LATE QUATERNARY CLIMATIC CHANGES IN INDIA: A GEOARCHAEOLOGICAL APPROACH

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ABSTRACT

One of the dominant environmental parameters that affects India's political, cultural and economic development is monsoonal rainfall. Any variation in monsoonal rainfall has an impact on human cultures in India and the possibility of climatic change in the future due to global warming is of serious concern. Historical disciplines like history, archaeology, geology and palaeobotany can provide data for understanding the long term record of past climatic change, which is needed for building predictive models of how climate might change in the future. We can also study the impact of climatic change on human cultures of the past. In the last two decades considerable effort has been made to study palaeoenvironmental changes in parts of the peninsular and coastal regions of India. In this paper we summarise some of the important geoarchaeological and geomorphological research of the last decade related to the Late Quaternary period.

The Quaternary record of the Indian sub-continent is extremely diverse as so many different geotectonic and climatic settings are represented. A major motivation for Quaternary studies in India has been to understand the context of Palaeolithic archaeological material and to understand the palaeoclimatic record. Therefore, a great deal of work has been done in the peninsular region where Palaeolithic artifacts are common in Quaternary deposits. Most of Peninsular India is an erosional landscape and Quaternary deposits can provide valuable evidence for Quaternary climatic change and human cultures, although such deposits are a minor component of the landscape. Dating of these deposits is quite difficult as few absolute dates are available. Relative dating, using the degree of weathering of pebbles in gravels, calcrete and soil development, and fluorine phosphate ratios of fossils, has been used (Mishra, Kshirsagar and Rajaguru 1988). Archaeological material found in the Quaternary deposits is perhaps the most sensitive relative dating indicator. For the past 40 kya period C14 dates are available, although their reliability is untested for the period earlier than 25 ka. This means that it is difficult to make precise interpretations of the data for the earlier part of the Quaternary record. In this paper we look at the palaeoclimatic data in relation to Palaeolithic cultures since the last interglacial (125 kya).

LAST INTERGLACIAL AND EARLY LAST GLACIATION

Evidence for the early part of the Late Quaternary is difficult to identify in the peninsular region. At Ranjani, about 80 km north of Pune, on the Mina tributary of the Bhima river, a gravel containing a Middle Palaeolithic assemblage has been reported (Mishra and Ghate 1989). A few Middle Palaeolithic artifacts have also been found at Chandoli, on the Ghod river, just a few kilometres south of Ranjani (IAR 1961/62: 27, 1962/1963: 14). The Middle Palaeolithic context at both these sites is a poorly sorted local gravel, indicative of a period when the river was aggrading due to low discharge and high sediment load in a climate more arid than that of the present. Sali (1990) has also reported Middle Palaeolithic tools from similar gravels in the Tapti basin at Dahivel, Amoda and Badne, district Dhule, Maharashtra. The arid climate during the Middle Palaeolithic might belong to the early part of the last glaciation, around 80 ka. In general, however, Middle Palaeolithic tools are rarely found in Quaternary deposits in the peninsular region, although they are common on the surface or in rubble/weathered regolith away from the main streams. This indicates that most of the streams were in an erosive mode during Middle

Palaeolithic times, as they are at present. This would conform with a Last Interglacial age for most of the Middle Palaeolithic.

The association of the Middle Palaeolithic with a relatively humid climate during the Late Quaternary is much better documented in the Thar desert. In a 20 metre deep trench excavated at Site 16R, Didwana, District Nagaur in the eastern margins of the Thar desert, a Middle Palaeolithic horizon is associated with evidence of dune stability during a relatively humid climate. TL and Th/U dating of this level places it in the Last Interglacial time period (Misra, Rajaguru and Raghvan 1988; Misra and Rajaguru 1989; Raghvan, Rajaguru and Misra 1989). At Jankipura and Mangalpura, about 30-40 km NNE of Didwana, Middle Palaeolithic artifacts were recovered by excavation (Misra *et al.* 1982). These artifacts occur in marly sediments of fluvio-lacustrine origin. Middle Palaeolithic artifacts have also been found in gravel deposits in the Luni basin (Misra 1962) and have been recently dated to greater than 100 kya by the TL method (Singhvi, personal communication). In the Jaisalmer region, close to the arid core of the Thar desert, surface finds of stone tools are either of Middle Palaeolithic type or Early Holocene microliths. Mishra, Rajaguru and Ghate (1993) have suggested, therefore, that the region around Jaisalmer might have been exploited by human groups only during the relatively humid phases of the Late Quaternary.

Gujarat is an alluvial plain which has been undergoing subsidence during the Quaternary (Sant and Karanth 1993). Unlike the peninsular rivers, the Mahi, Narmada and Sabarmati flow through alluvium. In all three rivers a conspicuous soil horizon has been correlated to the last interglacial by Zeuner (1950), Wainwright and Hegde (1964) and Chamiyal and Merh (1992). Only a few Late Acheulian artifacts, mostly from the Pre-Last Interglacial deposits, have been recovered from these deposits.

In Saurashtra, miliolite, interpreted as a coastal beach-dune complex formation at 4 m above sea level has been dated by Bruckner (1987, 1989) to 125 kya at Porbandar. Acheulian artifacts have been recovered from gravels underlying miliolite and graded to a low sea level at Umrethi, Junagarh and Gopnath (Marathe 1981). Middle Palaeolithic artifacts have been recovered from pebbly gravel at Jetpur in the Bhadar valley, Central Saurashtra, underlying a thin (2 metres) miliolite formation dated to around 56 kya by the Th/U method (Baskaran *et al.* 1986).

THE MIDDLE AND LATE PERIODS OF THE LAST GLACIATION

The largest number of radiocarbon dates are available for the Peninsular region (Table 1). Microlithic blades date from 28 kya at Dharangaon on the Godavari and 30 kya at Mehtakheri on the Narmada. Late Pleistocene gravels usually contain microliths, along with mollusc shells. These shells have provided a number of dates. The dates from these gravels cluster around 25 ka, 20-19 kya and 12-10 kya (Sadakata *et al.* 1995). These episodes of gravel deposition correlate with phases of global aridity; the period of 20-19 kya with the last glacial maximum and the period of 12-10 kya to the Younger Dryas. At Nevasa, a gravel dated to the last glacial maximum is part of a silty alluvial fill which covers a soil developed on alluvium containing Early Acheulian tools. At Inamgaon also, the gravel dating to 19-21 kya overlies a soil developed on alluvium (Sali 1974). Undated gravels overlie soil at Kalas on the Pravara river and at Talegaon on the Vel river. The gravels dating to the Pleistocene-Holocene transition (12-10 ka) are thin beds within alluvium and are not associated with any soil horizon. This is seen at Nevasa, Inamgaon and Gargaon (Rajaguru *et al.* 1980; Sadakata *et al.* 1995). The undated gravel at Chandoli probably belongs to this phase.

The most abundant record of human activities is preserved in the deposits belonging to the most arid periods of the Late Quaternary. This shows that humans were present in Western Maharashtra even during periods of unfavorable climate. The periods of arid climate were favorable for preserving evidence of human activity because of the episodic aggradational events incorporating tools into sediments, and also because human activity was more focused around water as it perhaps became a more scarce resource. The fact that the density of artifacts in gravels is so high and abrasion is quite moderate might indicate that the human activity producing the artifacts took place in the channels themselves, which might have been dry for much of the time.

The gravel aggradation during the period 12-10 kya is close in time to the Younger Dryas. This period of reversal of the trend towards a warmer and wetter climate was one of extremely abrupt climatic change (Bard and Broecker 1992), which must have been an extreme challenge to the human populations of that period.

In the coastal region of India, the rise in sea level was extremely rapid during the Pleistocene-Holocene transition (Kale and Rajaguru 1985). Recently, Hashimi *et al.* (1995) have summarized the available data from the west coast. They have tentatively identified a still-stand at about 11 ka, with sea level still 80 metres below the pre-

Table 1: Late Pleistocene radiocarbon dates from Peninsular India (converted from published half-life of 5570 years to 5730 years)

SITE NAME	LAB. NO.	DATE	MATERIAL DATED	REFERENCE
Bhedaghat	A 6619	25,160±550	freshwater bivalve shell	Mishra & Rajaguru 1993
Belan Valley, (Deoghat)	TF 1245	19,175±340	freshwater shells	I.A.R.72-73
Belan Valley, (Deoghat)	PRL 86	25,790+830/-730	freshwater shells	Mandal 1983
Chandrasal	GRN 10638	36,550±600	ostrich eggshell	Kumar 1988
Chandrasal	GRN 10639	38,900±750	ostrich eggshell	Kumar 1988
Dharampuri*	BS 286	25,890±850	freshwater bivalve shells	Mishra 1985
Gargaon	TF 1111	10,310±155	bone	Kale & Rajaguru 1985
Inamgaon	TF 1003	21,110+615/-570	freshwater bivalve shells	IAR 1969/70: 66
Inamgaon	TF 1177	19,290±360	freshwater bivalve shells	IAR 71/72: 84
Inamgaon*	BS 146	12,040±150	freshwater bivalve shells	Rajaguru *et al.* 1979
Kurnool caves	TL date	17,390±10%	burnt stones	Nambi & Murthy 1983
Mahagara	PRL 603	14,140+410/-390	freshwater shell	Mandal 1983
Mahagara	PRL 602	11,300±130	freshwater shell	Mandal 1983
Mahagara	SUA 1421	10,030±115	freshwater shell	Mandal 1983
Mehtakheri	A 6518	30,680+1040/-920	freshwater bivalve shells	unpublished
Mehtakheri	AA 8463	>41,900	ostrich eggshell	unpublished
Nagda	PRL 1196	>31,000	ostrich eggshell	Kumar 1988
Nandipalle	PRL 293	25,360+660/-710	freshwater gastropod shells	Reddy & Sudarsen 1978
Nevasa*	BS 517	13.220±190	freshwater bivalve shells	Rajaguru & Kale 1985
Nevasa*	BS 575	16,890±200	freshwater bivalve shells	Rajaguru & Kale 1985
Patne	GRN 7200	25,000±200	ostrich eggshell	Sali 1989
Ramnagar	PRL 1196	>31,000	ostrich eggshell	Kumar 1988
Rampur	Beta 4752	11,870±120	freshwater shells	Mandal 1983
Rampur	Beta 4793	26,250±420		Mandal 1983
Sangamner*	PRL 470	12,890±350	freshwater shells	IAR 1978/79: 105
Sangamner	BS 78	25,390±710	freshwater shells	IAR 1978/79: 105

sent. During the early Holocene there was continuing transgression of the sea and by 6 kya the level was more less as it is today (Ghate 1988).

The eastern part of the peninsula also shows the imprint of late Pleistocene aridity. Recently, Basak *et al.* (in press) have observed well developed nodular calcrete of pedogenic origin in alluvial deposits in the Tarapheni valley, District Midnapur. The presence of calcrete in this region, which receives 1600-2000 mm annual rainfall, is indicative of a climate much more arid than the present. Animal fossils like *Axis axis*, *Antilope cervicapra* and *Bos namadicus,* which indicate open, grassy savanna conditions, are associated with microliths in the upper part of the calcrete. Similar evidence has recently been observed further south in coastal Andhra Pradesh near Vishakapatnam. At Agraharam, about 10 km north of Visakhapatnam, microliths were found associated with calcrete below the "Red Sand" of early Holocene age (K.T. Reddy, pers. comm.).

In the northeastern region of Manipur and the Garo Hills, colluvial cone deposits have been extensively developed over alluvial and lacustral deposits tentatively dated to the early Late Pleistocene. In the Imphal valley these deposits, dating between 25-11 ka, disconformably cap fluvio-lacustrine formations. The sudden influx of colluvial material in the valley suggests a change in the relationships between soils, rainfall and vegetation cover, leading to erosion of hillslopes (Thokchom 1987). In the Garo hills, Meghalaya, Medhi (1981) has also observed colluvial silts of Terminal Pleistocene age in mountain streams. These silts disconformably cap channel gravel beds of Late Pleistocene age. Deposition of these colluvial silts in the presently humid parts of Meghalaya occurred in response to the glacial arid climate of the Terminal Pleistocene.

The former extensive developments of calcrete in alluvial deposits in Tripura (Ramesh 1989), in the Tarapheni valley in West Bengal (Basak *et al.* in press) and in fluvio-aeolian deposits near Visakhapatnam in Andhra Pradesh (Reddy 1994), are all suggestive of relatively high degrees of aridity in these presently humid to subhumid (900-2000 mm annual rainfall) regions of eastern India. The optimum development of pedogenic calcrete occurs in areas with rainfall between 500-700 mm.

In the Thar desert, artifacts occur on the stabilized surfaces of fossil dunes, within buried calcisols, in fossil playa deposits and in the cemented pebbly conglomerates laid down by ancient streams. A good number of TL dates on dune sands and a few carbon 14 dates on pedogenic carbonates developed within aeolian sands and fluvial silts have helped reconstruction of the interrelationship between Stone Age sites and palaeoclimate in these presently semi-arid to arid regions. The Upper Palaeolithic industry existed around 35 kya at Didwana, probably in response to somewhat better climatic conditions prevailing between 40 kya and 25 ka. Playas (as at Kavas) were carrying more water during this period and aeolian activity was interrupted by fluvial and pedogenic activity in a hillslope context at Shergarh, near Jodhpur.

So far, no sites in the core of the Thar desert have been dated to 18 ka, thereby suggesting that the aridity during the peak of the last glaciation led to the abandonment of this region. The period between 13 kya and 7 kya was environmentally dynamic. The southwest monsoon was gradually getting stronger, as indicated by intense sand dune development between 14-11 ka, by alternating layers of evaporites and organic-rich clays in the playa of Didwana, and by the development of calcisols on dunes and sandsheets. Mesolithic communities occupied almost the entire desert during this period.

The Early Holocene

The Pleistocene-Holocene transition was a period of unstable climate until about 7 ka. The Early Holocene was also a period of maximum monsoonal rainfall. The Thar between 6-4 kya enjoyed one of the best climatic phases in the entire Quaternary when the summer as well as the winter monsoons were strong and brought considerable moisture into the core of the present arid desert. Playas carried fresh water, dunes stabilized and fluvial activity was strong in the northwestern part of the Thar. Mesolithic cultures continued in the major part of the Thar and Harappan settlements occurred on the banks of braided streams. The peninsular rivers were in an erosional mode (Rajaguru and Kale 1985) and soils developed on older alluvial deposits.

The Middle Holocene

An increasing trend towards aridity returned during the middle Holocene. In Maharashtra, farming was adopted by some groups around 3.5 ka. These early farming villages occupied alluvial strips close to the rivers. However, a conspicuous "gap" in the archaeological record is seen between 3000 to 2500 years ago (Dhavilikar 1973, 1992). Dhavalikar has suggested that the abandonment of sedentary lifestyle during this period was due to severe aridity, although geological evidence for aridity during this period is so far scanty. Post-Chalcolithic alluvial fills have been taken as one indicator of renewed aridity during the Mid-Holocene (Kajale, Badam and Rajaguru 1976), but dating of these fills has been minimal so far.

In Rajastan and Gujarat, the sand dunes which had accumulated during the period of Late Pleistocene aridity were stabilized and most developed soils during the early Holocene. Some show evidence of later episodes of reactivation during the middle to late Holocene. At Langnaj, the late Mesolithic levels are associated with a land surface buried under about 80 cm of reactived sand (Sankalia 1965). Similarly, the middle Holocene Harappan site of Kanewal, located on the stabilized surface of a sand dune, was covered by re-activated sand after the Harappan period ended (IAR 1977/78: 20-21).

CONCLUSIONS

During the last interglacial, around 125 ka, the sea level was higher than now by a couple of metres and the monsoons were comparatively strong, as indicated by miliolite limestone and palaeosols in Saurashtra and the Thar desert respectively. During this relatively humid phase, Middle Palaeolithic cultures flourished in the present arid parts of the Thar desert. The early part of the last glaciation (80-40 ka) is difficult to date as it is beyond the range of radiocarbon dating. During this period, global climate became arid as glacial conditions became established. A few Middle Palaeolithic sites in gravels from Peninsular India most probably belong to this period. Quite a few of these dated gravels belong to around 25 ka, which may represent a separate phase of aridity. All the gravels dated to this period contain blade tools, most of them microlithic.

The last glacial period is well documented in various parts of India. Between 18 and 12 kya most of the rivers were aggrading, playas in the Thar desert were hypersaline, and sea level dropped by over a hundred meters in the Arabian Sea and the Bay of Bengal. In the present humid parts of northeast India, colluvial activity replaced earlier freshwater lacustral and alluvial regimes. These geomorphological changes were in response to weak monsoons in the Indian sub-continent. Though Upper Palaeolithic cultures survived in parts of Peninsular India, they were almost absent in most of the Thar desert.

The early Holocene (9-6 ka) was a period of good monsoons in India due to global climatic and geophysical factors. Dune activity, which was intense around 13-14 ka, became weak in the Thar, lakes expanded and carried fresh water, springs and waterfalls had higher discharge rates and streams became rejuvenated under conditions of less sediment load and more water. Sea level rose rapidly and reached its present level around 6 ka. Black soil developed over the aggraded alluvial plains in the northern Deccan and reddish-brown soil formed over stable dune surfaces in the Thar and also in the coastal parts of Tamilnadu. Mesolithic cultures flourished across most of the Indian subcontinent during the early Holocene.

The summer monsoon became weak between 3.5-3 ka. Lakes in the Thar started drying and there was a decrease in forest density in the coastal strip of western India. Early farming activity in the present semi-arid parts of western India was badly affected during this period. The Indian monsoon at this time seems to have been responding to global climatic and geophysical factors. Broadly, its strength has an inverse relationship with the degree of cold at higher latitudes, being reduced during glaciations. A better understanding of peak monsoonal activity around 6 kya may help to anticipate the effects of greenhouse warming in India during the next century.

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