A COMPARATIVE STUDY OF MONSOONAL AND NON-MONSOONAL HIMALAYAN LAKES, INDIA

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ABSTRACT. Sedimentological, mineral magnetic and carbon isotopic studies on cores from Mansar Lake in the Jammu area provide paleomonsoonal history dating back to 580 BC. From *ca.* 580 BC to AD 300, the region experienced precipitation similar to the present, whereas from AD 300 to 1400, the monsoon was relatively subdued. A small excursion *ca.* AD 1100 suggests an effect of medieval warming. Studies in the Kumaon region did not provide a proper precipitation record, as anthropogenic activity interfered with sedimentation. Manasbal Lake in Kashmir gave an inversion of ^{14}C chronology due to younger paleosols in the drainage basin. Further, the episodic nature of sedimentation in Manasbal Lake hampered the reconstruction of precipitation history in the area.

INTRODUCTION

Lake sediments can provide proxy records of paleoenvironmental changes spanning a few thousand years with a decadal to century resolution. In the Himalayan foothills, several lakes can provide paleoenvironmental information for the last few thousand years. We have studied lakes from diverse climatic and tectonic regions (Kusumgar, Agrawal and Sharma 1989; Kusumgar *et al.* 1992). Mansar Lake (32°42′N, 75°9′E) at 666 m asl, in the Jammu region and the lakes from the Kumaon region (29°18′–29°22′N, 79°31′–79°36′E) at 1400 m asl, are susceptible to southwest monsoonal conditions. Manasbal Lake in the Kashmir Valley (34°9′N, 74°52′E) at 1584 m asl, is shielded from the Indian monsoon by the 5000-m-high Pir Panjal Range and receives rains from regionally derived clouds as well as being influenced by Mediterranean conditions (Meher-Homji 1971, Fig.1). We report here some of our preliminary results on Mansar Lake in the Jammu region, and compare it with the data from other lakes.

SITE DESCRIPTION

Mansar Lake is *ca.* 0.75 km^2 with a maximum length of *ca.* 1.0 km, width of *ca.* 0.75 km and water depth ranging from 28 to 30 m (Fig. 1). The catchment area comprises sandstone, clays, claystone and clayey conglomerates of the lower Siwalik Subgroup. The lake is situated between northwest-southeast trending ridges, with an elevation ranging from *ca.* 700 to 800 m. There is no major drainage into the lake except for a small rivulet emerging from the northwest and running down toward the southeast. The present topography suggests that the southern flank of the lake is steeper than the northern flank, implying that the northern flank has been denuded and sediments thus eroded during the process of denudation have been transported into the lake. These sediments are preferentially deposited in the northwest flank of the lake.

METHODS

We raised eight cores 1–3 m long from Mansar Lake in 1992, using an inhouse-constructed Mackereth-type pneumatic piston corer (Mackereth 1958). We discuss here analyses on four cores: MN-4, MS-5, MS-7 and MS-8 (Fig. 1). All the cores were radiocarbon dated using a Quantulus 1220™ liquid scintillation counter (Gupta and Polach 1985). To confirm preservation of the top of the core, ^{210}Pb was measured in the top 15 cm of Core MS-5 using established techniques (Krishnaswami *et al.* 1971). We determined the $\delta^{13}C$ of the organic fraction of the sediments in Cores MN-4 and MS-8, and measured the frequency-dependent magnetic susceptibility in Cores MN-4, MS-5, MS-7 and

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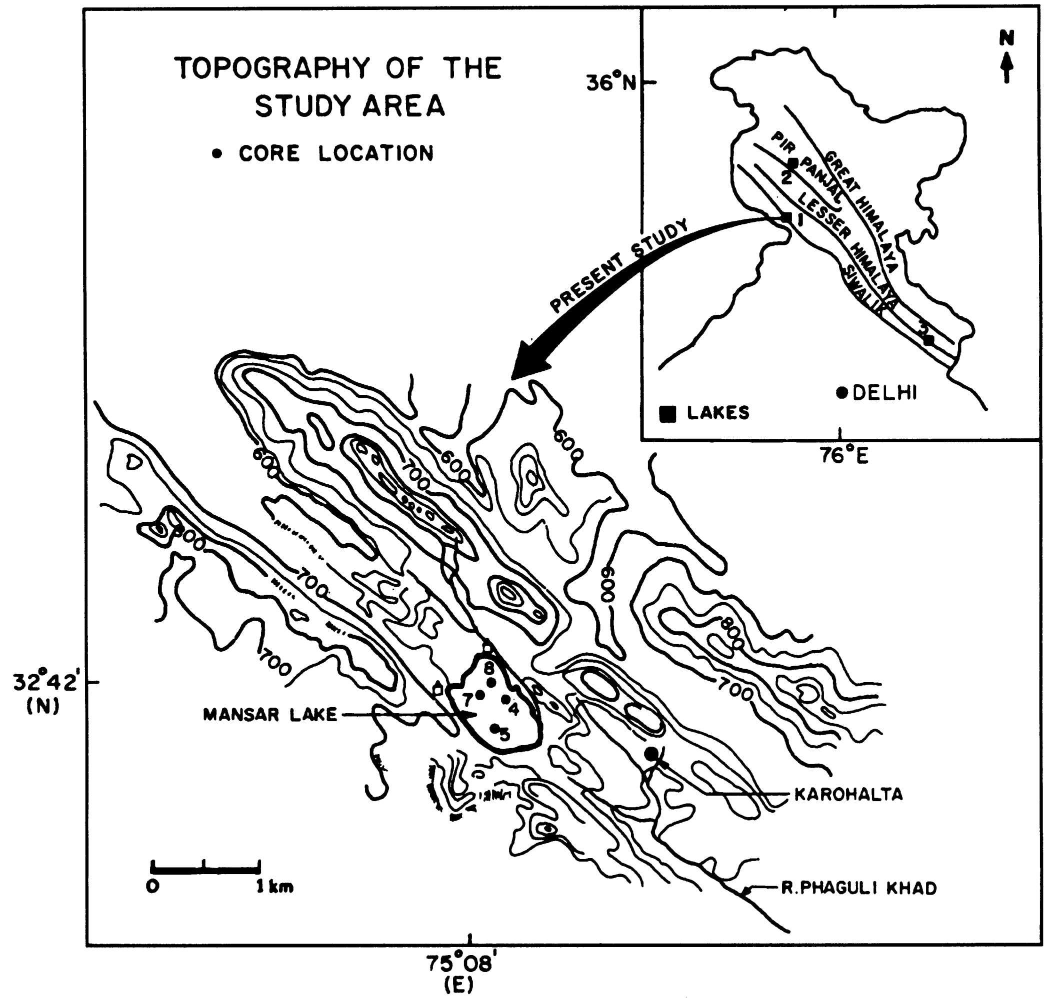

Fig. 1. Inset: Map of northern India showing four Himalayan mountain belts in the general area of the three sites studied. 1. Mansar Lake, Jammu; 2. Manasbal Lake, Kashmir; 3. Kumaon lakes. Large map: topography of the area around Mansar Lake, Jammu region. • = locations of Cores MN-4, MS-5, MS-7 and MS-8.

MS-8 (Thompson and Oldfield, 1986; Kusumgar, Agrawal and Sharma 1989). Granulometric studies were conducted in the MN-4 core using a Malvern laser particle size analyzer.

Results and Discussion

Except for MS-5, all the cores show increased sedimentation rates during the past 30–40 yr (Fig. 2). We observed bomb-produced ^{14}C at the tops of Cores MN-4, MS-7 and MS-8. Comparing the $\Delta^{14}C$ values of the sediment from core tops with the global atmospheric $\Delta^{14}C$ curve (Gupta and Polach 1985), we are able to assign an approximate chronology for the tops.

Figure 2 shows the sedimentation rates of different cores calculated using ^{14}C age *versus* depth, assuming a uniform density for sediments throughout the profile. Core MS-8, located near the northern tip of the lake, has the highest sedimentation rate of 24.28 mm yr^{-1} between 0–85 cm, and 1.32

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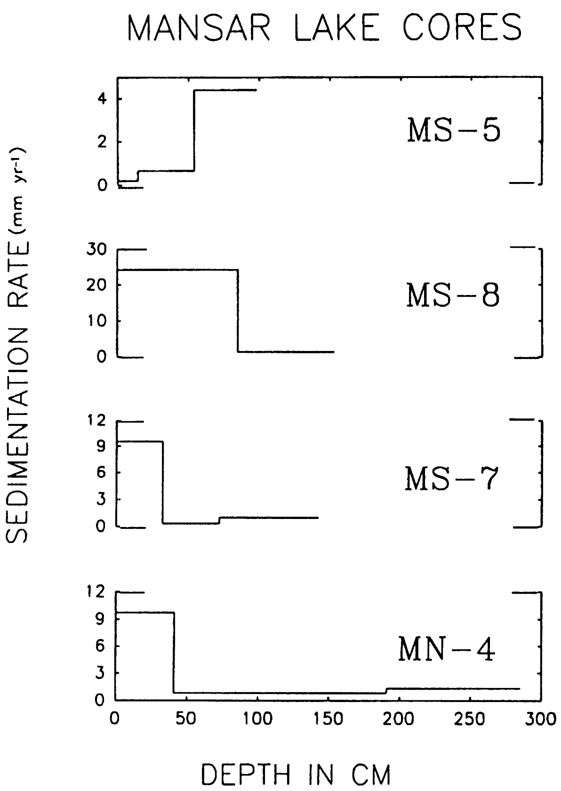

Fig. 2. Graph showing variation in sedimentation rate down the profile for various ^{14}C-dated cores

mm yr^{-1} between 85–153 cm. We found that the ^{14}C age at 153 cm is *ca.* AD 1440. Cores MN-4 and MS-7 were taken in the northeast and northwest areas of the lake, respectively, sharing higher and similar sedimentation rates in the top 30–40 cm. In Core MN-4, the sedimentation rate decreased down the profile, from 9.76–1.36 mm yr^{-1}, back to 580 BC. In Core MS-7, the sedimentation rate decreased down the profile, from 9.56–1.00 mm yr^{-1}, back to AD 140. Core MS-5 in the southern part of the lake has a lower sedimentation rate of 0.2 mm yr^{-1} at the top, increasing down the profile to 4.4 mm yr^{-1}, back to 570 BC. To determine the effects of bioturbation and to confirm the preservation of the core top, we measured excess ^{210}Pb and found 12.5 dpm gm^{-1} at the top and 6 dpm gm^{-1} at the depth of 5.0 cm, corresponding to a sedimentation rate of 2.0 mm yr^{-1}. Decrease in ^{210}Pb activity as a function of depth implies that sediments have not been disturbed by bioturbation after deposition.

The rate of sedimentation at the top reflects a major inflow of sediment into the lake from the northwestern flank. Adjoining Cores MN-4 and MS-7, which were taken from the southeastern and southwestern parts of the lake, respectively, show a high sedimentation rate in the upper part (9.76 and 9.56 mm yr^{-1}), indicating the reduction of sediment thickness as compared to Core MS-8. This suggests that the lake had been receiving the sediments predominantly from the northwest flank of the basin. The temporal changes in the sedimentation rate at various locations are due to the location of the core with respect to the lake margin. In the absence of tectonic or anthropogenic evidence, we can conclude that the variation in sedimentation rate is controlled by precipitation and should therefore reflect paleomonsoonal variability in the region. From the geomorphology of the lake, it is likely that the cores located in the northwest flank received sediments through its rivulet resulting in a high sedimentation rate.

Three lakes in the Kumaon region, which some of us studied (Kusumgar, Agrawal and Sharma 1989) show sedimentation rates of 0.55 mm yr^{-1}, 0.77 mm yr^{-1} and 1.05 mm yr^{-1}. In Naukuchiatal, the sedimentation rate varies from 0.61 mm yr^{-1} to 3.08 mm yr^{-1} with accelerated sediment influx events. The Kashmir lakes show a sedimentation rate of 5.5 mm yr^{-1} for the top 30 cm, as determined by excess ^{210}Pb. In Core MS-8, $\delta^{13}C$ values range from −28.0‰ at 12-cm depth to −26.0‰ at 85-cm depth and to −26.7‰ at 153-cm depth. The frequency-dependent component of the susceptibility ($\varkappa_{fd}$) varies between 0 and 3% in Cores MN-4, MS-5 and MS-7 along the core, which is lower than the *ca.* 3–12% observed in the Kumaon lakes and 2–12% in the Kashmir lakes (Kusumgar, Agrawal and Sharma 1989; Kusumgar *et al.* 1992).

In Core MN-4, we measured proxy paleoclimatic markers, $\delta^{13}C$, $\varkappa_{fd}$, and grain-size distribution. $\delta^{13}C$ of the organic fraction of the sediment can be used to infer the relative contribution of C_3 *vs.* C_4 type of plants (Smith and Epstein 1971). More negative $\delta^{13}C$ values indicate a humid and wet phase, whereas less negative values indicate an arid and dry phase. The higher $\varkappa_{fd}$ indicates the greater input of soil-derived ultra-fine secondary ferimagnetic grains, which most probably occur as a coating on the silt-size sediment grains (Thompson and Oldfield 1986).

For Core MN-4, more negative $\delta^{13}C$ values of *ca.* –28‰ are observed at depths 280 and 190 cm, corresponding to 580 BC and AD 110, respectively (Fig. 3). We found a higher silt content (~98%) and enhanced $\varkappa_{fd}$ (2–3%) at a similar depth in the core. In the absence of evidence for tectonic/anthropogenic activity, we attribute the enhancement in silt percentage to increased runoff in the lake catchment due to an increase in paleoprecipitation. This has been further corroborated by an increase in $\varkappa_{fd}$ at similar core depths. *Ca.* AD 300–1400, the silt percentage and $\varkappa_{fd}$ values drop down to *ca.* 94.5% and 0–1%, respectively, except for a minor excursion at AD 1100. This indicates weaker rainfall between AD 300–1400, with a sharp enhancement *ca.* AD 1100, which coincides with medieval warming.

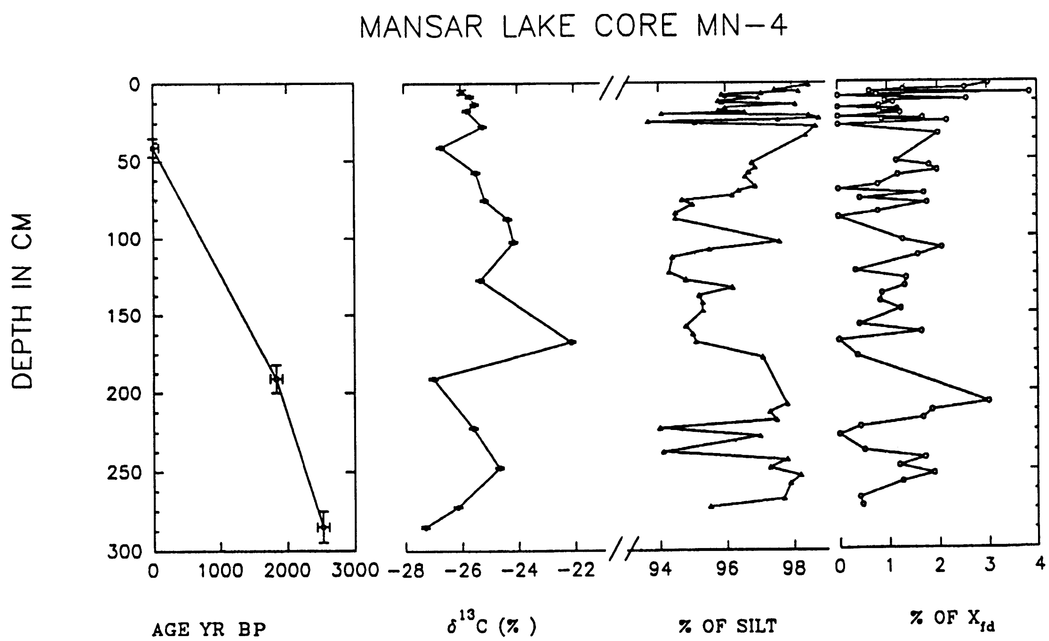

Fig. 3. Graph showing ^{14}C age, variation in $\delta^{13}C$, percent of silt and percent of $\varkappa_{fd}$ down the profile in Core MN-4

Conclusion

We have studied the monsoonal and non-monsoonal precipitation records preserved in the lake sediments of Jammu, Kumaon and Kashmir. A multidisciplinary proxy paleoclimatic investigation in Mansar Lake, Jammu, indicates periods of enhanced rainfall between 580 BC and AD 300. During this period, mainly C_3 vegetation thrived, which is indicative of a wet and humid phase. Enhanced silt also suggests that a relatively humid phase prevailed in the area, which is comparable to the present precipitation regime. We observed that from AD 300 to 1400, the area experienced a relatively dry and arid phase with medieval warming *ca*. AD 1100.

The lakes of the Kumaon region are influenced by the southwest monsoon, but the sedimentation record is affected by anthropogenic activity, which prevents us from deciphering signatures of paleomonsoonal influence. The non-monsoonal lake of Manasbal in the Kashmir Valley has shown chronological inversion due to the contribution of younger paleosols from the drainage basin, and the masking effect of anthropogenic activity has precluded the deduction of a paleoprecipitation record.

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