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Holocene history of vegetation and climate of fresh-water Punlota (Degana) Lake in Eastern Rajasthan, India

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ABSTRACT

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Pollen analysis of 2 m deep sedimentary profile from fresh-water Punlota Lake situated at the outskirt of Degana township in district Nagaur (Eastern Rajasthan), has revealed that around 9,000 years BP, the region had predominantly non-arboreal vegetation, depicting arid climatic conditions. Around 4,200 years BP, savannah type-vegetation covered the region demonstrating increase in the frequency of fern as well as fungal spores- indicating warm and moist conditions. Around 3,000 years BP, savannah vegetation witnessed reduction in tree taxa, ferns and grasses with simultaneous increase in Cyperaceae, Chenopodiaceae, etc., depicting decrease in the warm and moist conditions. Uppermost part of the investigated profile has revealed more or less similar conditions as witnessed in the preceding phase, except for the increase in Poaceae and Caryophyllaceae, reflecting comparatively drier climate.

Simultaneous elemental analysis of the profile reveal that all major (Al, Fe, Ca and Mg) and trace (Mn, Ba, Sr, Pb, Cu, Ni and Zn) elements change in their concentration at the middle of the profile or about 1 m depth from the surface i.e., around 4,200 years BP. Most of these elements abruptly increase by a factor of two or three at this section and maintain relatively higher values up to the surface. Higher elemental abundance above 1 m boundary in the sediment could arise due to accelerated weathering as well as in consequence to the enhancement in the rainfall.

Coupling radiometric data with major change in elemental abundance indicate maximum precipitation around 4,200 years BP, in the region which very well corroborate with the present palynological studies- the first radiocarbon dated Holocene profile from the fresh-water lake in Rajasthan.

Key-words—Holocene, Palaeoclimate, Modern pollen rain, Fresh-water, Punlota, Eastern Rajasthan.

भारत के पूर्वी राजस्थान की ताजी जलीय पुनलोटा झील की वनस्पतियों का होलोसीन इतिहास तथा जलवायु

छाया शर्मा, चंचला श्रीवास्तव एवं दीनानाथ यादव

सारांश

पूर्वी राजस्थान के नागौर जिले के देगाना कस्बे के बाहरी क्षेत्र में अवस्थित ताजी जलीय पुनलोटा झील से प्राप्त 2 मीटर गहरी अवसादी परिच्छेदिका के परागाणविक विश्लेषण से ज्ञात हुआ है कि विगत 9,000 वर्ष पूर्व के दौरान इस

क्षेत्र में अवृक्षीय वनस्पतियों की प्रधानता थी, जो शुष्क जलवायुविक स्थितियों का द्योतक है। 4,200 वर्ष पूर्व के आस-पास इस क्षेत्र को सवाना प्ररूप की वनस्पतियों ने आच्छादित कर लिया, जो फर्न (पर्णांग) तथा कवकीय बीजाणुओं की आवृत्ति में वृद्धि का परिचायक है तथा उष्ण एवं आर्द्र स्थितियाँ इंगित करता है। 3,000 वर्ष पूर्व के दौरान साइपरेसी, चीनोपोडिएसी, इत्यादि में समकालिक वृद्धि के साथ सवाना वनस्पतियों के वृक्ष वर्गकों, फर्न तथा घासों में कमी प्रेक्षित की गयी, जो उष्ण एवं आर्द्र स्थितियों में वृद्धि का संकेतक है। अन्वेषित परिच्छेदिका के ऊपरी भाग में पूर्ववर्ती प्रावस्था की भाँति की ही स्थितियाँ (पोएसी तथा कैरियोफिल्लेसी में वृद्धि के अतिरिक्त) प्रेक्षित की गयी हैं, जो अपेक्षाकृत शुष्क जलवायु का परिचायक है।

परिच्छेदिका के समकालिक तत्त्वीय विश्लेषण से प्रदर्शित होता है कि परिच्छेदिका के मध्य अथवा सतह से 1 मीटर गहराई पर अर्थात 4,200 वर्ष पूर्व के आस-पास सभी प्रमुख तत्त्व (As, Fe, Ca तथा Mg) एवं सूक्ष्म मात्रिक तत्त्व (Mn, Ba, Sr,Cu, Ni, तथा Zn) अपने सान्द्रण में परिवर्तनशील हैं। इनमें से अधिकांश तत्त्व इस परिच्छेद पर एक अथवा दो कारकों से आकस्मिक वृद्धि करते हैं तथा सतह तक अपेक्षाकृत उच्चतर कोटि बरकरार रखते हैं। अवसाद में 1 मीटर सीमा के ऊपर उच्चतर तत्त्वीय प्रचुरता त्वरित अपक्षयण तथा वृष्टि के परिणामस्वरूप हो सकती है।

रेडियोमितीय आंकड़ों को तत्त्वीय प्रचुरता में हुए बड़े परिवर्तनों से सम्बद्ध करने पर इस क्षेत्र में 4,200 वर्ष पूर्व के आस-पास अधिकतम वर्षण इंगित होता है, जो वर्तमान परागाणविक अध्ययनों अर्थात राजस्थान की ताजे जलीय झील से प्राप्त प्रथम रेडियोकार्बन आयुर्निधारित होलोसीन परिच्छेदिका के अध्ययन के सुसंगत है।

संकेत शब्द—होलोसीन, पुराजलवायु, आधुनिक परागकण वर्षा, ताजा-जलीय, पुनलोटा, पूर्वी राजस्थान।

INTRODUCTION

RAJASTHAN, in western India, is known for it's desert (part of the Thar Desert), surrounded by the Arabian sea in the west and Aravalli mountains in the east. The initiation of desert climatic condition with its temporal change in geographical coverage has always been an important topic of research for geologists, ecologists and palaeo-climatologists. It constitutes a significant phyto-geographical region of India. The Quaternary palaeo-floristic succession and climatic oscillations of the region are mainly known through the studies on the palaeo-environmental changes carried out by Singh *et al.* (1972, 1974), Vishnu-Mittre (1978), Bryson and Swain (1981), Swain *et al.* (1983), Wasson *et al.* (1983), Sharma and Chauhan (1991), Dhir *et al.* (1992) and Deotare *et al.* (2000). The Holocene vegetation history of this desert region has been reconstructed through the combined pollen sequences worked out from the salt-lake deposits at Lunkaransar, Didwana and Sambhar situated in western Rajasthan, corroborated by the pollen analytical data from Pushkar – the fresh water lake situated about 11 km from Ajmer city at the foothills of Aravalli hills, besides some analysed soil samples from the Indus Valley site Kalibanghan (Singh, 1971; Misra & Rajaguru, 1986). Modern pollen rain in the desert has been interpreted in the light of the prevailing vegetation (Singh *et al.*, 1973). Among the investigated sites in Thar desert, Didwana salt lake basin alone contained the sedimentary deposits which revealed the palaeo-environmental changes during the critical transition period from the Late Pleistocene (LGM) to the early Holocene (Singh *et al.*, 1990). Saxena (1984) also investigated the profiles from Kanodwala and Pokharan Ranns – both situated in south-west Rajasthan and from Budha-Pushkar which is hardly 2 km from the main lake Pushkar in addition to the two re-investigated profiles- Didwana and Pushkar.

The present study is focussed on the reconstruction of late Quaternary climate and vegetation based on geo-chemical and palynological results of Punlota freshwater lake sediment deposit from eastern Rajasthan, India. This lake bed has thick soil deposits with considerable amount of organic matter. At present, the lake basin is being extensively used for crop production by the local population. Both pollen grain analysis as well as geo-chemical measurements of major and trace elements have been made for the sedimentary profile so as to derive information on palaeo-vegetational, palaeo-ecological and palaeo-climatic changes that have taken place over the desert region, especially around the sampling sites.

PHYSIOGRAPHY

Rajasthan is endowed with several saline and fresh-water natural lakes, many of them lying in the desert region. The origin, evolution and geographic distribution of these lakes are attributed to the past climatic conditions, coupled with tectonic activities in the region. The region east of Aravalli Range, because of higher rainfall (50-60 cm per year) as compared to the region west of the Aravalli Range or the main desert (below 10 cm per year), is studded with a number of fresh-water lakes- many of them transformed long back into artificial reservoirs. Pushkar (26°29' N, 74° 33'50 E) which lies in the semi-desert plain close to the foothills of Aravalli Range

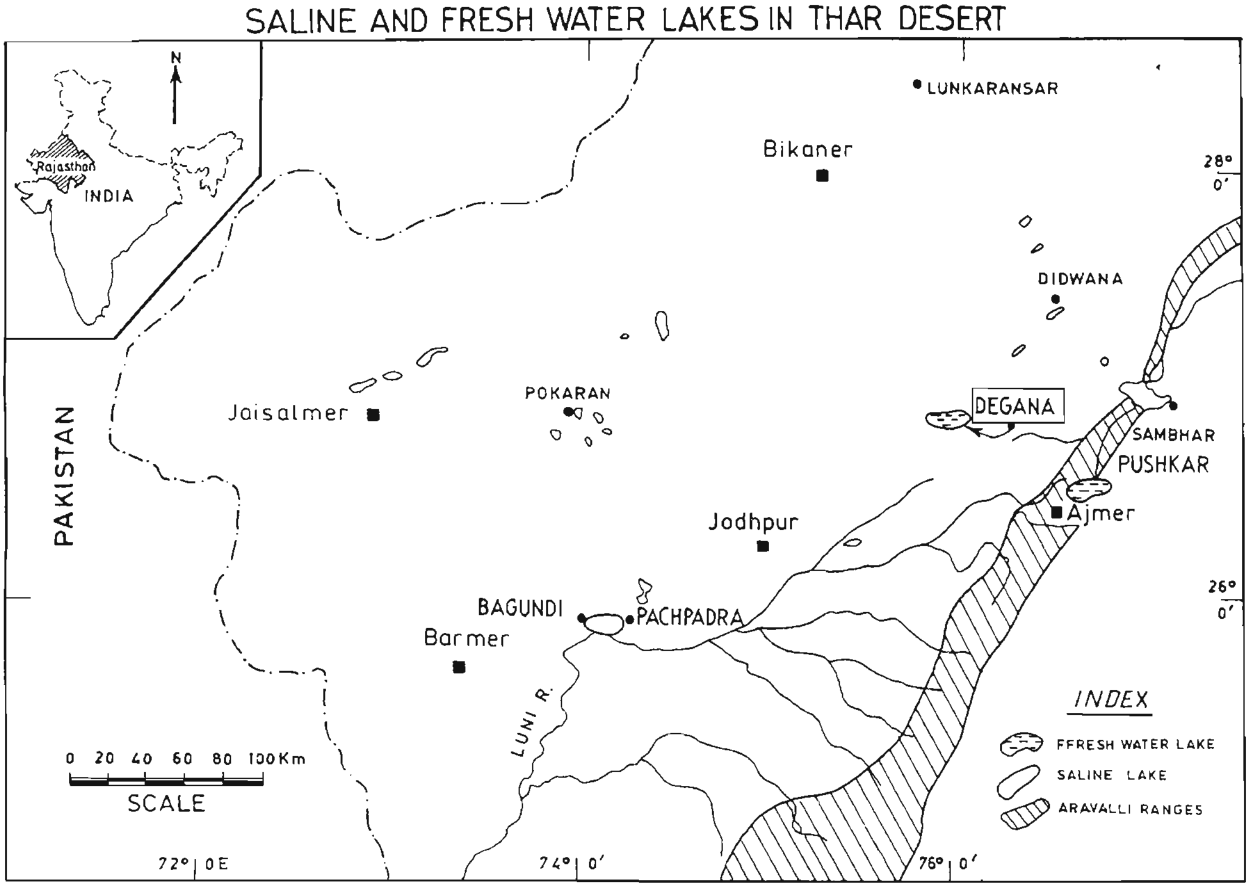


Fig. 1—Map showing the location of the investigated lake site and surface samples.

at the outskirts of Ajmer township happens to be the only other fresh-water lake in Rajasthan which has been earlier pollen analysed though the column remains undated.

However, the present investigated profile is from another fresh-water lake Punlota from Rajasthan. It lies about 12 km S-W to Degana town in district Nagaur (26°50.4' N, 74°21' E), eastern Rajasthan (Fig. 1). The lake now is just a dried up patch of flat land subjected to extensive crop cultivation in the vicinity of the lake bed.

VEGETATION

The vegetation around the present site is xerophytic, typical of semi-arid climatic regions of Rajasthan. *Euphorbia caducifolia* and *Calotropis procera* are the two prominent xeric species characterising the shrubby elements. *Euphorbia caducifolia* is the most commonly occurring species inhabiting hillocks as well as the plains and distributed evenly throughout Rajasthan, whereas *Calotropis procera* prefers mostly open sandy plains. Arboreal components of the xerophytic vegetation of Rajasthan are chiefly *Prosopis cineraria, Acacia nilotica, A. leucophloea, A. senegal, Ailanthus excelsa, Azardirachta indica, Tamarix dioica, Ficus glomerata, Salvadora persica, Balanites roxburghii* and *Anogeissus pendula*, the last one generally occupying the montane habitats. Other commonly seen shrubby elements, often attaining the habit of a small tree, are *Mimosa hamata, Acacia jacquemontii, Dichrostachys cinerea, Leucaena glauca, Capparis decidua, Leptadenia pyrotechnica, Ziziphus nummularia*, etc. *Crotalaria burhia, Sericostoma pauciflorum, Aerva pseudotomentosa*, etc., sometimes form gregarious patches on stabilized sand-dunes.

The ground flora is rich in grasses whereas main ephemeral or seasonal species are *Cleome viscosa, Polygala erioptera, Arnebia hispidissima, Achyranthes aspera, Alysicarpus* spp., *Boerhavia diffusa, Borreria hispida, Corchorus* spp., *Hibiscus* spp., *Justicia simplex, Kickxia ramosissima, Peristrophe paniculata, Pedalium murex, Sida* *cordifolia, Heliotropium* spp., *Spergula fallax, Tephrosia* spp., *Trianthema portulacastrum, Tribulus terrestris, Tridax procumbens, Vernonia cinerea, Xanthium strumarium, Zornia gibbosa*, etc. (Bhandari, 1990).

METHODS

Sample location & Sampling technique

As stated, the freshwater palaeolake-Punlota, was selected for the present study. The lake site (26°50.4' N, 74°21' E) is situated about 12 km south-west to Degana Town in Nagaur District of Rajasthan (Fig. 4). For sampling, the place was visited during Feb.'98 and a trench (0.90 x 1.00 x 2.00 m) was dug at the lake margin. Soil samples were collected by scooping one of the walls of trench using a steel scraper at the marked positions from the surface. Following this technique, soil samples were collected at every 10 cm (depth) interval for geo-chemical and palynological investigations. In addition, 3 samples were taken at every 50 cm (depth) interval for radiocarbon analysis Fig. 2. These samples were collected up to a depth of 2.00 m from the surface and well preserved in clean polythene bags for laboratory analysis.

In addition, 3 surface samples were gathered from the vicinity of the lake site to evaluate the modern pollen deposition pattern so as to provide a comparative data-base for interpretation of pollen diagram in terms of past vegetation and climate.

Geo-chemical and pollen analysis

For geo-chemical analysis, the moist soil samples were dried at ~ 100°C in an oven for 2 days, powdered, homogenised by thorough mixing and then stored in clean polyethylene vials. About 0·5 gm sample HNO_3 medium by HF- HNO_3 – $HClO_4$ acid treatment using clean teflon beakers (Yadav, 1995). A few duplicate samples were also prepared following above method so as to ascertain precision of major and trace elemental determination. About a dozen major and trace elements viz., Ca, Mg, Fe, Al and Sr, Ba, Zn, Pb, Ni, Mn, V were measured using Induced-Coupled Plasma Atomic Emission Spectrophotometer (ICP-AES) of JY 38 S Jobin Yvon model at Chemistry laboratory, Physical Research Laboratory, Ahmedabad. Other two major elements, viz., Na and K, were measured using Atomic Absorption Spectrophotometer (AAS). The accuracy of analytical measurement was checked with respect to NOVA PRL control standard and MAG-1 international standard. In all the above analytical measurements, the precision for most elements was found to be less than 5% whereas accuracy was within 10% of analytical uncertainty.

Pollen/spores from surface and profile samples were extracted as per conventional acetolysis technique (Erdtman, 1943). Pollen count in most of the samples in both cases varied from 150-450. However, the counting ranged from 80-100 in a few cases due to the poor pollen yield. Percentage of the recovered pollen/spores was calculated in terms of total terrestrial pollen and the encountered taxa were arranged in the constructed pollen diagram in a sequence i.e., arboreals, non-arboreals, ferns, aquatics, etc.

Lithology and Radiocarbon dates

The rate of sedimentation calibrated on the basis of the three radiocarbon dates, is apparently uniform (Fig. 2), approx. 1 cm/46 years for the zone below the middle of the litho-column and 1 cm/53 years for the above 100 cm zone.

RESULTS

Modern Pollen Vegetation Relationship

Pollen analysis from the three surface samples has revealed the dominance of non-arboreals, such as Poaceae, Cyperaceae, Cheno/Ams, Caryophyllaceae, Acanthaceae, Liguilifloreae, Tubulifloreae, *Xanthium strumarium*, Malvaceae, Mimosaceae, Convolvulaceae, Rosaceae, Brassicaceae, *Polygonum*, etc.

Arboreals are represented by the sporadic encounter of pollen of few taxa viz., *Ephedra*, *Ziziphus*, *Holoptelea* and Oleaceae, besides the pollen of *Pinus roxburghii* transported to the site from some distant locality (Fig. 3).

Overall pollen assemblage reflects more or less the existing vegetation around the site but many important taxa characteristic of xeric/scrubby vegetation in the region remain un-represented.

Depth (cm)	Lithology	Lab No.	Sample No. (Depth)	Radiocarbon dates
0-50	black clay with organic matter	BS-1516 S-2201	40-50 cm	2320±140 Yr. B.P.
50-100	black clay with organic matter	BS-1477 S-2161	90-100 cm	4180±150 Yr. B.P.
100-150	silty clay			
150-200	sandy clay	BS-1450 S-2119	190-200 cm	8730±500 Yr. B.P.

Fig. 2—Lithology and Radiocarbon dates.

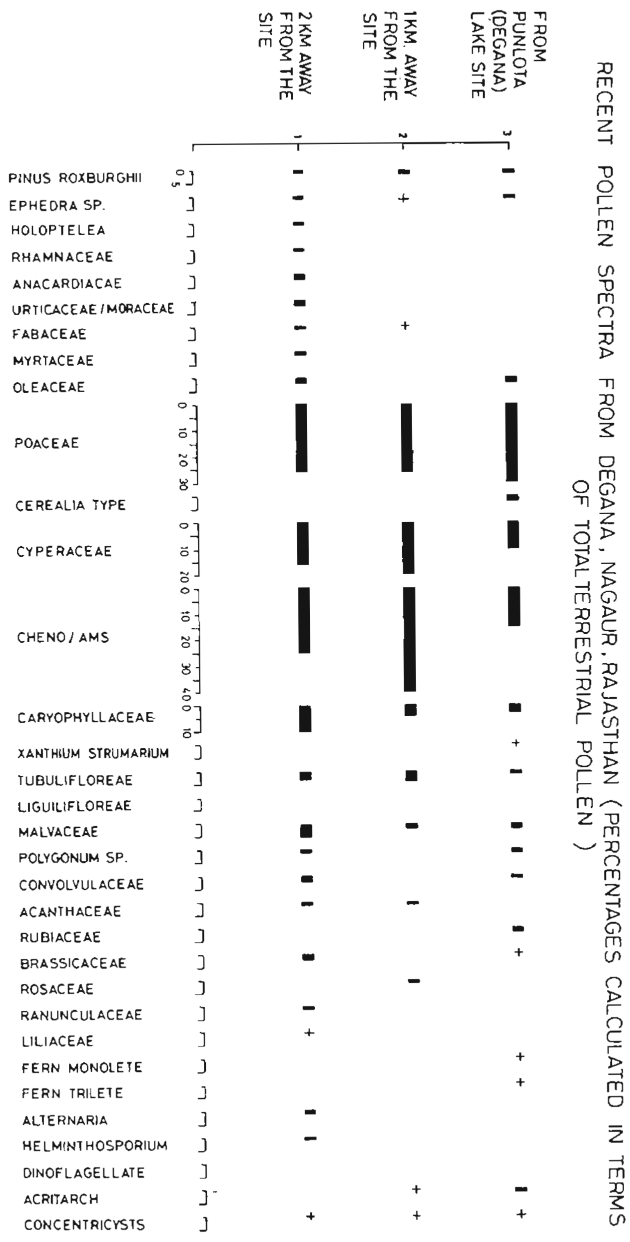


Fig. 3—Recent pollen spectra from Degana, Eastern Rajasthan.

Description of pollen diagram

The pollen diagram is divided bottom upwards into four pollen assemblage zones viz., I, II, III and IV, based on the fluctuations seen in the representation of prominent arboreals and non-arboreals. Each pollen zone is prefixed by DG, the abbreviation for Degana, signifying the popularly known investigated site (Fig. 4).

Pollen zone DG-I (200-175 cm): Poaceae-sedges-Cheno/Ams-Oleaceae-Ephedra Assemblage

The bottom of this pollen zone radiocarbon dated to 8,730±500 years BP, revealed the vegetation scenario covering the time span of about 700 years i.e., period between 9,200 and 8,050 years BP, depicting dominance of non-arboreals and poor representation of arboreals. Among the non-arboreals, Poaceae (40-50%), Cyperaceae (25-30%), Cheno/Ams (10-15%), Caryophyllaceae (2-5%) are the major constituents, whereas *Cerealia* (5%), Tubulifloreae and *Polygonum* (3% each), Liliaceae (3%), Malvaceae, Acanthaceae (2% each) are represented sporadically in low values. *Potamogeton* (1%) is the sole encountered representative of aquatic vegetation. Ferns (monolete and trilete), are scantily present.

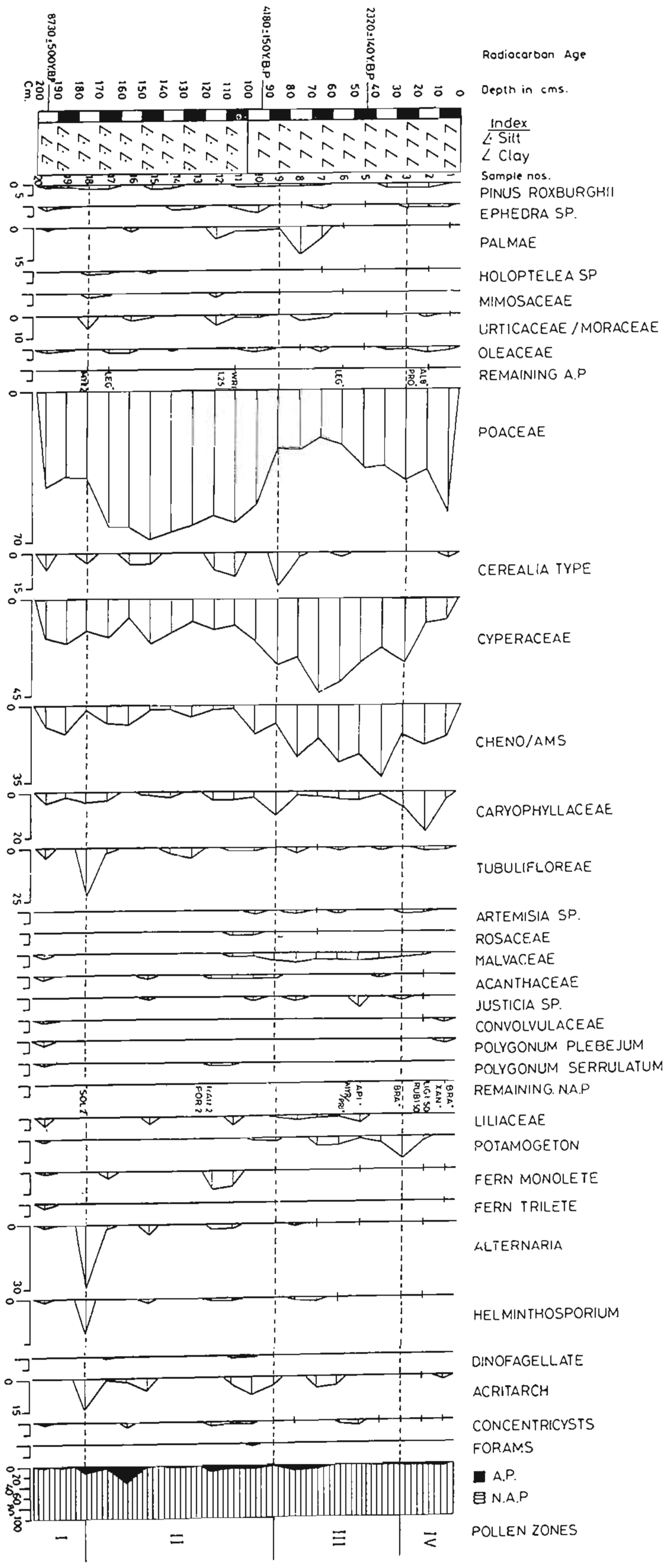
Pollen zone DG-II (175-85 cm): Poaceae-Cyperaceae-Cheno/Ams-Ephedra-Mimosaceae-Urticaceae/Moraceae Assemblage

This pollen zone, radiocarbon dated 4,180±150 years BP for the middle of the investigated litho-column encompassing the time span of next over 4,000 years, covering the period between 8,050 to 3,810 years BP, revealed a better representation of arboreals as well as non-arboreals as compared to the preceding pollen zone. Poaceae (35-70%) and Cyperaceae (15-35 %) also exhibit comparatively higher values in this zone. Cheno/Ams (5-25%) and Tubulifloreae (5-25%), together with fern spores (monolete 2-5%) though with increased presence, were recorded in fluctuating frequencies. *Helminthosporium* (2-20%), Acritarch (5-15%) and other fungal spores (5-35%), also exhibit much increased values whereas dinoflagellates (2%) are met with for the first time in this zone.

Among the arboreals, *Ephedra* (2-10%), Urticaceae/Moraceae, Palmae (2-5% each), Oleaceae (2-3%), showed increasing trend in their frequencies as compared to the pollen zone DG-I. Mimosaceae and *Holoptelea* (2% each) appear for the first time in this zone, though with low frequencies.

Pollen zone DG-III (85-25 cm): Sedges-Poaceae-Cheno/Ams-Palmae -Urticaceae/Moraceae Assemblage

This pollen zone radiocarbon dated to 2,320±140 years BP, at 40-50 cm depth demonstrates a steep decline in Poaceae (25-35%) and Caryophyllaceae (5%) in the upper half during 3,810 to 1,325 years BP, whereas Cyperaceae (30-45%) and Cheno/Ams (25-35%) exhibit simultaneous improvement. Other



POLLEN DIAGRAM FROM PUNLOTA LAKE, DEGANA IN NAGAUR DISTRICT, RAJASTHAN
(Percentages calculated in terms of total terrestrial pollen)

taxa, such as Malvaceae (2-4%), Acanthaceae (2-5%), *Artemisia* and Liliaceae (2% each), together with the aquatic element *Potamogeton* (2-5%) are recovered in increased frequencies.

Pollen zone DG-IV (25-0 cm): Poaceae-Cyperaceae-Cheno/Ams-Ephedra-Oleaceae-Urticaceae/Moraceae Assemblage

This pollen zone covering the period of last 1,325 years BP exhibits an increasing trend in grasses (50-70%), followed by Caryophyllaceae (5-20%) and associated with a corresponding decline in Cyperaceae (10-30%) and Cheno/Ams (15-20%). Other constituents of the ground flora, such as *Artemisia*, Malvaceae, Acanthaceae and aquatic element-*Potamogeton*, also turn more sporadic in this zone. Likewise, the arboreal taxa viz., *Ephedra, Holoptelea* and Palmae, also register considerable decline at the commencement of this zone.

Geo-chemical data

Study on trace and major elemental geo-chemistry has been made so as to couple the geo-chemical data with palynological findings. These results will address the issues of vegetational and climatic changes during Holocene Period.

Data on more than a dozen major and trace elemental concentration of sediment section at every 10 cm depth interval are presented here. Among these elements Fe, Mn and V are redox sensitive, while Zn, Ni, Pb, Cu, Al and Ba are heavy metals being insensitive to changing oxidising and reducing conditions of the prevailing environment. The other elements, viz., Ca, Mg, Na and K, are weathering derived and precipitate in lake environment as authigenic minerals. Because of wide variations in geo-chemical properties of these elements, their

Fig. 4—Pollen diagram from Punlota (Degana) Lake.
Abbreviations used-

A. P. Arboreal pollen
ALB *Albizzia*
PRO *Prosopis*
LEG Legume
WRI *Wrightia*
MYR Myrtaceae
N. A. P. Non-arboreal pollen
BRA Brassicaceae
XAN *Xanthium*
LIG Liguiliflоreae
RUB Rubiaceae
API Apiaceae
MYR Myrtaceae
PRI Primulaceae
RAN Ranunculaceae
POR *Portulaca*
SOL Solanaceae

	Ca	Mg	Fe	Al	Sr	Ba	Zn	Ni	Pb	Mn	V	Cu	Na	K
Ca	1	0.793	0.703	0.746	0.881	0.705	0.599	0.573	0.311	0.853	0.672	0.624	-0.695	0.181
Mg		1	0.982	0.963	0.667	0.888	0.913	0.914	0.478	0.897	0.883	0.921	-0.909	0.254
Fe			1	0.960	0.561	0.902	0.934	0.952	0.541	0.839	0.876	0.940	-0.912	0.270
Al				1	0.557	0.820	0.833	0.854	0.488	0.814	0.786	0.836	-0.859	0.395
Sr					1	0.629	0.529	0.476	0.316	0.793	0.634	0.521	-0.492	0.031
Ba						1	0.904	0.904	0.549	0.894	0.862	0.899	-0.832	0.096
Zn							1	0.983	0.495	0.842	0.874	0.975	-0.901	0.092
Ni								1	0.525	0.804	0.874	0.979	-0.901	0.165
Pb									1	0.346	0.289	0.470	-0.380	0.147
Mn										1	0.815	0.844	-0.839	0.038
V											1	0.906	-0.821	0.056
Cu												1	-0.933	0.042
Na													1	-0.034
K														1

Fig. 5—Inter-elemental correlation matrix for major and trace elements.

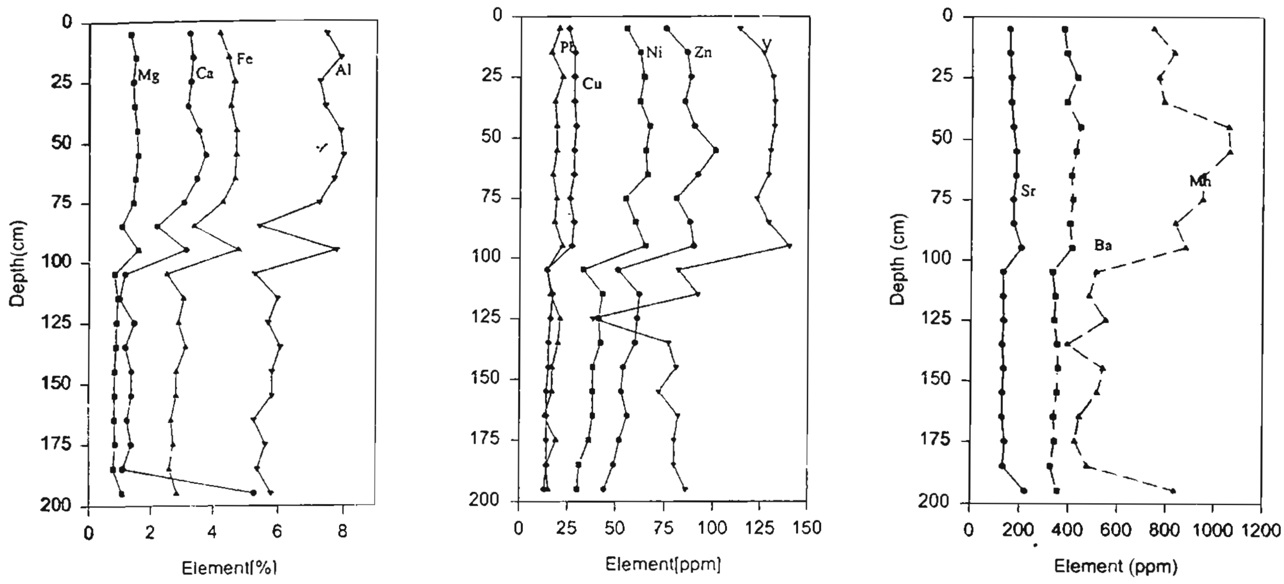


Fig. 6—Diagram showing down-core variation of elements in Punlota (Degana) Lake sediments.

study is expected to bring out interesting phases and history of environment that the lake would have experienced since the geological past. The discordance in their variations will have implication to their contrasting geo-chemical properties, whereas their similar trends down the sediment profile will have implication to a common cause, the influence of weathering and prevailing palaeo-climatic conditions. With this concept in mind, varieties of major and trace elements have been measured along the sedimentary profile to interpret their variations in terms of the palaeo-climatic conditions.

Among various elements studied, Ca, Mg, Fe, Al, Na and K are the major elements with their concentrations in range of 1-7 %, whereas rest other elements' concentrations are in trace level with their range 20-1000 ppm (Fig. 5). The elemental variations down the sediment profile is shown in Fig. 4. Most of the major elements viz., Al, Fe, Ca and Mg and trace elements viz., Mn, Ba, Sr, Pb, Cu, Ni, Zn, V (Cox, 1992) show distinct changes in their concentration at about 1.00 m depth interval from the surface of profile. The concentrations of these elements abruptly increase by a factor of two to three at this section compared to that down and above the sediment profile. Such an increase in elemental concentration is like that of addition of spike in the sediments. Sudden increase in elemental concentration at 1.00 m boundary of the profile could arise due to high influx of eroded material into the lake basin from the catchment area.

DISCUSSION AND CONCLUSION

Pollen analysis of the sedimentary profile from fresh-water Punlota (Degana) Lake has yielded significant proxy data to interpret the palaeo-climatic and palaeo-vegetational changes in the region since early Holocene. Around 9,000 years ago, the vegetational condition was open type (**Pollen zone I**) with dominance of non arboreal pollen (NAP), especially grasses indicating somewhat dry climatic condition. This inference is also supported by the geo-chemical results showing relatively high concentration of Na down the profile below 1.00 m depth section (Fig. 6). Commencement of favourable climate started showing more abundance of arboreal and non arboreal pollen species during the time interval between 9,000 to 4,200 yrs BP (**Pollen zone II**). The inferred climatic condition in this zone is semi-arid. The geo-chemical results of Al and several other major and trace elements also indicate maximum fluvial input along with allochthonous minerogenic matter into the lake system at about 4,200 yrs BP, i.e., at 1.00 m boundary from the surface of profile. Thus, at 4,200 yrs BP, the lake level was maximum and soil erosion was more, thereby indicating heavy rainfall in the region. This is further supported by the prevalence of Savannah type vegetation (**Pollen zone III**) with an increase in arboreal vegetation along with swampy non-arboreal elements such as *Potamogeton* and acritarch during the time period 4,200 to 2,000 yrs BP. The inferred climatic condition in this pollen zone is moist and humid. The relative decrease in several major and trace elements including Al (Fig. 6) compared to previous pollen zone with scanty distribution of arboreal and non-arboreal vegetation marked by increase in Poaceae and Caryophyllaceae in **Pollen zone IV** (Fig. 4) represents semi-arid environmental condition being prevalent during the period 2,000 yrs BP to present.

According to earlier finds by Singh *et al.* (1972, 1974) improvement in climate has also been recorded in Rajasthan desert though for a wider temporal range i.e., from 9,000 to 5,000 years BP. Similarly, during 5,000 to 3,000 years BP, the Rajasthan desert also experienced 50 cm more rainfall than what prevailed earlier in the region. The plant taxa indicative of increase in summer and winter precipitation came in prominence during the mid-Holocene and declined during the late-Holocene in harmony with the witnessed decline in lake level (Singh *et al.*, 1990).

Parallel and changing climatic trend witnessed for entirely different phytogeographical regions falls within the limit of the "Period of Climatic Optimum" which has been recorded globally for the period 7,000 to 3,000 years BP.

Holocene is the period during which major climatic fluctuation has been inferred globally. The onset of arid climate occurred in two phases i.e., during 4,700-3,700 and 2,000-1,700 BC. Both phases had fairly wide impact not only on the Indian subcontinent resulting in the desertification of western Rajasthan but also in other countries, mainly Africa in the development of Sahara and Nubian deserts. The commencement of global desertification is dated back to 5,400 BP i.e., 3,400 BC which greatly affected the regional precipitation and consequently the river systems too. The change from wetter to arid conditions destroyed steadily the vegetation and indirectly the climate over the region (Sankaran, 1999).

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