

POLLEN ANALYTICAL STUDIES AT THE NAL LAKE (NALSAROVAR), GUJARAT

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ABSTRACT

The pollen analysis of 6 m profile from the brackish water shallow Nal Lake about 60 km south-west of Ahmedabad reveals the Holocene history of the grassland-chenopod savannah in its vicinity. The chenopods show a declining trend from early Holocene to 3,500 years B.P. and *Holoptelea integrifolia*, a tree member of the riverain dry deciduous forest, shows a rising trend until 4,000 years B.P.

Three episodes of estuarine conditions, before 7,000 years B.P., between 3,500-6,000 years B.P. and around 160 years B.P. are recorded. These may be ascribed to the repeated overflowing of the flooded Little Rann caused by marine inundation possibly as a result of the tectonic disturbances. The lake had perhaps originated as a marine inlet.

Key-words — Pollen analysis, Nal Lake, Late Quaternary (India).

सारांश

नल झील (नलसरोवर) गुजरात पर परागाणु-विश्लेषिक अध्ययन - विष्णु मित्र एवं छाया शर्मा

अहमदाबाद से लगभग 60 कि० मी० दक्षिण-पश्चिम की ओर खारी एवं उथली नल झील से प्राप्त छः मीटर की परिच्छेदिका का परागाणु-विश्लेषण उस क्षेत्र के ग्रास-पास ग्रासलैंड-कीनोपॉड-सवाना का होलोसीन कालीन इतिहास प्रदर्शित करता है। कीनोपॉड्स प्रारम्भिक होलोसीन से 3,500 वर्ष बी०पी० तक अवनति की तथा नदतटीय-शुष्क-पर्णपाती वन का एक सदस्य वृक्ष, होलोप्टीलिया इन्टैग्रीफोलिया, 4,000 वर्ष बी०पी० तक अपनी उन्नति की प्रवृत्ति प्रदर्शित करते हैं।

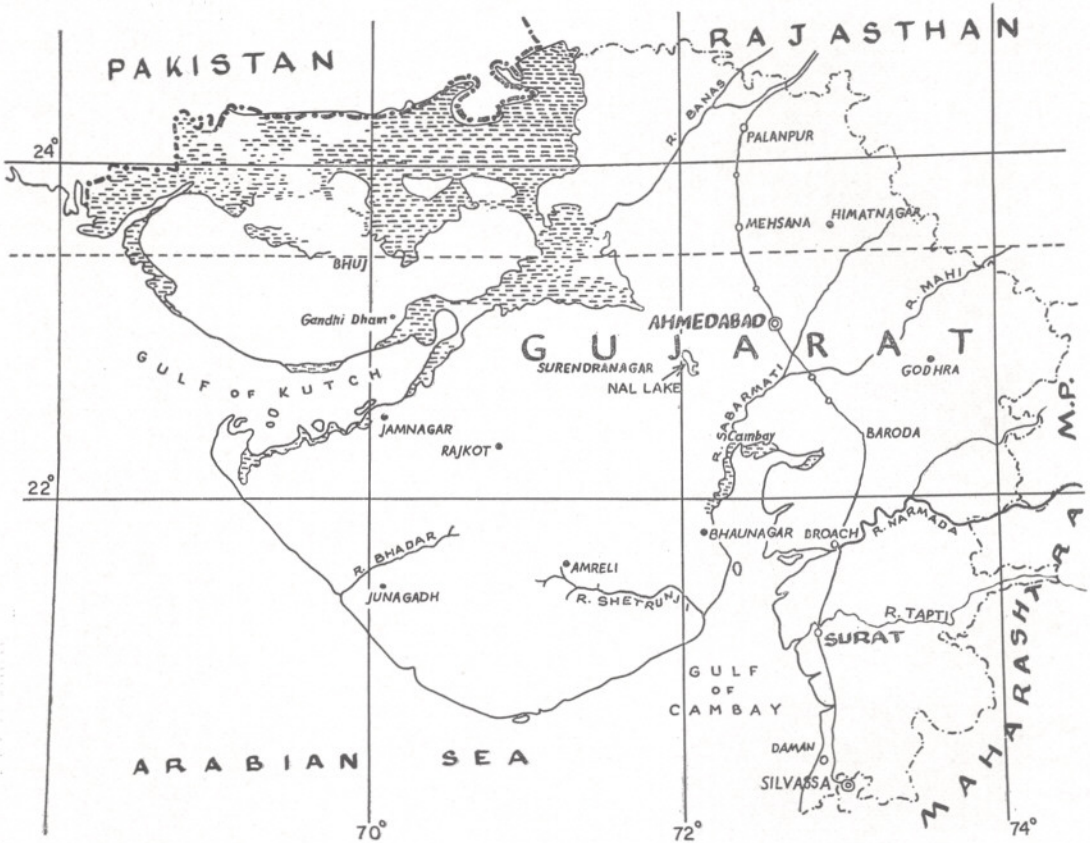
ज्वारनदमुखीय दशाओं की तीन घटनायें - 7,000 वर्ष बी०पी० से पूर्व, 3,500 - 6,000 वर्ष बी०पी० के बीच तथा 160 वर्ष बी०पी० के लगभग - भी अभिलिखित हैं। ये घटनायें छोटी रन के समुद्री आप्लावन से बार-बार बाढ़ग्रस्त होने के कारण मानी जा सकती हैं जो कि संभवतया विवर्तनिक उत्पत्तियों का परिणाम था। कदाचित् इस झील की उत्पत्ति समुद्री अन्तर्गम से ही हुई थी।

INTRODUCTION

THE Nal Lake (22°45'N, 72°6'E) is a brackish water shallow lake situated about 60 km south-west of the city of Ahmedabad (Maps 1, 2). It measures about 30 km long and up to 6 km at its widest, extending over an area of about 80 sq km (Oldham & Pascoe, 1964). Nearly 300 Islands (called *Bete* by local people) of different sizes and shapes occur in the lake, the largest amongst them is the Panvarh Island. The lake, an important bird sanc-

tuary, is visited by birds from far off places even from outside the Indian Sub-continent.

The lake lies in the low alluvial tract separating Ahmedabad from Saurashtra and connects the south-eastern extremity of the Rann of Kutch with the head of Gulf of Cambay. The present Rann of Kutch is believed to have been a gulf of sea until recent times and the estuarine conditions had probably occurred in the neighbourhood of the Nal Lake. According to Fuljams (1853) the alluvial depression including the



MAP 1—The bold broken line is the International boundary; the small broken line, the state boundary; the marshes are shaded; road shown as straight line (from Survey of India Map; Scale—1·1 cm = 50 km).

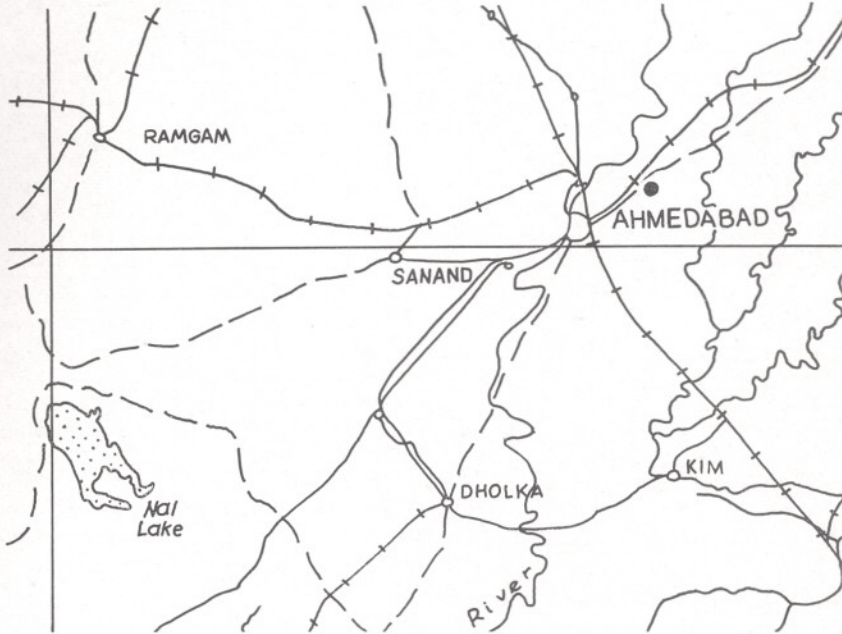
Nalsarovar is probably an old marine inlet silted up in recent times.

Fuljams (1853) found the lake surrounded by thick and impenetrable stands of *bulrushes, *Scirpus* sp., some tall sedges and grasses extending considerable distance inland along its western, southern and northern margins but not along the eastern margin. The lake visited by the junior author only along its eastern margin was found open and free of bulrushes, though at some places only isolated plants comprised the scanty vegetation. The plantations of *Casuarina*, *Prosopis juliflora*, *Parkinsonia aculeata*, *Zizyphus*,

Salvadora persica and *Azadirachta* have been raised here and there in recent years. The ground vegetation comprises largely of grasses among which occur members of Chenopodiaceae, Amaranthaceae, Cyperaceae, Compositae, etc. A part of the surrounding area is brought under cotton and wheat cultivation.

The detailed account of vegetation of Nalsarovar situated on the western boundary of Ahmedabad District is not available. Flora of Northern Gujarat (Saxton & Sedgwick, 1918) reports besides large number of genera and species of the families Gramineae, Compositae, Papilionaceae, Convolvulaceae and Cyperaceae distributed in the vicinity of Ahmedabad, the occurrence of *Nymphaea lotus* Linn. var. *pubescens* Hook. f. and Thomas, and *Scirpus kysoor* in and along

*The name "bulrush" is sometimes given to *Scirpus lacustris*, sometimes to *Typha*. The former use is correct but the latter is more common. Cf. Tansley, A. G., *An Introduction to Plant Ecology*, 1954, p. 34. London.



MAP 2— The broken line is the district boundary; the crossed line, the rail track and plain straight line represents road. The longitude and latitude are 72° and 23° respectively (from International Map of vegetation of Kathiawar, Inst. Francais, Pondichery; Scale— 1 cm = 8 km).

the Nal Lake. The flora of Ahmedabad does not refer to species growing in and around the Nal Lake (Vaidya, 1967).

The geomorphological studies of the Nal Lake and the surrounding area were made by Col. Fuljams (1853) during about a quarter of a century, he spent in this area. He had observed loose sand undulations probably of drift sand and caused by violent wind action during the monsoon along the eastern side of the lake, which extended then in the northwesterly and southwesterly directions. He found the extensive bays between the ridges encrusted with salt and bare of vegetation and nodules of lime dispersed through thick fine loose sand making the bays. The latter led him to infer dry climate with violent wind activity. These sand ridges according to Fuljams were thrown up by tectonic activity causing sinking of the country occupied by the Nal Lake or having upraised the land which divides Kathiawar from Gujarat.

Fuljams further observed the rain water channels north of the lake draining water

into the southern extremity of the little Rann and the passing of the superfluous waters of the lake in its southern extremity through the Bogawara and the Oonkar rivers uniting about 32 km south of the lake and subsequently joining the Sabarmati River after flowing in a southeasterly direction. He also observed the formation of new rivers and channels and their subsequent closing up during his stay of 25 years. Among Fuljam's other important observations may be mentioned the formation of channels uniting their waters near the Haddala Village with those of the Nal Lake and flowing down the Bogawara River; the extension of tides as far as Haddala in 1824, and many kilometers further up in 1853; and the conversion of the Nal Lake and the surrounding country into a vast sheet of water during heavy floods. He ascribes the source of salinity to such floods. He further observed that the brackishness of the lake did not normally show up until several months after when the water level had lowered considerably by evaporation and or absorption by soil.

MATERIAL AND METHODS

The material comprising 13 samples collected by using six inch hand augur at an interval of 50 cm from 6 m deep profile was sent to the senior author in 1969 by Dr S. K. Gupta of the Geophysics Group of the Tata Institute of Fundamental Research, Bombay presently at the Physical Research Laboratory, Ahmedabad. The stratigraphical details of the samples as supplied by Dr S. K. Gupta are given below :

0-0-70	m	Black grey clay
0-70-1-30	m	Grey clay
1-30-2-10	m	Black clay
2-10-2-60	m	Fine brown sand
2-60-3-50	m	Brown clay with kankar
3-50-4-65	m	Brown mud with sand
4-65-6-00	m	Sand

After deflocculation with 10% KOH solution, 5 gm of each sample were treated with HF and acetolysed (Erdtman, 1943). No seeds and fruits were recovered in the process. Temporary mounts in 50% glycerine were prepared of the acetolysed material for microscopic examination.

The pollen sum (comprising all land plants pollen) varies from 120 to 200 but for samples 60 and 62 where it could not be raised beyond 102 and 92 respectively. Some samples were found barren.

The pollen sum for surface samples prepared by acetolysis, however, varies from 150-300 except for one sample where only 150 pollen grains could be counted. Pollen was not found in the water samples.

MODERN POLLEN RAIN AT THE LAKE

Text-fig. 1

The area surrounding the lake is desolate, sandy waste populated by grasses and sedges with scattered plants of *Salvadora persica*, *Suaeda fruticosa*, Composites, *Amaranthus*, *Acacia*, *Prosopis*, *Zizyphus*, *Calotropis*, etc. and as described in the introduction of this paper. Modern surface and water samples were collected from the following seven islands:

1. Bor Bete (two soil & one water sample).
2. Dharawla Bete (two soil samples).
3. Sur Bete (two soil samples).
4. Limsee Bete (soil & water samples, one each).

5. Jhumaria Bete (soil & water samples, one each).

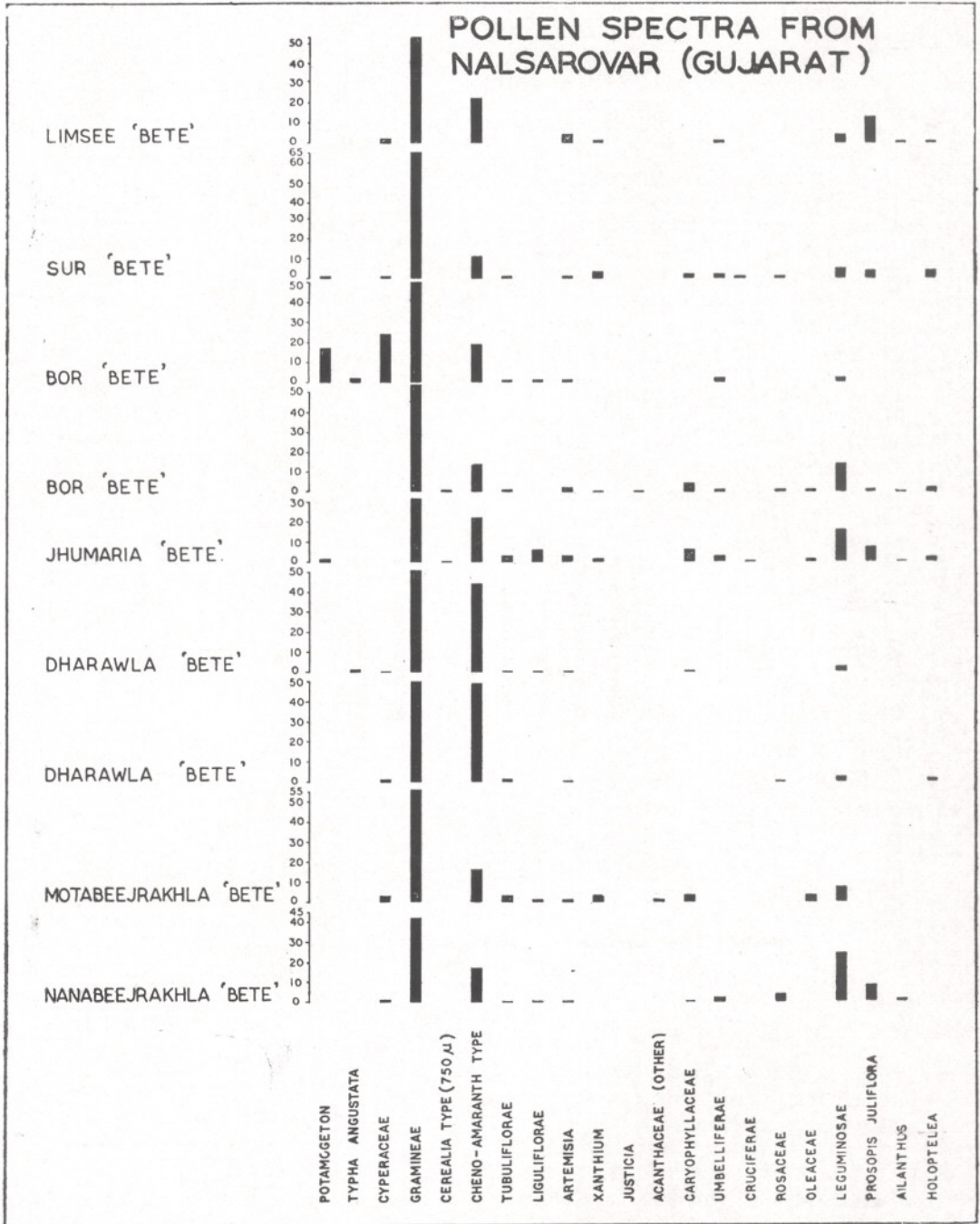
6. Nanabeejrakhla Bete (one soil sample).

7. Motabeerjrakhla Bete (one soil sample).

The vegetation on all these islands is dominated by grasses (together with bamboo at Limsee Bete), with some sedges, members of Compositae and Chenopodiaceae. Jhumaria Bete being the nearest to the main road and the rest house, is within immediate reach of the transport of pollen from plantations, road-side trees and garden plants. *Prosopis juliflora*, *Parinsonia aculeata*, and *Zizyphus nummularia* are the common planted trees here. Dharawla Bete, the largest island, is populated by buffalo keepers. The flora here is as at Jhumaria Bete.

All the pollen spectra are dominated by 30 to over 50 per cent grass pollen. The pollen of chenopods next in order of abundance is 15 to 20 per cent in most spectra but about 50 per cent in those from Jhumaria and Dharawla Bete. Sedge pollen about 24 per cent is noted in one of the pollen spectra from Bor Bete together with 17 per cent of *Potamogeton* pollen but in the remaining pollen spectra pollen grains of sedges and *Potamogeton* are under 3 per cent. Pollen of Leguminosae ranks the next in abundance in three pollen spectra from Nanabeejrakhla, Jhumaria and Bor islands. Pollen grains of the other constituents are comparatively slightly higher in the spectrum from Jhumaria Bete, owing to the nearness to the source of pollen at this island. The plantations of *Prosopis juliflora* are indicated by under 13 per cent pollen.

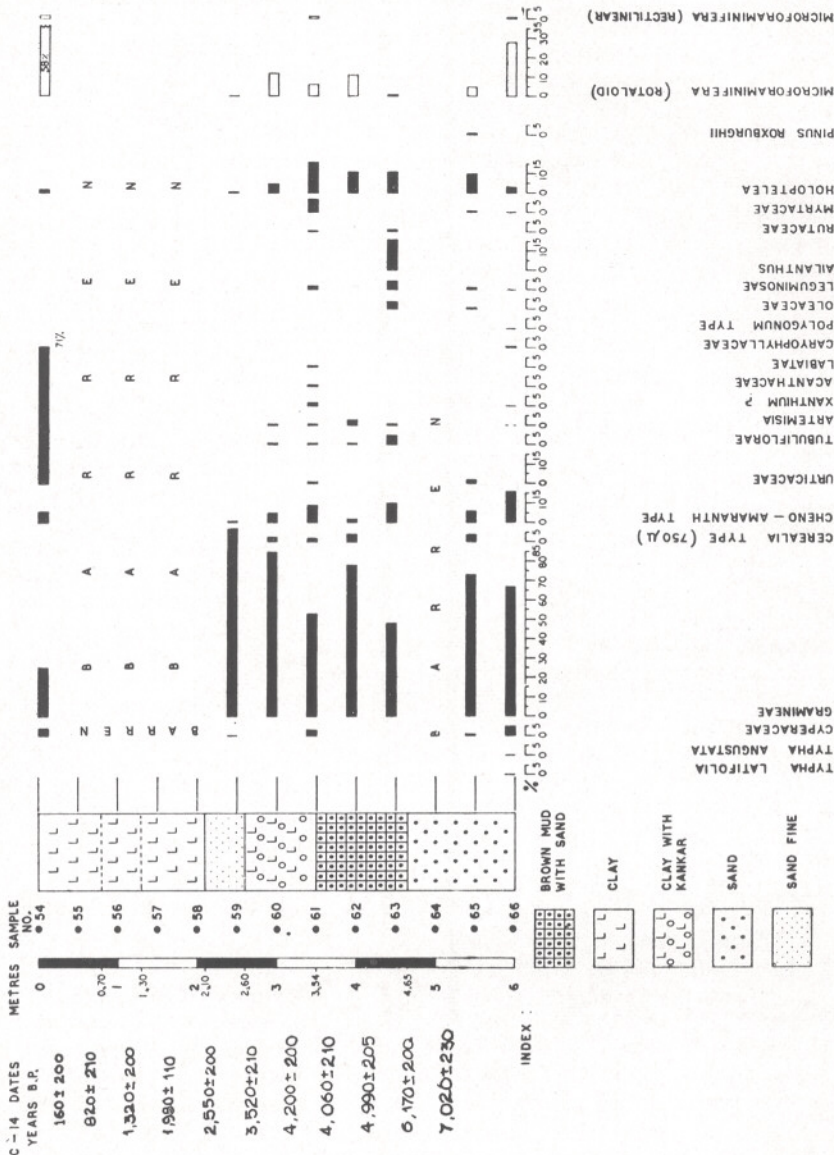
The fossil pollen spectra (Text-fig. 2) show 50-90 per cent grass pollen except the extreme top pollen spectrum where it is 30 per cent. Obviously, the grass pollen frequency here is highly depressed owing to overwhelming frequency (70%) of Urticaceae pollen. Pollen assigned to Urticaceae has not been observed in modern pollen spectra. Chenopods are under 15 per cent. Pollen of Leguminosae is usually under 5 per cent though varying from 4 to 10 per cent. Myrtaceae pollen is absent in the modern pollen spectra but from traces to 5 per cent it occurs in some fossil pollen spectra particularly the one from the kankary clay (Text-fig. 2).



TEXT-FIG. 1.— Shows percentage (calculated in terms of land plants pollen) of pollen grains in modern pollen spectra from surface samples collected from islands in the Nal Lake.

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(PERCENTAGES CALCULATED IN TERMS OF TOTAL LAND PLANTS POLLEN)



TEXT-FIG. 2 — Pollen diagram from the Nal Lake. For delimitation of local pollen zones, NS1 to NS4, kindly see section Biostratigraphy in the text.

ENVIRONMENT OF DEPOSITION IN THE LAKE

The presence of microforams at the bottom of the profile between 5.50 to 6 m is highly suggestive of the infilling of the lake basin by fluvial transport influenced by marine waters. The bottom sandy layer is of wider occurrence in the little Rann of Kutch based upon the grain size distribution (Gupta, 1975). The top clayey layers deposited under quiet environment are of detrital origin (Gupta, 1975). Being devoid of microforams, the clayey layers were sedimented from fresh water run-off.

A large part of the profile from 2.60-4 m comprising kankary clay and brown mud with sand containing marine foraminifera suggests infilling of the lake through inundation influenced by sea water. The top fine sand between 2.10-2.60 m too, is a fresh water deposit as it is devoid of microforams. However, the extreme top reveals inundation of the lake by tidal influence as abundant microforams are present in it.

The deposition seems to be uninterrupted as the C-14 dates reveal no time gap interval between the sediments. Unlike in the Rann where the sandy clay horizon extends from 9,000-4,200 years B.P., in this landlocked Nal Lake the sandy deposition of sand had continued until 2,500 B.P. If the percentage of microforams is any measure of the intensity of *marine influence, then it would appear that the marine influence was of higher intensity before 7,000 years B.P. than from 6,000 years B.P. to 3,500 years B.P. During the latter much erosion was caused resulting in the transport of kankar in to the lake. The most recent marine influence observed towards the extreme top of the profile is radiocarbon dated to 160 years B.P.

Thus, the environment of deposition of sediments in the lake has been also fluvial ever since the early Holocene and this was repeated again during the mid-Holocene and recently. The overlying 2 m of

the clay (black & grey) was deposited under undisturbed conditions and is of fresh water origin. The absence of pollen in lacustrine clay may be due to conditions uncondusive for preservation of pollen and perhaps also owing to drier climate.

POLLEN ANALYSIS

The pollen diagram (Text-fig. 2) is dominated by pollen of Gramineae and Chenopodiaceae and amongst the arboreals pollen of *Holoptelea* is found consistently and of the others sporadically suggesting the fluctuations in the Grassland-Chenopod Savannah. The lake, an important bird sanctuary, is visited by migratory birds. The abundant pollen of Urticaceae in the topmost sample and of *Ailanthus* in one or two samples only may be ascribed to the migratory birds visiting the lake.

The C-14 dates for the samples dated at the Radiocarbon Dating Laboratory of Tata Institute of Fundamental Research, Bombay and published by Gupta (1975) are shown in Table 1.

TABLE 1 — SHOWING RADIOCARBON DATES OF NAL LAKE SAMPLES

SAMPLE NO.	DEPTH IN METERS	RADIOCARBON DATES (YRS B.P.)	
		ORGANIC FRACTION	INORGANIC FRACTION
54	0.0	105 ± 200	160 ± 200
55	-0.5	700 ± 200	820 ± 210
56	-1.0	1200 ± 205	1320 ± 200
57	-1.5	2000 ± 185	1890 ± 110
58	-2.0	2500 ± 200	2550 ± 200
59	-2.5	3500 ± 200	3520 ± 210
60	-3.0	4060 ± 200	4200 ± 200
61	-3.5		4060 ± 210
62	-4.0		4990 ± 205
63	-4.5		6170 ± 200
64	-5.0		7020 ± 230

The C-14 dates from both the organic and inorganic fractions (shell & shell debris) show considerable correspondence and consistency. The dates from the inorganic fraction are adopted for the pollen diagram. Although, the two bottom samples are not dated yet but the trend of the dates seems to suggest that the base of the diagram may be dated to the beginning of the Holocene.

*Extensive biostratigraphical studies should be carried out in the lake sediments to solve the mystery of the occurrence of microforams interpreted here due to marine influence. Cf. Col. Fuljams' observations dated 1853, in the Introduction to this paper, of extension of tides several kilometres beyond Haddala and the former occurrence of water channels between Haddala and the Nal Lake.

BIOSTRATIGRAPHY

As the samples are fairly widely spaced, 0.50 cm apart, the tentative local pollen assemblages recognized include :

- 0-0-20 m NS4 Urticaceae-Gramineae
Assemblage.
0-20-2-60 m NS3 Gramineae Assemblage.
2-60-5-50 m NS2 Gramineae-Chenopodi-
aceae-*Holoptelea* Assemblage
5-50-6-0 m NS1 Gramineae-Chenopodia-
ceae Assemblage.

HISTORY OF VEGETATION AND CLIMATE BEFORE 5000 YEARS

The early Holocene vegetational history (Pollen Zone NS1) begins with open almost treeless vast stretches of grasslands with several Chenopods occurring in the saline-alkaline areas. Traces of pollen of Tubuliflorae suggest their presence in the grasslands and of *Polygonum* along river banks or dry banks of the lake. Pollen of *Artemisia* seems to be derived or else Artemisias were of extremely rare occurrence. The saline areas were, as today in the little Rann near Khargoda, populated by *Suaeda nudiflora*, *Salsola foetida*, perhaps *Indigofera pauciflora* (Leguminosae pollen), grasses such as *Corchorus antichorus*, *Aleuopus villosus* and other halophytic plants as *Lauenea pinnatifolia*, etc. The only tree species was *Holoptelea integrifolia*, a dry deciduous constituent of riverain community. And possibly *Eugenia heyneana* (Myrtaceae pollen) was another member of this vegetation. Pollen of *Typha* too seems either derived from long distance or a few plants had occurred along the margin of the lake.

During Pollen Zone NS2 chenopods were reduced nearly by half, *Holoptelea* increased by about 8-10 per cent and pollen of Urticaceae appeared. Presently, *Ficus hispida* and *Ficus glomerata* occur wild here along the banks of small streams and *Streblus asper* is of occasional occurrence. Increase in riverain vegetation though slight did take place. By about 6,000 years ago, chenopods increased slightly at the expanse of grasses. *Ailanthus* presently occurring very commonly on sandy soil records sudden increase whereas *Holoptelea* continued as before. There was increase in Leguminosae (possibly *Indigofera pauciflora*) and also in Oleaceae

(?*Nyctanthes arbortristis*, the only member of this family in the region believed to be truly wild vide Saxton and Sedgwick, (1918, p. 275). Rutaceae perhaps represented by *Feronia cretica*, also occurred.

By 5,000 years B.P., the vegetation reverted to grassland savannah but with much reduced chenopods, and with the only tree *Holoptelea* maintaining consistent values.

5000 YEARS TO PRESENT

After 5,000 years, *Holoptelea* showed a distinct increase together with that of Myrtaceae (*Eugenia*) though members of Rutaceae probably *Feronia*, Leguminosae, Labiatae, Acanthaceae, *Artemisia*, Compositae, Urticaceae were represented by small pollen frequencies. Chenopods continued as before though grasses were slightly suppressed but still continued dominance. Thereafter, the chenopods were further reduced together with considerable decrease in *Holoptelea* pollen frequency. Traces of Compositae and *Artemisia* pollen suggest their rare occurrence in the grassland savannah. By about 3,500 years B.P. both *Holoptelea* and chenopods were considerably reduced and the grasses were predominant, the latter dominated Pollen Zone NS3 though several pollen spectra are devoid of pollen.

During Pollen Zone NS4 the grassland-chenopod savannah with poor *Holoptelea* continued to the present, even though the pollen percentages of grasses and chenopods are considerably depressed by 71 per cent of Urticaceous pollen possibly of *Ficus* spp. (*hispida*, *glomerata*) and its pollen seems derived from an inflorescence dropped by a bird into the lake.

The entire sequence shows fluctuations in grassland-chenopod savannah with the most consistently occurring trees *Holoptelea* and a member of Myrtaceae (*Eugenia*). The first increase in tree pollen over the non-tree pollen is observed at 6,000 years B.P. and the second at 4,200-4,500 years B.P., both due to expansion of dry deciduous riverain forest. Although, on these two occasions increase in arboreal content is accompanied by decrease in grass pollen frequency, yet the chenopods remained unaffected suggesting that the saline areas continued as usual. This would suggest

that the increase in tree elements was not caused by increase in precipitation.

In view of the fluviably transported material between 2.10 m to 6 m the transport of some pollen by water can not be overlooked nor the impact of frequent floodings of the lake upon the geomorphology of the site and its vicinity. The early Holocene flooding was accompanied by brackish tidal waters and this explains considerable increase in chenopods which declined when the waters turned less brackish than before. The increase in chenopods population at 6,000 years B.P. suggests increase in the saline areas under the then continuing dry climate. The subsequent immense flooding of the lake between 5,000-3,500 years B.P. caused the deposition of transported kankary clay into the lake but the waters were probably less brackish than before as suggested by the reduced microforam frequencies. Thereafter, the lake continued to be fresh water and perhaps dried up and shrank along its margins resulting in conditions at the site of sampling unfavourable for the preservation of pollen.

By about 160 A.D., the lake was flooded again by brackish waters and the grassland-chenopod savannah had continued.

The gradual and consistent rise of pollen frequencies of *Holoptelea integrifolia* would readily suggest gradual improvement in the environmental conditions which became suitably favourable (possibly moister as earlier interpreted by us in the pollen diagram from Malvan, Gujarat; Vishnu-Mitre & Sharma, 1975) for its increase and spread.

Holoptelea today occurs at Ahmedabad and in the vicinity as an occasional road side tree and is of common occurrence in northern Gujarat (Saxton & Sedgwick, 1918, p. 299) and more common at Surkhej about 40 km north-east of the lake. We have no modern pollen spectra to compare from Surkhej or from northern Gujarat. The modern pollen spectra from the lake and its islands show under 4 per cent *Holoptelea* pollen under the present-day precipitation near about 780-800 mm, per annum (precipitation data for Ahmedabad where the temperature in the hottest months is 45°-47°C and of the coldest from 14°-12°C).

At Lucknow and the vicinity where over 500 trees occur scattered or in groves, the percentage frequency of *Holoptelea* pollen in water and soil samples (Khandelwal & Vishnu-Mitre, 1975) varies from 6 to 44 per cent but does not reveal any relation to the number of trees present in the vicinity of the samples. The averages for water and surface samples turn out to be 14 per cent and 19 per cent respectively.

Factors affecting pollen preservation in water and surface samples differ from those affecting lake sediments. The percentage that may actually be preserved in lake sediments is unknown. More research is indeed required in this regard.

The comparison between modern and fossil pollen spectra at the lake reveals increase in *Holoptelea* before 3,500 years B.P. which is either suggestive of increase in the population of *Holoptelea* trees (*Holoptelea* is a very high pollen producer, vide Khandelwal & Vishnu-Mitre, 1975) or the intensity of wind or water transport (the trees occur along water courses).

Holoptelea integrifolia is a member of the primary seres of the dry deciduous riverain forests on immature riverain sandy and gravelly soils liable to frequent flooding. Its occurrence as a member of the primary succession is governed by the influence of soil exceeding that of climate and leading eventually to the climatic climax vegetation of the area (Champion & Seth, 1968). The primary riverain seres with *Holoptelea* as member occur in a variety of climates from Uttar Pradesh to Kerala and from Punjab to Assam. Whereas its occurrence reflects instability of soil concentration in various stages of consolidation, its distribution suggests control by edaphic factor than climate. The frequent or continuous flooding episodes, as apparent from sediments, provide suitable edaphic situations encouraging increase in its population. Its past occurrence with *Eugenia* and *Ailanthus*, the other members of dry deciduous riverain forest, is highly suggestive of former prevalence of an environment consisting of instability of soil concentration resulting from repeated floods, and its decline was governed by absence of flooding thereafter. The palynological evidence at the site does not reveal the formation of the climax forest rather the development of the climax forest here was arrested at the primary seral stage. The

declining chenopod pollen percentages could be largely due to the periodic brackish water flooding and the instability of soil consolidation.

Although, occasional heavy and incessant downpour as in 1976 (106 mm in one day, *Pioneer*, Sept. 1, 1976) may cause flooding of the low lying areas in the vicinity of the lake, yet the three major floodings of the lake prior to 7,000 years B.P., 6,000-4,000 years B.P. and the most recent dated to 160 years B.P. were accompanied by tidal influences also which could not have been due to heavy rains but possibly by tectonic movements raising the sea level. The most recent flooding of the lake about 160 years B.P. seems to correspond with the 1819 earthquake which had caused extensive marine inundation of western part of Kutch. The 6,000-4,000 years B.P. flooding almost corresponds with the world eustatic rise in sea level. The inundation prior to 7,000 years B.P. might well have been caused by another tectonic event because the sea level at this time was much below the present and there is no evidence of its rise due to other causes. Thus, the vegetation in this area has been affected by the combined

effects of flooding and the soil instability under the prevalent dry climate which supported scanty vegetation. The xerarch succession remained arrested at the primary seral stage. Had there been trend towards slight wetness, the climax dry deciduous forest would have developed? The cessation in flooding from 3,500 years B.P. caused the drying up of the lake at least at the sampling site and the lake rejuvenated with the renewed flooding caused by tectonic disturbance, the earthquake of 1819.

The evidence of strong marine inundation in the early Holocene about 9,000-10,000 years ago is indeed suggestive of the fact that this shallow brackish water lake had perhaps originated as an old marine inlet during early Holocene as postulated by Oldham and Pascoe (1964).

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