Late Holocene vegetation of Darjeeling (Jore-Pokhari), eastern Himalaya

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Pollen analysis of Late-Holocene lacustrine sediments from Jore-Pokhari, a temperate lake of eastern Himalaya, has revealed that around 2500 yr B.P. mixed broad-leaved Oak forests existed, reflecting to a warm-temperate and humid climate in the region. Between 1600 and 1000 yr B.P. a short term cool-oscillation is witnessed as evidenced by decline in broad-leaved tree taxa and a simultaneous increase in the conifers. The anthropogenic activities have also been noticed during this period as evidenced by the increase in grasses together with culture pollen such as Chenopodiaceae/Amaranthaceae, Caryophyllaceae, *Artemisia* and Asteraceae as well as appearance of Cerealia type pollen. Between 1000 and 300 yr B.P. the improvement in the broad-leaved taxa, viz., *Quercus, Betula* and *Alnus* and reappearance of *Rhododendron* as well as simultaneous decline in *Pinus* indicate the amelioration of climate which became warm-temperate the humid once again.

Key-words—Palynology, Vegetation, Palaeoclimate, Late Holocene, West Bengal.

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सारांश

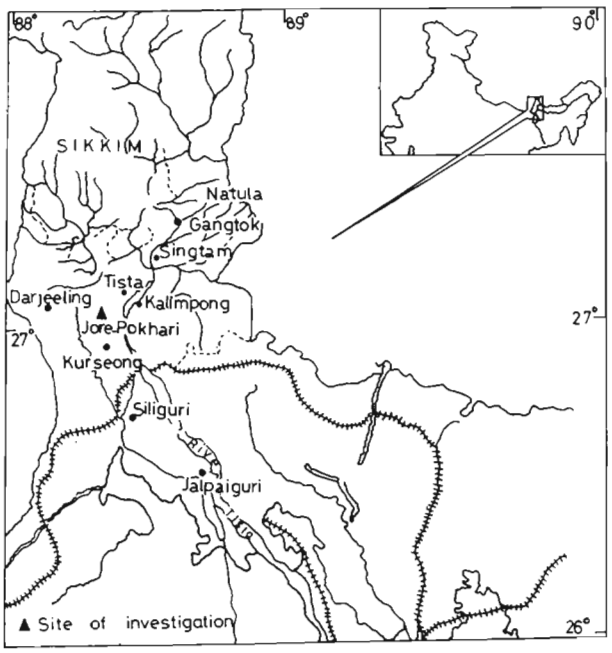
पूर्वी हिमालय में दार्जिलिंग (जोर पोखरी) की अनंतिम होलोसीन कालीन वनस्पति

मोहन सिंह चौहान एवं छाया शर्मा

पूर्वी हिमालय में जोर पोखरी नामक एक शीतोष्ण झील के अनंतिम होलोसीन सरोवरी अवसादों के परागकण विश्लेषण से व्यक्त होता है कि लगभग 2500 वर्ष पूर्व यहां मिश्रित चौड़ी पत्ती वाला ओक वन विद्यमान था जिससे उष्ण शीतोष्ण एवं नम जलवायु का होना इंगित होता है। लगभग 1600–1000 वर्ष पूर्व के मध्य चौड़ी पत्ती वाले वृक्ष वर्गकों में ह्रास के कारण तथा कोनिफरों में वृद्धि के कारण अल्पकालिक ठंडी परिस्थिति की विद्यमानता इंगित होती है। घास एवं कीनोपोडिएसी/अमरेन्थेसी कैरियोफिल्लेसी, आर्टिमिसिआ, एस्टेरेसी तथा सीरिएलिया प्रकार के परागकणों के प्रादुर्भाव के कारण मानवीय गतिविधियों का भी होना इंगित होता है। 1000 से 300 वर्ष पूर्व के मध्य *क्वरकस, बिटुला* एवं *ऍल्नस* नामक चौड़ी पत्ती वाले वर्गकों की बढ़ती संख्या तथा *रोडोडेन्ड्रॉन* के प्रादुर्भाव तथा *पाइनस* के परागकणों में साथ-साथ कमी से पुनः उष्ण शीतोष्ण एवं नम जलवायु का होना इंगित होता है।

EASTERN Himalaya, one of the richest botanical provinces of the country, has not received adequate attention as regard to the vegetation and climatic succession in the region, except for some scattered information (Bhattacharya & Chanda, 1986; D'Costa & Mukherjee, 1986). Recently, Sharma and Chauhan (1994) worked out a maiden profile from Mirik Lake, Darjeeling unravelling vegetational history and inferring climatic oscillations in the region since Last Glacial Maximum. Though, the investigation from Mirik Lake has brought out very significant information since last 20,000 yr B.P., however, the upper part of the profile dated to 2400 yr B.P. could not be portrayed owing to the paucity of pollen in the sediments. The investigated profile from Jore-Pokhari, Darjeeling has enabled us to bringout the vegetational and climatic changes in the region since 2500 yr B.P. which remained partly concealed in the earlier investigated profile from Mirik Lake.

Jore-Pokhari, a temperate lake, lies at an altitude of 2260 m a.s.l. about 18 km east of Darjeeling township and 10 km south-east of Kurseong between 87°59' and 89° 53' Long. and 26° 31' and 27° 18' Lat. (Map 1). It is almost circular in outline and is quite small today, measuring only 15 m in length and 10 m in breadth but with a wide skirting dried up or marshy margin. The lake is perennial and is fed by the subterranean source of water. The swampy lake margin is overgrown with *Typha,* aquatic weeds and grasses.



Map 1—Showing the area of investigation.

CLIMATE

The geographical situation of Darjeeling is such that it gets the full blast of the monsoon from Bay of Bengal and thus receives excessive rainfall. Consequently, Darjeeling and its surrounding environment remain enveloped in thick clouds during the monsoon period. All this is congenial to the luxuriant growth of vegetation in the region. The humid climate in the region has a mean maximum summer temperature of 22.4°C. January is the coldest month and the lowest minimum recorded temperature is often below zero. June, July, August and September are the main rainy months with a mean annual rainfall of 2595 mm. The winter months are from October to March, and it is during November and December when the area gets its snow quite frequently at 2100 m altitude.

VEGETATION

Darjeeling is known as a plant lover's paradise. So far, about 1000 species of flowering plants, 300 species of ferns, including rare tree ferns and numerous types of lower plants such as lichens, fungi, algae and mosses occur in the region. Orchids are also reported in good numbers.

The vegetation in the vicinity of Jore-Pokhari is chiefly dominated by *Cryptomeria japonica* forest. This important element was introduced from Japan in 1891 and since then it has been extensively cultivated in and around Darjeeling region (Biswas, 1966; Mathew, 1969, 1971). The conifer forests are mainly confined to higher steep mountain slopes and are devoid of any undergrowth. On the other hand, the valley areas and the shady hill slopes are clothed with gregarious mixed broad-leaved forests, which are dominated by *Quercus laminosa, Q. lineata* together with their close associates, viz., *Rhododendron decipens, R. campanulatum, Alnus nepalense, Elaeocarpus* sp., *Machilus champaca, Castanopsis hystrix, Nyssa sessilifolia*, etc. The shrubby vegetation is quite luxuriant and comprises chiefly *Viburnum cotonifolium, Berberis asiatica, Rosa moschata, R. serica, Daphne cannabina, Gaultheria griffithiana, Rubus ellipticus* and *Crataegus crenulata.*

The rich ground flora underneath the broad-leaved forests is composed of *Viola biflora, Hypericum reptens, Ranunculus diffusa, Polygonum nepalense, Geranium* sp., and *Gentiana pedicillata.* In the marsh or swampy habitat, *Polygonum plebejum, P. pterocarpium, Ammania baccifera, Rotala indica, Cyperus rotundifolia, Hydrocotyle sibthorpioides, Ocimum americanum*, etc. grow quite profusely. Ferns such as *Hymenophylla simosianum, Phymatodes malacondon, Asplenium ensiformae, Adiantum peruvianum, Alsophila andersoni, A. spinosa, Lygodium flexuosum*, etc. occur abundantly throughout the region (Mehra & Bir, 1964). The aquatic elements such as *Lemna polyrrhiza, Nymphoides cristatum, Potamogeton indicus, Wolfia arrhiza* and *Nymphaea* sp. occur meagerly in the lake.

STRATIGRAPHY AND RADIOCARBON DATES

After a number of trial borings at this lake site, a 1.5 m deep profile was dug out from the swampy margin and soil samples were collected at an interval of 5 cm. Beyond this depth, it could not be possible to collect the samples owing to the presence of hard substratum and it became difficult to penetrate further with the available borer. Lithologically, the entire profile is divisible into two distinct lithozones : the upper clayey zone and lower comparatively much thicker zone of sandy-clay.

Stratigraphical details of lithocolumn:

Column Depth	Lithology
0-35 cm	Clay
35-150 cm	Sandy-clay

Radiocarbon date—The solitary 14C date available for the Jore-Pokhari profile is 1890±200 yr B.P. (BS-926) at a depth of 110-120 cm of the sandy-clay zone.

POLLEN ANALYSIS

Extraction of pollen grains from the sediments as well as the pollen percentage calculations are done here by the same procedure as was adopted for the earlier investigated Mirik Lake profile (Sharma & Chauhan, 1994).

Description of Pollen Diagram

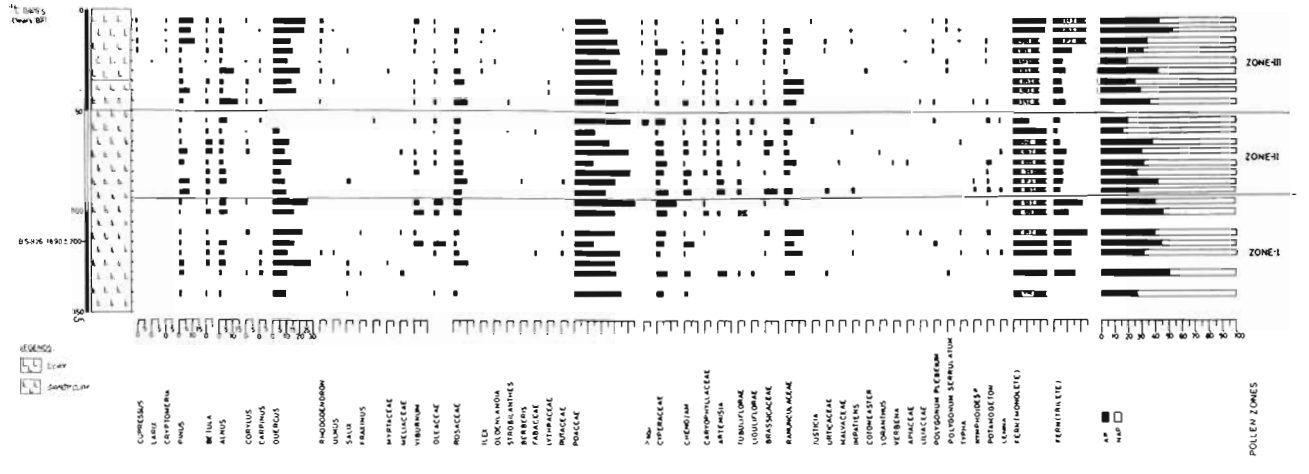
The constructed pollen diagram (Text-figure 1) has been divided into three distinct pollen assemblage zones I-III from bottom to top on the basis of changes in pollen sequence. These are described as under :

Pollen Zone I (150-93 cm): Oak-Alder-Birch-Rosaceae-Grasses-Fern Assemblage—This pollen zone dated to BS-926 1890±200 yr B.P. at the depth of 110-120 cm is characterized by the high values of *Quercus,* followed by *Alnus, Betula, Pinus* and *Carpinus* whereas, *Corylus, Ulmus, Salix, Rhododendron,* etc. are recorded very scantily. Among the shrubby taxa, Rosaceae dominate followed by Oleaceae and *Viburnum*. Fabaceae and Rutaceae are sporadic and in low values.

The non-arboreal vegetation shows much higher values of Poaceae, besides prominently associated Cyperaceae, Ranunculaceae and Chenopodiaceae/Amaranthaceae whereas, Caryophyllaceae, Asteraceae, Urticaceae, *Impatiens,* Brassicaceae are met with sporadically. However, Liliaceae, Apiaceae, *Polygonum plebejum* and many aquatic taxa such as *Potamogeton, Lemna, Typha* and *Nymphoides* are represented in extremely low frequencies. Fern spores are recorded in exceedingly high values throughout the zone. The overall AP/NAP ratio denotes the existence of open-mixed broad-leaved Oak forests in the region.

Pollen Zone II (93-50 cm) : Oak-Pine-Alder-Birch-Rosaceae-Sedges Assemblage—In this pollen zone, the vegetation pattern is more or less similar to the above zone, except for the slight decline in Oak, marked decline in *Carpinus* and simultaneous increase in the values of *Pinus,* grasses and sedges. Also *Rhododendron* pollen is not encountered in this zone. However, *Alnus, Corylus* and *Betula* maintain more or less the same frequencies as is witnessed in the preceding zone. The shrubby elements, viz., *Viburnum* and Oleaceae have a decreasing trend whereas, Rosaceae exhibit slight, improvement than seen before.

The non-arboreals, i.e., Poaceae followed by Cyperaceae, Chenopodiaceae/Amaranthaceae, Caryophyllaceae, *Artemisia,* Tubuliflorae, Liguliflorae, Brassicaceae and Ranunculaceae are represented by their increased values. Cerealia type pollen appear for the first time at the extreme top of



Text-figure 1—Pollen diagram from Jore-Pokhari, Darjeeling District, West Bengal (percentage calculated in terms of total land plant pollen).

this zone. Liliaceae and marshy element *Polygonum* are encountered in extremely low values as compared to the aquatic taxa, viz., *Potamogeton, Lemna* and *Nymphoides* which have slightly increased frequencies than what is witnessed in the preceding zone. Ferns in this zone too maintain throughout their preponderance. The overall AP/NAP ratio reflects much open type of forest conditions as compared to the Pollen Zone- I.

Pollen Zone III (50-0 cm): Oak-Pine-Rhododendron-Alder-grasses Assemblage—In this zone, *Quercus* and *Pinus* exhibit improved frequencies. *Cryptomeria* appears for the first time whereas, *Rhododendron* reappears in good frequencies after its disappearance in Pollen Zone-II. Other arboreals, viz., *Alnus, Betula, Corylus* and *Carpinus* maintain more or less same values, but *Larix* makes its scanty presence for the first time in this zone. Many shrubby elements such as Rosaceae, *Viburnum* and Oleaceae decline considerably in the zone.

Among the non-arboreals, Poaceae constantly maintain its well-marked dominance right from Zone-I. Cerealia type pollen appears from the middle of this zone and remain consistent till the end of this zone. Other taxa such as Chenopodiaceae/Amaranthaceae, Caryophyllaceae, *Artemisia*, Brassicaceae decline slightly. However, these are consistently represented in this zone. *Polygonum plebejum, P. serrulatum* and Apiaceae are somewhat better represented than earlier whereas, Liliaceae appear again in this zone.

HISTORY OF VEGETATION AND CLIMATE

Eastern Himalaya which today possesses a diversified and luxuriant vegetation has not received much attention regarding its palaeovegetational succession and palaeoclimatic oscillations until recently when Sharma and Chauhan (1994) in their maiden effort from one of the temperate lakes—Mirik, situated in Darjeeling Himalaya, unravelled the vegetational succession and inferred climatic fluctuations dating back to about 20,000 yr B.P. (Table 1).

Jore-Pokhari pollen diagram has solitary 14 C date of 1890±200 yr B.P., but the extrapolation of date, based on rate of sedimentation reveals the palaeovegetation scenario covering the last 2500 yr B.P. or so. The vegetation history in Jore-Pokhari area began with open mixed broad-leaved forests in which *Quercus* together with its close associates, viz., *Alnus, Betula, Carpinus* and shrubby elements of Rosaceae, Oleaceae and *Viburnum* were the major constituents. The overall emerging vegetation

Table-1

	JORE-POKHARI (2260 m a.s.l.)			MIRIK LAKE (1700 m a.s.l)	
Period (yr B.P.)	Vegetation assemblage	Climate	Period (yr B.P.)	Vegetation assemblage	Climate
Up to 300	Mixed broad-leaved Oak-Alder-*Rhododendron* forests with *Cryptomeria* and Pine	Warm-temperate and humid	Up to 500	Barren Zone	-
300-1000	Increase in broad-leaved taxa, Oak-Alder and reappearance of *Rhododendron*	Amelioration of climate	500-2000	Mixed Oak-Pine forests	Warm-temperate with gradual deterioration of climate as well as evidence of agriculture
1000-1600	Decline in broad-leaved taxa, Oak-Alder-Hornbeam and increase in Pine	Deterioration of climate and evidence of agriculture			
1600-2500	Mixed broad-leaved Oak-Alder-Birch-Hornbeam forests	Warm-temperate and humid	2000-4000	Barren Zone	-
			4000-10000	Oak forests	Amelioration of climate (climatic optimum)
			Around 11000	Decline in Oak and increase in grasses	Cool oscillation
			12000-18000	Mixed Oak-Pine forests	Amelioration of climate (Warm temperate)
			Around 20000	Open grasslands with Pine-Cypress-Hemlock	Cold temperate

scenario is suggestive of the prevalence of warm-temperate and humid climate in the region, which is further testified by the preponderance of fern spores throughout the sequence. Among the conifer elements, *Pinus* had probably scattered distribution in the area or it was sparse and confined to only certain dry mountain slopes. The herbaceous coverage was quite profuse and chiefly comprised of grasses, sedges, Chenopodiaceae/ Amaranthaceae, Ranunculaceae, etc.

During the subsequent period between 1600-1000 yr B.P. though more or less similar type of vegetation existed, but it was probably more open in composition than before as is witnessed by the decline in the numbers as well as in the frequencies of most of the forest constituents such as *Quercus, Alnus, Carpinus* and *Salix,* coupled with the disappearance of *Rhododendron, Fraxinus* and *Ulmus*. Likewise, shrubby elements also dwindled considerably during this phase. However, *Pinus* has a simultaneous improvement at the commencement of this phase. This change in vegetation pattern signifies to the probable deterioration in climate which turned less humid than before. The enhanced values of grasses together with other culture pollen, viz., *Artemisia*, Caryophyllaceae, Asteraceae, Brassicaceae, Chenopodiaceae/Amaranthaceae and the appearance of Cerealia type pollen indicate the expansion of agricultural practice in the region. The most significant event witnessed just at the beginning of this phase is the abrupt decline in Oak alongwith its other associates with a corresponding increase in *Pinus* and grasses for a short period, reflecting to a brief spell of climatic deterioration.

Around 1000 yr B.P. a distinct improvement is seen in the values of Oak as well as other broad-leaved taxa such a *Rhododendron, Alnus, Corylus* and *Carpinus*. This change in vegetation scenario could perhaps be the result of the impact of enhanced precipitation inducing amelioration of climate in the region. Much late, around 300-200 years ago, gradual but significant rise in *Cryptomeria* and *Pinus* sp. (*patula*?) is recorded which is obviously the result of old plantation of both these exotic taxa in the region. The good representation of grasses, alongwith other culture pollen, viz., Chenopodiaceae/ Amaranthaceae, Asteraceae, Caryophyllaceae and *Artemisia* truly demonstrate the intensive agricultural practices in the region as these elements are indicators of anthropogenic activities.

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