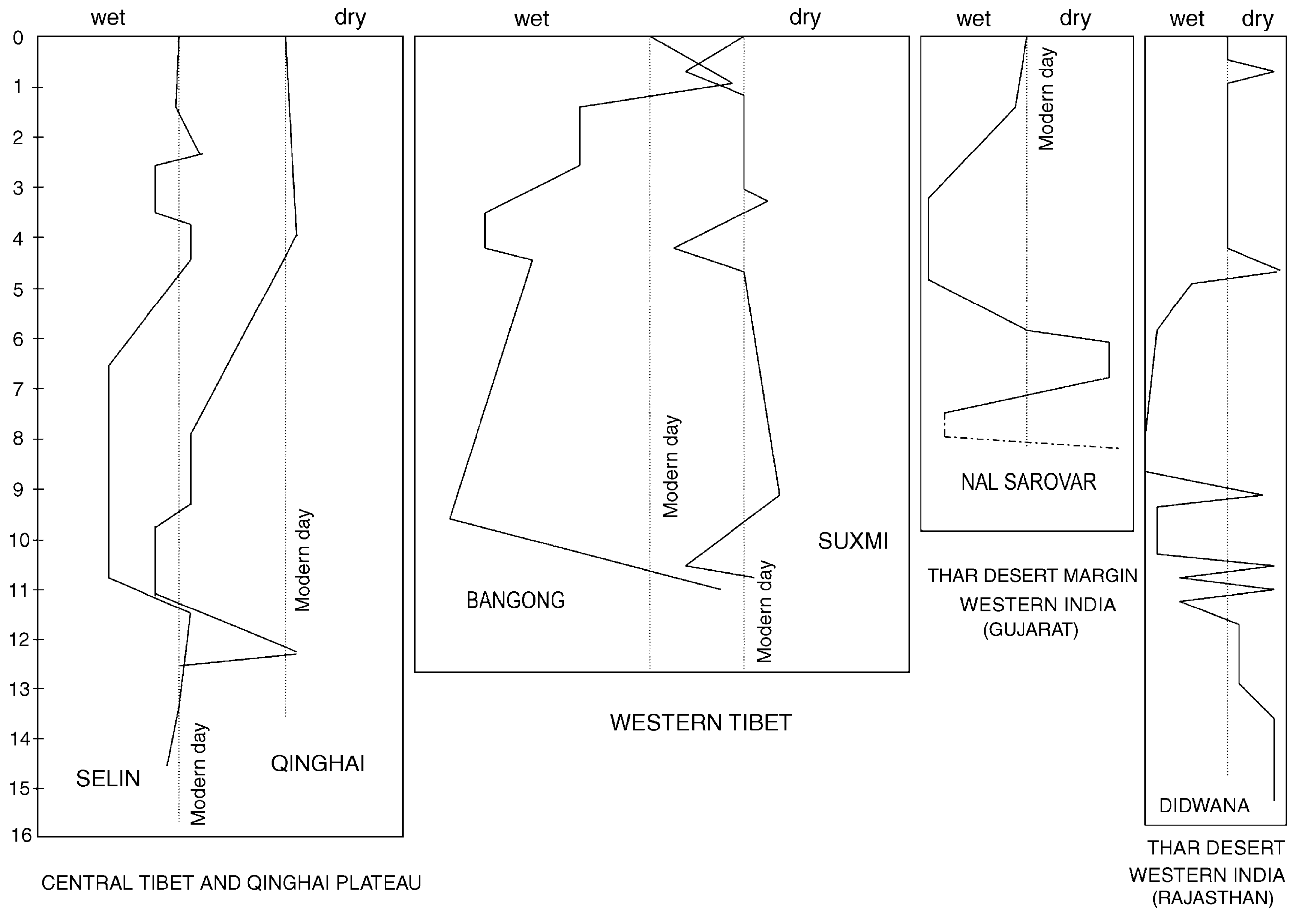
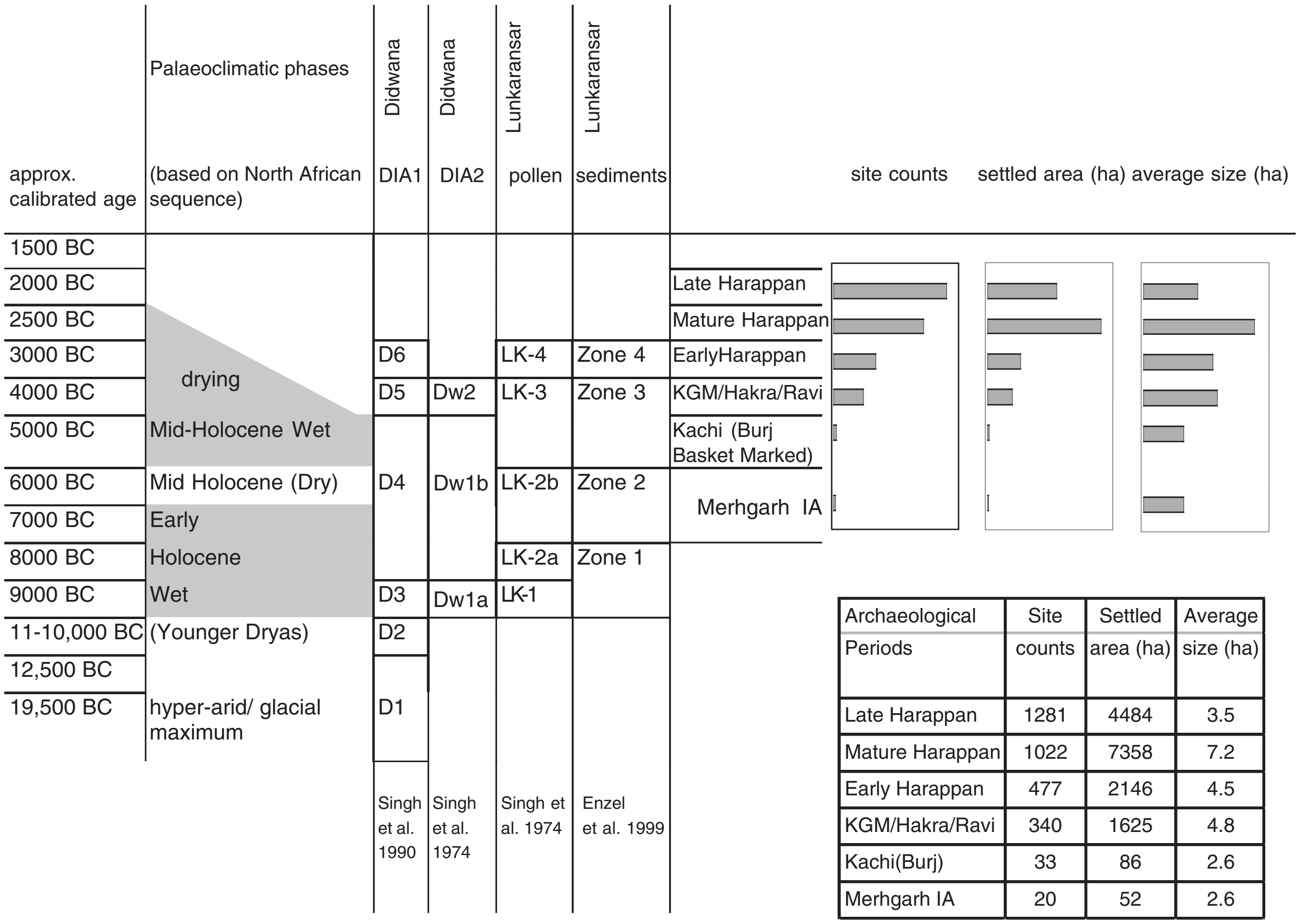


Fig. 8. Correlation between the African, Indian, Tibetan and Chinese palaeoclimatic records (see text for references and discussion).

during this wetter period utilised fire for various purposes, such as game drives (cf. Allchin and Allchin, 1982; Vishnu-Mittre, 1985). Another important factor is the strong possibility that this period saw heightened winter rainfall.

A wet phase began after 5000 cal BC and is most strongly indicated by the high and continuous lake levels reconstructed for Lunkaransar Zone 3 (Enzel et al., 1999) and for Didwana Zone D5 (Wasson et al., 1984; Singh et al., 1990). In contrast to northern Africa, this mid-Holocene wet period in Rajasthan appears to have been wetter than the early Holocene wet phase. It is likely that much of this additional moisture was unconnected to the monsoon but rather came from the northwest as winter rains (see Bryson and Swain, 1981). A further indication of the differences between the early and mid-Holocene wet phases comes from the palaeolakes of the Arabian Peninsula (Fig. 6). Evidence for the mid-Holocene wet phase (5000–4000 cal BC) is largely absent from these lakes, except from dated stands from the northwestern-most Arabian lakes of the an-Nafud region. The water levels at the an-Nafud lakes during this period are thought to be connected to rainfall from the winter Mediterranean system (Lézine et al., 1998, p. 298). This suggests that the Indian Ocean monsoon and its summer rainfall were highest during the early Holocene, while winter rains from the northwest supplemented the monsoon during the mid-Holocene period in some regions like northern Arabia (see also Phillips et al., 2000; Staubwasser et al., 2003). For two of the northwestern South Asian sequences an arid phase had fully set in before 2500 cal BC (2900–2700 cal BC for Lunkaransar and 2850–2450 cal BC for Didwana). In the Sambhar sequence, a corresponding trend can be recognised by the decrease in *Artemisia* and *Oldenlandia* (Zone SM-3a), dated by two radiocarbon dates at 3640–3340 and 3370–3020 cal BC (4665 $\pm$ 115 and 4510 $\pm$ 110 BP) (Singh et al., 1974). As noted by Enzel et al. (1999), this significantly predates the extrapolated date of aridification suggested by earlier authors (Singh, 1971; Singh et al., 1974; Bryson and Swain, 1981; Allchin and Allchin, 1997) and removes from consideration a correlation between this drying out and the collapse of Harappan urbanism. Rather it supports the contentions of others that Harappan urbanism occurred in the face of declining rainfall (Vishnu-Mittre, 1979; Shaffer and Liechtenstein, 1989). Indeed, this drying out was probably a drawn out trend that began by the mid-fourth millennium cal BC, as indicated by the first dated gypsum level at Lunkaransar above the high lake stand. This would be in line with the 'time transgressive' nature of aridification towards modern levels inferred for the African past.



Archaeological Periods	Site counts	Settled area (ha)	Average size (ha)
Late Harappan	1281	4484	3.5
Mature Harappan	1022	7358	7.2
Early Harappan	477	2146	4.5
KGM/Hakra/Ravi	340	1625	4.8
Kachi(Burj)	33	86	2.6
Merhgarh IA	20	52	2.6

Fig. 9. Summary of the palaeoclimatic phases and archaeological periods in the Greater Indus Valley shown together with site counts and settled area for each period. See text for a discussion.

A possible abrupt aridification event at ca 2200 cal BC has been the focus of much discussion in recent years but evidence for its impact in South Asia is less clear. Scenarios of catastrophic abandonment of cities and urban decline in the Near East and Egypt linked to a 2200 cal BC event have been postulated (e.g., Dalfes et al., 1996; Hassan, 1997b; Cullen et al., 2000; Hsu and Perry, 2002, Fig. 2, event K; de Menocal, 2001; Staubwasser et al., 2003). The potential impact of this event in the Harappan context must be considered, although the Rajasthan pollen sequences make it clear that this could only represent an acceleration of trends already underway in South Asia. Furthermore, the relationships between climatic changes and social changes are complicated by relationships of scale (Rosen and Rosen, 2001).

Naidu (1996), on the basis of distinctive planktonic foraminifers (especially the indicator species *Globigerina bulloides*) from an Arabian Sea core (Fig. 6), calculated the upwelling due to the southwestern monsoon in the Arabian Sea over the past 19,000 yr. Upwelling indices reveal that the lowest values during the Holocene occurred between ca 3500 BP (ca 1500 cal BC, corrected for marine reservoir effect) and 1200 BP (ca 750 cal BC, corrected for reservoir effect) suggesting a decrease in the monsoon activity over the Indian sub-continent by this period, followed by some increase. Staubwasser et al. (2003) postulated a combination of weaker summer monsoon rain and diminished winter/spring rain on the basis of the $\delta^{18}O$ from *Globigerinoides ruber* record of the Indus delta.

The sedimentary successions of the turbidite systems along the Makran and Sindh/Indus Fan continental margins in the Arabian Sea (Fig. 6) provided additional information on glacio-eustatic sea-level fluctuations, terrigenous sedimentation processes, Sr/Ca and Mg/Al ratios in bulk sediments, and $\delta^{18}O$ from foraminifera as related to climate changes (Prins and Postma, 2000; Prins et al., 2000). Seasonal laminated sediments (varves) deposited in the oxygen minimum zone off the Makran and Karachi coasts have been interpreted to indicate a decrease in sedimentation which von Rad et al. (1999) suggest could attest to a decrease in precipitation in southern Pakistan after 4000–3500 yr BP (ca 2400–1750 cal BC). When aligned with the oxygen isotope evidence of Stuabwasser et al. (2003) (Fig. 2), however, it appears that varve thickness generally increases during the second half of the third millennium BC while ^{18}O declines. This suggests that other factors may be affecting sedimentation rates, such as sediments from agricultural erosion associated with the intensive Harappan occupation of the Indus Valley. In addition, there is the possible drying up of the additional Ghaggar-Hakra palaeoriver (e.g., Agrawal and Sood, 1982; Misra, 1984; Courty and Federoff, 1985; see above). What Thar Desert pollen and lake level data sets clearly indicate is the culmination of a trend towards aridification in later third millennium BC. This correlates with a general decline in δ^{18}O. But it should also be noted that the amplitude of fluctuations between drier and wetter conditions, suggested by δ^{18}O, as well as varve thickness is particularly marked during the latter third millennium BC, and it may be this instability on a sub-century scale together with cultural responses, that requires further research attention.

7. The environmental setting of the Harappan Civilisation

Our current understanding of the palaeoenvironmental evidence allows us to see the rise and fall of the Harappan Civilisation from a new perspective. While previous authors, relying on earlier and less well-dated data sets, inferred that the Harappan Civilisation flourished during a period of optimal rainfall and ended at least in part due to declining rains (e.g., Singh, 1971; Agrawal, 1982b; Allchin and Allchin, 1997), the more extensive palaeoclimatic record available today contradicts this (as already suggested by Shaffer and Liechtenstein, 1989). It is worth considering, however, what role the higher rainfall of the mid-Holocene may have played in the spread of agriculture and sedentism in the greater Indus Valley and beyond, and to what extent it fostered increased agricultural surpluses that contributed to the emergence of social complexity. With higher rainfall, small village communities may have been more dispersed in northwestern South Asia. The higher winter rainfall, in particular, as inferred by Bryson and Swain (1981) but re-dated to a pre-Mature Harappan period by the more extensive and calibrated dating evidence available today (e.g., Phillips et al., 2000), would have been particularly significant for the cultivation of the winter–spring crop package (wheat, barley, peas, lentils, grasspea and linseed) that served as the subsistence base of the pre-Harappan village cultures of the Indus Valley and its western borderlands (see Meadow, 1996; Tengberg, 1999; Fuller and Madella, 2001; Fuller, 2002; Weber, 2003). In addition, the higher precipitation would have increased flood levels in the river system and allowed more extensive cultivation on receding floods. These increased surpluses would have supported trade as well as demographic expansion, both of which would have contributed to the spread of agriculture and social complexity.

It is notable that during this period evidence for the first establishment of sedentary agricultural settlements in regions east of the Indus Valley is available. For example, recent excavations at the site of Balathal indicate that the earliest levels of ceramic-producing, sedentary occupation, with wattle and daub structures, date back to at least 3000 cal BC, replaced by stone architecture in the early third millennium BC (Misra et al., 1997; Misra and Mohanty, 2000, 2001; Shinde, 2000). Although archaeobotanical evidence from the earliest levels of this site has not yet been reported, the evidence from the later third millennium BC (Kajale, 1996) indicates the dominance of the winter-crop package of Southwest Asia origin (wheat, barley, peas and linseed) which was already well established in modern Pakistan regions to the west, although there is also evidence for summer crops of tropical Indian origin such as *Vigna* spp. and a couple of species of millets (provisionally reported as *Panicum* and *Setaria*). This indicates both the dispersal of winter-cropping systems east of the Indus Valley prior to the rise of the Harappan Civilisation, as well as their integration with local summer-cropping systems—the origin of which remains obscure but is probably broadly peninsular (see Fuller, 2002, 2003). It might be suggested that in regions such as eastern Rajasthan, which receive predominantly monsoon rainfall, the early establishment of winter crops was facilitated by the increased winter rainfall of the mid-Holocene wet phase indicated by the *Artemisia* levels in the western Rajasthan pollen sequences. By contrast winter crops do not appear to have ever been of agricultural significance further south in Saurashtra, where all the available archaeobotanical evidence indicates a dominance of summer millets and pulses (Weber, 1991; Reddy, 1994; Kajale, 1996; Fuller and Madella, 2001). Although palynological evidence is sparser in this region, available evidence does not indicate significant presence of *Artemisia* or other winter rainfall indicators. In addition, it is also probably during the later fourth to early third millennium cal BC that pastoralism became more widespread in Gujarat and Rajasthan (cf. Possehl, 1999; Chattopaddaya, 2002; Meadow and Patel, 2003; Thomas, 2003). It is plausible that the wetter mid-Holocene created more potential grazing area. During the third millennium BC water buffalo is domesticated in part of the core area of the Harappan Civilisation (Meadow and Patel, 2003) and perhaps in the marginal areas of the Indus system, such as the Bannu Basin (northwest of the Greater Indus Region). Here, it becomes evident that the introduction of the water buffalo and its use (together with cattle) was primarily for secondary products such as milk as well as agricultural work (Thomas, 2003). The use of water buffalo and cattle for agricultural work also indicates a greater integration in the farming system (Thomas, 2003), which also could have contributed to increasing social complexity.

While higher rainfall levels of the fourth millennium BC may have promoted the more widespread adoption of cultivation and sedentary settlement, subsequent decline in rainfall may have contributed to growing population density in certain regions. It can be suggested that the increase in sites next to the Ghaggar-Hakra and Indus during the Mature Harappan period (Figs. 1 and 9) could have been in part due to a concentration of the settlements along river systems as rain-fed cultivation became more difficult. Changing cultural practices involving some kind of water management—even at very low scale—may also have encouraged this concentration of population along water courses, although such practices are conjectural and not yet documented with archaeological evidence. Increasingly concentrated agricultural populations in the river valleys and more intensive methods of cultivation, which included arid-tillage from at least the first half of the third millennium cal BC (Lal, 1971), may have contributed to greater soil erosion rates, loss of natural vegetation, and movement of wind-blown sediments during the dry summer months (Schuldenrein, 2001). It is some of these processes that are likely to have contributed to the increased varve thickness in the Karachi Delta (cf. von Rad et al., 1999). Increasing aridity could have promoted further agricultural intensification efforts, requiring mobilisation of labour, and consequent landscape modification that might be inferred from at least some geoarchaeological data sets. By the time of the Mature Harappan period there must have been at least some summer cultivation of non-staple crops like sesame and cotton (see Fuller and Madella, 2001) which are likely to have required some watering during these months, although they were possibly grown on a much smaller scale than the staple food plants.

Also important to consider are agricultural changes during the course of, and after the decline of, the Harappan Civilisation. Late Harappan sites provide much more widespread evidence for the cultivation of small millets and rice, which are significant as summer, monsoon-watered, cereals in contrast to the winter/spring germination of the Harappan staples wheat and barley (Fuller and Madella, 2001; Madella, 2003; Weber, 2003). The evidence for the adoption of millets may begin in some areas prior to the rice of the Harappan Civilisation, while rice may begin ca 2200 cal BC at Harappa. It is, nevertheless, clear that from 2000 cal BC smaller, more widespread Late Harappan sites show consistent evidence for these crops (Fuller and Madella, 2001; Madella, 2003). Considered in the light of the possibility of a 2200 cal BC climatic event, we might see the archaeobotanical evidence as suggesting a cultural adjustment in terms of subsistence strategies towards more drought tolerant rain-fed crops and increasingly reliance on two cropping seasons. These would have been most feasibly grown on the eastern distribution of the Harappan Civilisation area within the normal monsoon zone, which is the region which shows the greatest degree of site continuity and new site foundation (Fig. 1). In addition, as these species produce lower yield per unit area, they might have been less suitable for the support of large urban centres and their cultivation may have encouraged larger numbers of smaller communities. What is more, the established urban Harappan system presumably depended on the accumulation and storage of grain surplus that was sequestered (or taxed) on wheat and barley. Strategic shifts by farmers to other crops may have contributed to the decline of the economic foundations of Harappan urbanism. In this regard, it is intriguing that the interpretation of evidence for crop processing from archaeological cereal chaff and weed remains suggests a shift from more centralised labour in prior-to-storage crop-processing to something of smaller scale and more household based (Fuller and Madella, 2001, p. 347; Weber, 2001, 2003). Thus, the shifts in the nature of settlement that are seen in the Late Harappan transition might be seen in part due to agricultural readjustment to slightly altered climatic circumstances.

8. Conclusions

On the basis of the present evidence we cannot attribute the 'end' of the Harappan Civilisation to a harsh climatic event. Archaeologically, this process is characterised by decentralisation and the net abandonment of more western sites (in Sindh) and the possible proliferation of sites in the eastern regions of the Harappan area. While many archaeologists have long argued against a climatic cause for the end of Harappan urbanism, this notion persists in some Quaternary science literature. We propose that shifting agricultural strategies at a local level, which may have been encouraged by climatic change or instability, probably contributed to the emergence of Harappan urbanism at ca 2600 BC, and again to de-urbanisation starting in the period 2200–2000 cal BC. In the former, ever more intensive agriculture and control of surpluses, which buffered inter-annual shortfall, contributed to urban centralisation. In the latter, more diversified and extensive agriculture provided strategic risk buffering for smaller, local groups and could have contributed to social changes that ultimately resulted in the restructuring of the urban Harappan social system. A climatic event cannot be blamed simplistically for collapse and de-urbanisation, but Quaternary science data make it clear that we cannot accept a view of climatic and environmental stability since the mid-Holocene in the region (as promoted by Possehl, 1999, 2002). Rather we must address the issues of climatic dynamics, the diverse responses of different regional ecosystems, and social processes at the level of individual agricultural communities that engaged with these local environments.

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