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ENVIRONMENTAL CHANGES IN INDIA DURING LAST 4 MILLION YEARS

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Fossils have been used to provide relative chronologies and evolutionary trends. In recent years, they have acquired a sharper edge to also provide definitive evidence about climatic and environmental changes in the past. In the last two decades, especially among the younger workers, an interdisciplinary approach has inspired Quaternary research in India. A variety of physical, chemical, geological, stable isotopic and palaeontological techniques are being used both to delineate climatic and environmental changes and to date these events. However, such interdisciplinary data of definitive character are so far available only from Kashmir, Rajasthan and, to some extent, Gujarat and the Arabian Sea. In rest of the subcontinent, such interdisciplinary studies have yet to take off. In this talk, I propose to summarise the recent evidence and suggest further areas of research. I propose to cover Kashmir, Rajasthan, Gujarat and the Arabian Sea.

KASHMIR

A team of workers derived from the universities of Kashmir, Chandigarh, Garhwal, Delhi, Lucknow, Gujarat, Birbal Sahni Institute of Palaeobotany, Geological Survey of India and Physical Research Laboratory worked together to provide a history of climatic, environmental and sedimentary changes in the Kashmir basin during the past 4 Ma. Let me delineate the outline of these changes.

It appears that the rise of the Pir Panjals impounded the Himalayan drainage in early Pliocene times, thus giving rise to a vast lake in the Kashmir valley. These lake sediments show effects of tectonic uplifts and the lake was finally drained out by the emergence of the Jhelum river after which there was only aeolian deposit on the exposed lacustrine sediments. These lacustrine deposits have been analysed and dated through a variety of techniques. The earliest Karewa sediments have been exposed by the river Rembiara at Dubjan. The magnetic dating and the extrapolation of the fission-track dates places these sediments in the Gilbert magnetic chron (<3.4 Ma). It may be noted that the Pir Panjals have also played a major role locally in determining the climatic changes in Kashmir. It appears that the Pir Panjal range acquired its present height of about 5,000 metres during the last 2.8 Ma. This barrier now effectively insulates the Kashmir valley from the warmth and the moisture of the southwestern monsoon. In Dubjan, in the Rembiara valley, the earliest sediments indicate a warm-temperate transitional climate. The Upper Dubjan strata show a temperate climate with higher precipitation. The Dubjan strata are overlain by a 200m thick conglomerate, perhaps the result of a major tectonic upheaval. The Rembiara exposes the lower Karewa sediments along its course. The Hirpur III locality stratigraphically overlying the thick conglomerate (I), dated to Upper Pliocene, starts with a sub-tropical climate with minor variations in precipitation. The upper part of Hirpur III shows a cold temperate and dry climate. It appears that the sub-tropical climatic regime gradually cooled off without any abrupt transition. In the Rembiara section, there is a gap in the pollen profile till one reaches the Krachipatra locality. Krachipatra locality date can be extrapolated to about 1.5 Ma.; it shows cold temperate and moist climate. Now more detailed data are available from the Karewa section exposed by the Romushi river, though significant parts of the section are generally poor to barren in pollen. The upper Romushi section, falling within the Brunhes chron, shows five cold periods separated by warmer periods. Thus, roughly between 0.65and 0.2 Ma there are five cold glacial-like oscillations.

It appears that the Jhelum emerged sometime later than 0.2 Ma,after which there was only aeolian deposition on the Pir Panjal flank. The lake continued for some more time on the Himalayan side, before the emergence of the Jhelum, and therefore the Himalayan loess deposits are generally less than 8 metres in thickness with five or less palaeosols, compared to the southwest side, the loess thickness is more than twenty metres with nine palaeosols. TL and ^{14}C dates suggest that the loess deposition is younger than 0.2 Ma. Nine palaeosols therefore would indicate a climatic change with a periodicity of only 20,000 years.

The last 20,000 years are better documented in terms of well-dated pollen profiles of Butapathri, Tosh Maidan, Anchar etc. It may be pointed out here that the deglaciation started in Kashmir around 18,000 years B.P. as indicated by broad-leaved elements in the pollen profile, development of palaeosols, C_3 type of plants and an Upper Palaeolithic culture. Now evidence of early deglaciation from the continent is becoming evident not only from Kashmir but also from Nepal and Japan (30°-40° N latitude).

Climatic amelioration at *c.*18,000, *c.*5,000, *c.*1,800 and *c.*1,000 years B.P. in the Kashmir valley is indicated by both pollen and pedogenic evidence. It is interesting to note that the peaks of population density in the Kashmir valley appear to coincide with those of climatic amelioration.

RAJASTHAN

A team of Deccan College, Physical Research Laboratory and Australian scientists have worked in Rajasthan to unravel the Quaternary sequence. In the early Quaternary period, most of Rajasthan was marked with perennial rivers having wide beds which carried heavy bedloads. Recent tectonics have disorganized and uplifted parts of these relict river beds (Jayal Formation). Some workers have mistakenly identified these riverbeds as glacial moraines. During the middle Quaternary times there was less energy in the fluvial systems resulting in meandering of the rivers and formation of playas. At this stage rivers were carrying only sand. Both from the banks of the playas and the river beds early Stone Age (Acheulian) tools have been reported. The Thar desert (Didwana Formation) seems to be a product of the last glaciation (less than 200,000 years). For the last 20,000 years, however, one has more detailed data.

Singh *et al.* (1974) have produced well dated pollen diagrams for the Lunkaransar, Sambhar, Didwana and Pushkar lades. The sequence shows an arid phase before 10,000 years. Between 10,000-6,000 years lacustrine conditions prevailed, but the wettest period was 5,000-3,000 B.P. After 3,000 years B.P. aridity set in. Palaeosalinity changes dated by ^{14}C, in the Didwana lake profile, indicate that the lake became hypersaline previous to 12,500 years. The interbedding of anthropogenic calcite and dolomite crystallised in the mud lamini indicate occasional floods. The period between 12,500-6000 yrs B.P. is marked by frequent fluctuations between hypersaline and freshwater conditions. Between 6,000-4,000 yrs B.P. the lake became fresh indicating higher precipitation. After 4,000 years B.P. arid conditions set in and the lake became saline. Thus there is a fair concordance between geochemical, sedimentological and pollen data from Didwana.

The Rajasthan evidence is consistent with the sea core data obtained by Duplessy (1982) and Van Campo *et al* (1982).

Let us have a look at how these environmental changes affected early human settlements.

HUMAN HABITATION

In the arid to semi-arid region of Rajasthan changes in precipitation exercise considerable control on human settlement pattern and demographic densities. In Rajasthan, at least so far there is no trace of early Palaeolithic tools coeval with the Jayal Formation which signifies a relatively higher precipitation and a perennial integrated drainage system. Once this drainage disorganized and became defunct, early man fabricated his tools on the relict river beds using pebbles as raw material. Such Acheulian tools have also been found in a primary context on the banks of the playas coeval with the Amarpura Formation.

The Amarpura Formation underlies the Didwana Formation: the latter marking the advent of the Thar desert. The Didwana Formation records the history of the Thar desert as to when it became mobile or got stabilized. The events of stabilization of the Thar desert marking relative increase in precipitation are indicated by the buried soils (palaeosols). The upper Palaeolithic and the Mesolithic artifacts are associated with the different palaeosols in the body of the Didwana Formation. Thus it becomes clear that the Stone Age man was occupying the Thar desert only during periods of increased rainfall and was perhaps migrating to greener areas during arid phase. In fact, this trend continued during the subsequent Bronze and Iron Ages.

The pre-Harappan and the Harappan civilizations flourished in Rajasthan between *c.*4,500-3,500 B.P., the wettest period in the last 10,000 years as indicated by both palynological and palaeoslinity data. There is a cyclicity in the pattern of human settlement e.g., the Harappans withered after *c.*1,700 B.C., the Painted Grey Ware appeared *c.*700 B.C. and vanished: the Rang Mahal Culture appeared *c.*200 A.D. and disappeared. The settlement patterns have been further affected by the changes in the river courses caused by neo-tectonic movement,s as a result of which the palaeo-Yamuna gradually shifted towards and merged with the Ganga and the palaeo-Sutlej with the Indus. Both these originally were the tributaries of the Saraswati (modern Ghaggar) On the other hand, in areas of higher rainfall or sub-tropical to tropical climate man has been able to adapt himself more easily to the changes of climate.

ARABIAN SEA

A comparison of $^{18}O/^{16}O$ measurements on *Globorotalia ruber* and *G. menardil* from the Andaman Sea and the Arabian Sea cores shows that during the last glacial maxima (*c.*18,000 B.P.) and at *c.*10,000 B.P. the southwest monsoon was weaker than today but the northeast monsoon was stronger. During this time the Persian Gulf region, Rajasthan, and the Zagros mountains were drier than today.

Van Campo *et al's* (1982) comparison of oxygen isotopic and pollen data shows three distinct glacial stages at *c.*18,000, *c.*70,000 and *c.*120,000 yrs B.P. Both benthic and planktonic foraminifera show heavier

^{18}O values. There is a positive correlation between ^{18}O and Chenopodiaceae pollen values. Thus Van Campo et al (1982) have correlated littoral aridity with sea level fluctations and oxygen isotopic stratigraphy.

Agrawal and Guzder (1978) had established a marine transgression at *c*.5,000 B.P. on the western coast. Gupta (1972, 1973) worked out three marine transgressions at *c*.120,000, 30,000 and 5,00 B.P. on the Saurashtra coast. The 5,000 B.P. marine transgression seems to coincide with the **mid-Holocene** warming up. On rechecking, the 30,000 B.P. eustatic rise does not seem to be so well authenticated. The 120,000 transgression appears to coincide with the onset of the last glaciation and therefore a bit difficult to explain. Perhaps this is due to large errors in uranium series dating and may represent the interglacial eustatic rise of the sea preceding the last glaciation and therfore should be older than 120,00 B.P.

CONCLUSIONS AND PROSPECTS

The climatic and environmental history of the Indian sub-continent seems to be fairly well delineated in a southwest-northeast transect covering the Arabian Sea, Gujarat, Rajasthan and Kashmir. In Kashmir the record seems to be quite complete upto 4 Ma. For the last 20,000 years B.P. the data have far better resolution. Unfortunately, well-dated climatic and environmetal changes in the rest of the sub-continent are sketchy so far. We do hope that in the coming years we will have far more detailed data for the rest of the subcontinent also. In the adjoining areas of India, gradually more data are coming. In Pakistan, the Potwar plateau **has yielded a complete sequence of loess which can** be interpreted in terms of climatic change. From Nepal also considerable pollen data of the whole Quaternary period are now coming up, thanks to the Japanese effort. We hope to provide a detailed palaeoenvironmental sequence of the Narmada basin in the coming years. In the next phase of our work in Kashmir we propose to calibrate the pollen record with the meteorological data to obtain a quantitative palaeoclimatic record of the valley. It is heartening to see the efforts of Birbal Sahni Institute of Palaeobotany, Lucknow, Deccan College, Poona, and Indian Institute of Tropical Meteorology, Poona, delineating the palaeoclimatic picture of the subcontinent. In the next decade one can expect to see much better documented proxy climatic data with higher resolution.

These proxy climatic data open up new prospects of understanding the role of the Tibetan plateau in forcing climatic change, in comparing periodicities of different earth processes (e.g. soil-loess couplets) with the Milankoviche's parameters. Thus a new phase of palaeoclimatic studies has emerged which in long run can provide basic data for not only global, but also for meso-and micro-level climatic models.

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