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Pollen analytical study of late-Holocene sediments from Trans-Yamuna segment of Western Doon valley of Northwest Himalaya

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ABSTRACT

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A trench across a Quaternary fault in a berm was dug out at Sirmuri Tal in the Trans-Yamuna segment of Western Doon valley in Himachal Pradesh. Pollen analytical investigation of 4.90 m deep trench profile from Sirmuri Tal has shown that between 2800 to1800 years BP, mixed open vegetation comprising chiefly grasses, sedges, Cheno/Am, *Artemisia* and Ranunculaceae together with sparsely distributed trees viz., *Emblica officinalis*, *Shorea robusta*, *Holoptelea*, *Mallotus*, *Grewia*, Meliaceae, etc. grew in the region under dry climatic regime. The lake did exist, but it was small in dimension as indicated by the meagre presence of aquatic taxa such as *Typha* and *Potamogeton*. Subsequently, between 1800 to 400 years BP, mixed deciduous forests were established as reflected by the improvement in *Emblica officinalis*, *Mallotus*, *Grewia*, etc. as well as invasion of *Terminalia*, *Adina cordifolia*, *Acacia* and *Syzygium* in the region. The overall increased diversity in the forest floristics signifies that the moist climatic condition prevailed in the region during this period. Lake became wider in expanse as implied by the improved frequencies of *Potamogeton* and *Typha* and first encounter of Dinoflagellate cysts in good number. Since 400 years BP and onwards, the climate deteriorated as evidenced from the decline in the vegetation cover. The lake transformed into a swamp as evidenced by the increase in sedges and Chen/Am and a simultaneous decline in aquatic vegetation. The excessively high frequencies of *Pinus* pollen denotes its transportation by wind and water from nearby subtropical belt where chirpine forests occur luxuriantly.

Key-words—Pollen analysis, Palaeofloristics, Late-Holocene, Sirmuri Tal, Western Doon valley.

उत्तर-पश्चिमी हिमालय की पश्चिमी दून घाटी के ट्रान्स-यमुना अंश से प्राप्त अन्तिम होलोसीन कल्प के अवसादों का परागाणु विश्लेषणात्मक अध्ययन

मोहन सिंह चौहान, गोविन्दराज राजगोपालन, एम.पी. साह, जी. फिलिप एवं एन.एस. विरदी

सारांश

हिमाचल प्रदेश की पश्चिमी दून घाटी के ट्रान्स-यमुना अंश में स्थित सिरमुरी ताल के एक बर्म में क्वाटरनरी भ्रंश के चारों ओर एक गर्त्त खोदी गयी। सिरमुरी ताल की 4.90 मीटर गहरी गर्त्त परिच्छेदिका के परागाणविक विश्लेषण से प्रदर्शित होता है कि विगत 2800 से 1800 वर्ष पूर्व के बीच शुष्क जलवायु के अन्तर्गत क्षेत्र में विरलतः वितरित वृक्षों, जैसे-*एम्बलिका ऑफ़िसिनेलिस, शोरिया रोबस्टा, होलोप्टीलिया, मैलोटस, ग्रीविया,* मीलिएसी इत्यादि के साथ-साथ सम्मिश्र

विवृत वनस्पतियाँ, जिनमें घासें, प्रतृण, चीनो/एम, *आर्टीमीज़िया* तथा रैननक्युलेसी उगती थीं। यहाँ झील भी विद्यमान थी, परन्तु यह कम विस्तृत थी, जो *टाइफ़ा* तथा *पोटामॉजीटॉन* जैसे जलीय वर्गकों की अल्प उपस्थिति द्वारा इंगित है। तत्पश्चात् विगत 1800 से 400 वर्ष पूर्व के मध्य में सम्मिश्र पर्णपाती वन स्थापित हुए, जो क्षेत्र में *एम्बलिका ऑफ़िसिनेलिस, मैलोटस, ग्रीविया* इत्यादि में सुधार तथा *टर्मिनेलिया, एडीना कॉर्डीफ़ोलिया, एकेशिया* एवं *साइज़ीज़ियम* के विस्तार द्वारा प्रदर्शित है। वन वनस्पतिजात में सकल वर्धित वैविध्य इंगित करता है कि इस काल के दौरान क्षेत्र में आर्द्र जलवायुविक स्थितियाँ विद्यमान थीं। *पोटामॉजीटॉन* एवं *टाइफ़ा* की बेहतर आवृत्तियों तथा उत्कृष्ट संख्या में प्राप्त घूर्णीकशाभ पुटियों द्वारा झील का फैलना इंगित होता है। विगत 400 वर्ष पूर्व तथा तत्पश्चात् से जलवायु बिगड़ने लगी, जो वनस्पति आच्छादन में ह्रास से पुष्ट होता है। फलतः झील एक अनूप में परिणत हो गयी, जो प्रतृणों एवं चीनो/एम की वृद्धि तथा जलीय वनस्पतियों में तत्समय हुए ह्रास से अभिप्रमाणित है। *पाइनस* परागकण की अत्यधिक उच्च आवृत्तियाँ इसका समीपवर्ती उपोष्ण कटिबन्धीय बेल्ट से पवन तथा जल द्वारा परिवहन संकेतित करती हैं, जहाँ चिरपाइन के वन प्रचुर मात्रा में विद्यमान थे।

संकेत शब्द—परागाणविक विश्लेषण, पुरावनस्पतिजातविज्ञान, अन्तिम होलोसीन, सिरमुरी ताल, पश्चिमी दून घाटी.

INTRODUCTION

Tropical deciduous forests, which constitute a major part of vegetation wealth in central India and plains of northern India, have not been adequately studied for their antiquity and climatic fluctuations that they have experienced during the Quaternary period. The available information on this aspect includes investigation on a few megafossils recovered from Siwalik bed of Himachal Pradesh (Tiwari *et al.*, 1979; Prasad *et al.*, 2002) and pollen analysis of some sediment cores from Doon valley, Uttaranchal (Rawat, 1984) and the plains of Uttar Pradesh (Gupta, 1978; Chauhan *et al.*, 1990) and north-eastern part of Madhya Pradesh (Chauhan, 1995, 2000) and a few clay samples from Siwalik bed of Himachal Pradesh (Tiwari *et al.*, 1979). In the present communication an attempt has been made to understand the vegetational and climatic succession in the Siwalik region through the pollen analytical investigation of a Quaternary section exposed at Sirmuri Tal, Sirmur District (H.P.).

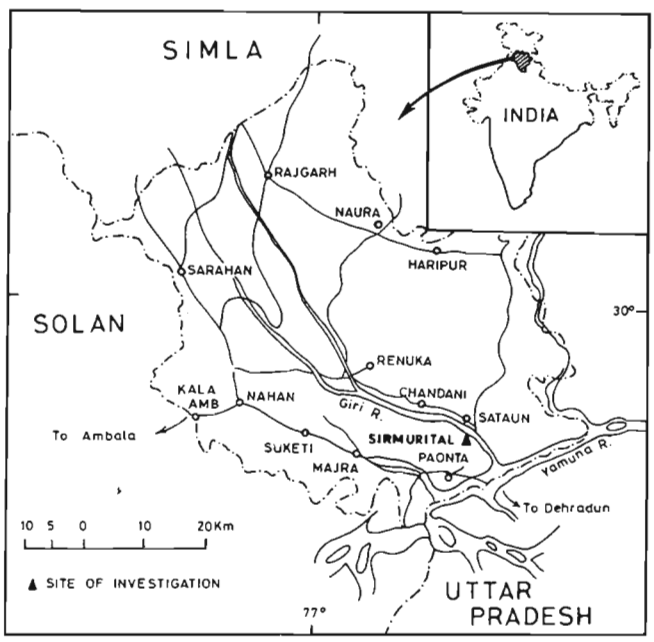

Fig. 1—Map of Sirmur District (H.P.) showing the site of investigation.

Sirmuri Tal is situated about 65 km west of Dehra Dun between 77°39'45" E and 30°32'5" N at an altitude of 580 m a.s.l. on the right bank of Giri River (Fig. 1). Reactivation of fault in Sirmuri Tal area in the Trans-Yamuna segment during Quaternary Period resulted in dislocation of many landforms like river terraces, alluvial fans, stream and ridges and the formation of other morphotectonic features such as sag ponds, berms, triangular facets, pressure ridges, controlled drainage, etc. (Philip & Sah, 1999). Sirmuri Tal presently is a flat cultivated area, in the Western Doon valley. The morphotectonic features as well as the lithological sequence of the dug out trench (15 x 5 x 4 m) have provided ample evidence for the existence of a lake in the past, which was formed as a sag pond in the vicinity of an active fault known as Sirmuri Tal Fault (STF). The hill slopes adjacent to the area are gentle and possess a large number of boulders, conglomerates and gravels. Presently, this ancient lake basin is in the form of a berm (Philip & Sah, 1999).

GEOLOGICAL SETTING

The Trans-Yamuna segment of the Doon valley lies in a tectonically active zone between a number of faults, such as the Main Boundary Thrust (MBT)/Krol Thrust, the Himalayan Frontal Thrust and the Main Boundary Fault/Bilaspur Thrust. The lithotectonic setting and the regional geological map of the area (Fig. 2) exhibit that there are three geological units, i.e., the pre-Tertiary, Tertiary and Quaternary (Fig. 3). The pre-Tertiary rocks are exposed to the north of the Giri River. The Tertiary sediments range from marine shale limestone through the fossiliferous limestone of the Subathu (Paleocene-Eocene age) and the brackish water Dagshais (red, purple and green mudstones and sandstone) to the molassic Siwalik Group. The

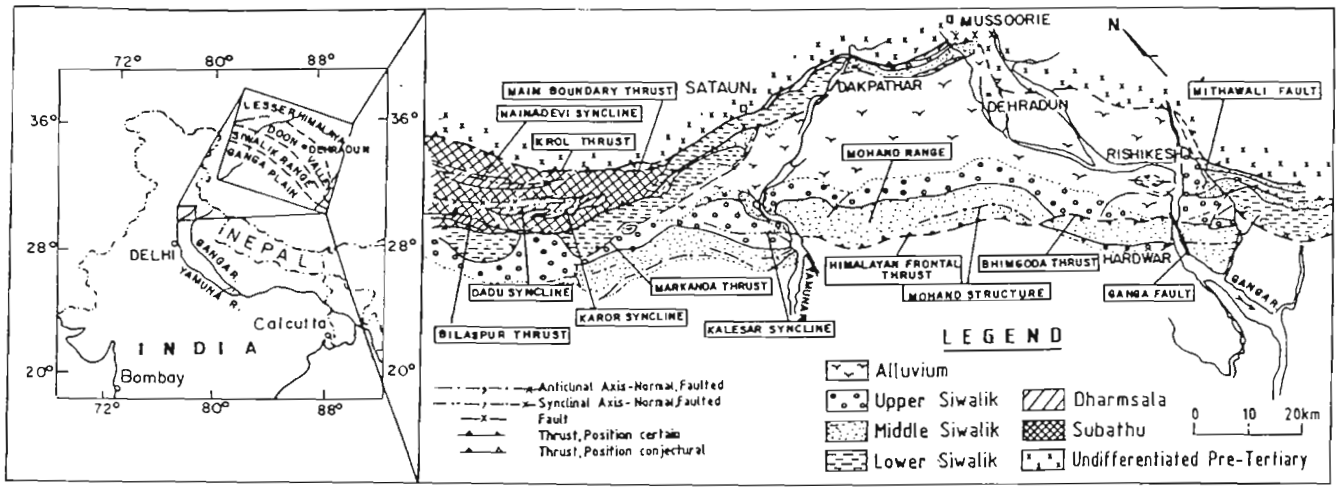

Fig. 2—Geological map of the Trans-Yamuna segment of Western Doon valley (after Karunakaran & Raja Rao, 1979).

Quaternary sediments, which are derived chiefly from the Tertiary rocks, occur as a cover over the Tertiary formations, mainly the Upper Siwalik (Karunakaran & Ranga Rao, 1979; Raiverman *et al.*, 1983). Although, the Tertiary and pre-Tertiary have been mapped by several workers, however, little attempt has been made to map the Quaternary formations in this valley. These deposits are the best indicators of the processes involved in the Quaternary landform evolution of the area,

Age		Group	Lithology
Quaternary		Undifferentiated Post-Siwalik sediments	
	-----	——— Himalayan Frontal Thrust ———	
		Siwalik	Conglomerates, Sandstones and clays
	L	——— Main Boundary Fault / Bilaspur Thrust ———	
	O		
T	W		
E	E		
R	R		
T		Kasauli	Shales, sandstones, red,
I			purple and green mud
A	T	Dagshai	stones and Limestone
R	E		
Y	R	Subathu	(fossiliferous)
	T		
	I		
	A		
	R		
	Y		
		——— Main Boundary Thrust ———	
		Tal	Limestones
Pre-Tertiary		Krol	(mainly)
		Infra Krol	
		Blaini Boulder bed	
		Nagthat	Quartzites
		Chandpur	Phyllites
		Mandhali	Limestones

Fig. 3—Lithotectonic setting in the Trans-Yamuna segment of the Doon valley.

and also demonstrate different phases of active tectonics (Philip & Sah, 1999).

VEGETATION

Sirmuri Tal area is characterized by the presence of a mixed type of vegetation. *Grewia oppositifolia*, *Celtis australis*, *Mallotus philippensis*, *Melia azadirachta*, *Ficus cunia*, *F. roxburghii*, *F. palmata*, *Murraya* sp., *Bauhinia variegata*, *Zanthoxylum alatum*, etc. are the common trees around the site investigated. Scattered thickets of *Adhatoda vasica*, *Vitex negundo*, *Ziziphus jujuba*, *Carissa opaca*, *Lantana camara*, *Berberis asiatica*, *Rubus ellipticus*, *Rosa moschata*, *Colebrookea oppositifolia* and *Woodfordia fruticosa* can be seen throughout the area.

The herbaceous vegetation includes, *Oxalis acetosella*, *Rumex hastatus*, *Ageratum conyzoides*, *Micromeria biflora*, *Portulaca oleracea*, *Indigofera* sp., *Boerhaavia diffusa*, *Artemisia parviflora*, *Polygonum plebeium*, *Geranium nepalensis*, etc.

The southern hill slopes adjacent to the site of investigation support sal (*Shorea robusta*) forests. Apart from sal; *Lagerstroemia parviflora*, *Adina cordifolia*, *Buchanania lanzan*, *Anogeissus latifolia*, *Terminalia tomentosa*, *Semecarpus anacardium*, *Ehretia laevis* and *Bauhinia* sp. occur frequently in these forests, whereas *Emblica officinalis*, *Olea glandulifera* and *Lannea coromandelica* are met with occasionally. Few *Syzygium cumini* trees are seen along the bank of the streams.

MATERIAL AND METHODS

A 4.90 m deep trench was dug at Sirmuri Tal, Sirmur District (Himachal Pradesh) to collect samples for pollen analytical investigation. Upper part of the section comprised mainly bouldery hillside slope scree and reworked sediments and hence not considered for sampling. Forty samples were picked from the remaining lithocolumn at different intervals, depending upon the visible change in the lithology of the section. In addition, samples for radiocarbon dating were also collected from the trench.

The exposed section comprised broadly six lithozones (Fig. 4). The topmost zone is constituted of bouldery hillside scree and reworked material. This overlies the sand with pebble zone, which is fluvial in origin. Below this are the zones of peat with sand and sandy clay. These are supposed to be deposited in a ponding environment. A good number of charcoal pieces were also encountered in these lithozones. Underlying these, are sandy and clayey-sand zones and they are fluvial in nature.

To calibrate the sedimentation rate for this trench profile, the two radiocarbon dates, i.e., 610±100 years BP (3.60 m) and 2280±110 years BP (4.15 m) have been taken into consideration (Fig. 5). The upper part (2.70-3.60 m) of the profile has the high sedimentation rate of 15 cm/100 years, whereas in the lower part (3.60-4.30 m) it declines to 3 cm/100 years. These sedimentation rates have been used for the extrapolation of three more dates, i.e., 2800 years BP at 4.30 m depth, 1800 years BP at 4.00 m depth and 400 years BP at 3.25 m depth for the precise demarcation of alterations in the vegetational composition and corresponding climate in a chronological order.

Depth	Lithology
0-1.85 m	Bouldery hillside scree and reworked material
185-2.95 m	Sand with pebbles
2.95-3.50 m	Alternate bands of peat and sand
3.50-4.30 m	Sticky sandy clay with charcoal pieces and rootlets
4.30-4.60 m	Sand
4.60-4.90 m	Clayey sand

Fig. 4—Depth-wise lithostratigraphical details.

The standard procedure of acetolysis (Erdtman, 1943) through the use of 10% aqueous KOH solution, 40% HF and acetolysing mixture (9:1, acetic anhydride and concentrated H_2SO_4) was followed to extract pollen/spores present in the sediments. Only the samples analysed from the middle part of the section, constituted of peat and sticky clay, have yielded appreciable number of pollen. The upper and lower parts of this section, composed of sand with small pebbles and sand with clay, respectively, have proved palynologically barren.

The pollen sums range between 100-356, depending upon the pollen productivity of the samples analysed. The percentage frequencies of the recovered pollen taxa have been calculated in terms of total land plant pollen. The plant taxa have been grouped as trees, shrubs, herbs, ferns and dinoflagellate cysts and are put in the same order in the pollen diagram.

Depth	Lithology	Radiocarbon dates
2.70 m	Sand with pebbles	BS-1315 Modern
3.60 m	Sticky sandy clay with charcoal pieces and rootlets	BS-1382 610±100 years BP
3.80 m	—do—	BS-1383 1310±90 years BP
4.00 m	—do—	BS-1374 1350 ±120 years BP
4.15 m	—do—	BS-1443 2280 ±110 years BP

Fig. 5—Radiocarbon dates for investigated trench profile.

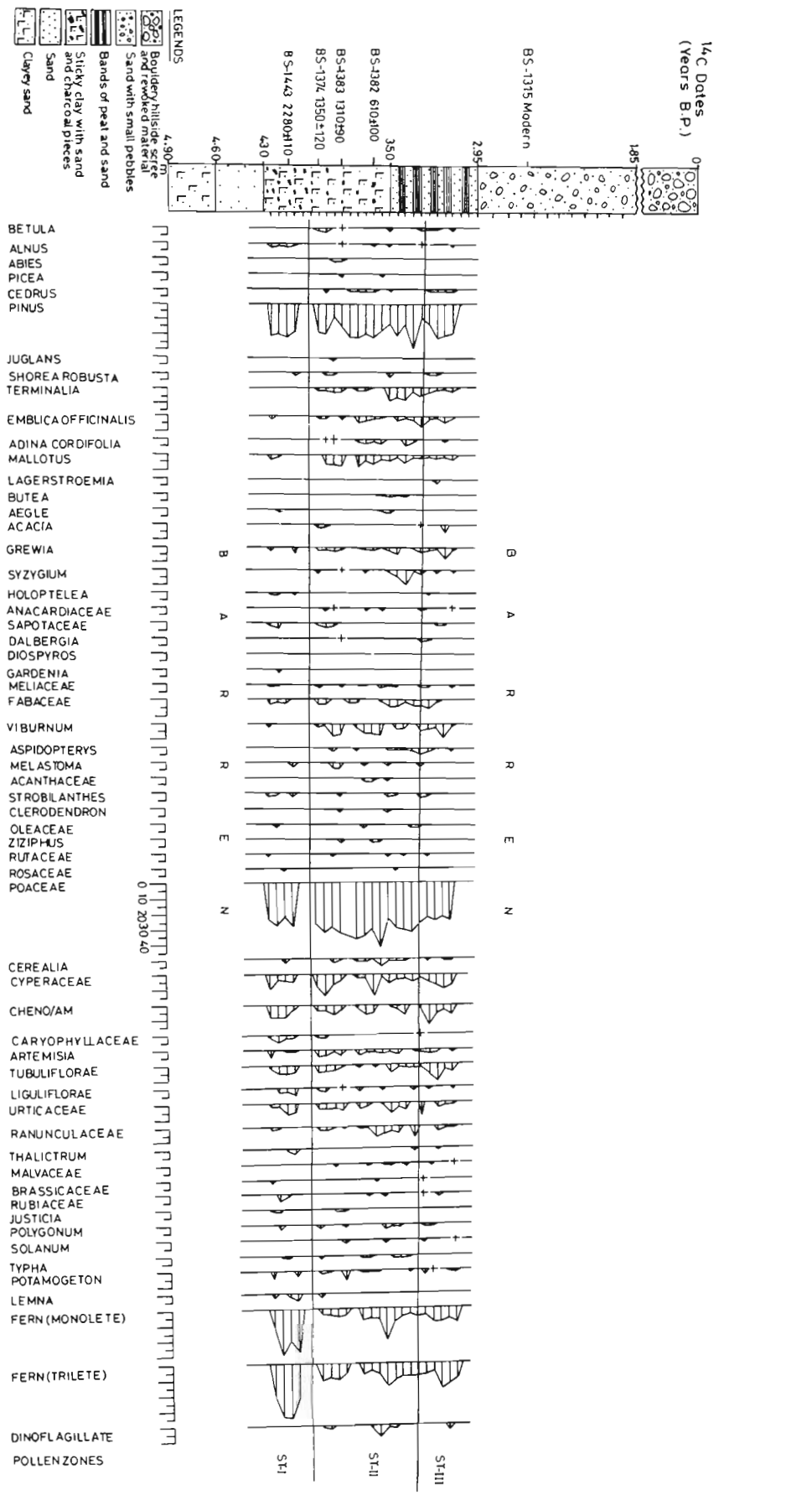

Fig. 6—Pollen diagram from Sirmuri Tal, District Sirmur (Himachal Pradesh).

POLLEN ANALYSIS

To understand the sequential alterations in the palaeofloristics and climate in the region, the pollen diagram constructed from Sirmuri Tal has been divided into three distinct pollen zones from bottom to top, based on the fluctuations in the frequencies of some prominent arboreals and non-arboreals (Fig. 6). These pollen zones are prefixed with the initials 'ST' after the name of investigated site.

Pollen Zone ST-I (4.30-4.00 m): Poaceae-Cyperaceae-Cheno/Am-Mallotus-Holoptelea-Fern Assemblage

This pollen zone with a radiocarbon date of 2280±110 years BP (4.15 m), covering the time span of 2800 to 1800 years BP, depicts high values for non-arboreals and poor representation of arboreals. Among the non-arboreals, Poaceae (grasses 21-30%), Cyperaceae (sedges 5-12%), Cheno/Am (Chenopodiaceae/Amaranthaceae), Urticaceae and Tubuliflorae (3-8% each), Liguliflorae (3-5%) and *Artemisia* (1-5%) are consistently represented with good frequencies. *Thalictrum* and Rubiaceae (2-5% each), Cerealia (2%), the aquatics, *Potamogeton* (3-5%) and *Lemna* (2-5%) are met with sporadically. Fern spores (monolete 21-30% and trilete 20-35%) are quite frequent.

The arboreals, *Mallotus*, *Grewia* and Sapotaceae (1-3% each) and *Holoptelea* (1-2%) are low and sporadic, whereas *Gardenia*, *Emblica officinalis*, *Shorea robusta*, *Aegle* and Meliaceae are marked by their stray occurrence. The shrubby elements viz., Fabaceae (2-4%) and *Strobilanthes* (1-2%) are better represented than those of Rosaceae, Oleaceae and Rutaceae.

The Himalayan element, *Pinus roxburghii* (20-23%) is encountered in high frequencies whereas *Alnus* (1-3%) is also represented consistently in low values.

Pollen Zone ST-II (4.00-3.25 m): Terminalia-Mallotus-Syzygium-Emblica officinalis-Poaceae-Cyperaceae Assemblage

This pollen zone dated to 1350±120 years BP (4.00 m), 1310±90 years BP (3.80 m) and 610±100 years BP (3.60 m) and encompassing a time interval of 1800 to 400 years BP, is characterised by the abrupt improvement in both arboreals and non-arboreals. The arboreals, *Mallotus* (2-8%), *Emblica officinalis* (2-7%), *Grewia* (2-6%) and Meliaceae (2-4%) have much enhanced values than in Pollen Zone ST-I. On the other hand, *Terminalia* (2-8%), *Syzygium* (1-10%) and *Adina cordifolia* (2-5%) appear in high frequencies for the first time together with sporadically represented taxa such as *Butea*, *Acacia* (2% each), *Dalbergia* and *Diospyros* (1% each). The shrubby taxa such as *Viburnum* (2-10%), Fabaceae (3-5%) and *Melastoma* (1-4%) are recorded in increased frequencies.

The non-arboreals such as Poaceae (25-42%), Cyperaceae (2-15%), Ranunculaceae (2-10%), Urticaceae and Tubuliflorae (3-8% each), Cheno/Am (2-7 %), *Artemisia* (2-6%) and Cerealia (1-5%) are better represented than in Pollen Zone ST-I. The aquatic elements, *Potamogeton* (1-7%) and *Typha* (1-3%), also have increased frequencies than in the preceding pollen zone. Fern spores (monolete 3-21% and trilete 6-14%) show reduced values in contrast to previous pollen zone. Dinoflagellate cysts (2-10%) are recorded frequently for the first time.

Pinus (9-30%) is recorded in more improved values than in the Pollen Zone ST-I. *Betula* (3%), *Cedrus*, *Abies* and *Picea* (2% each) turn up sporadically for the first time.

Pollen Zone ST-III (3.25-2.95 m): Emblica officinalis-Terminalia-Fabaceae-Viburnum-Poaceae-Cyperaceae-Cheno/Am Assemblage

This pollen zone, with a temporal range of 400 years BP to the present, exhibits a decline in the number as well as frequencies of both arboreals and non-arboreals. The tree taxa viz., *Emblica officinalis* (2-5%), *Mallotus* (1-4%), *Terminalia* (2-3%) and *Syzygium* (1-2%) are consistently represented in reduced frequencies. However, *Grewia* (1-8%) and *Acacia* (6%) are recovered in somewhat improved values, though sporadically. *Shorea robusta*, *Holoptelea* and Meliaceae are scantily present.

Among the herbaceous components, Poaceae (22-25%) followed by Urticaceae (2-10%), Ranunculaceae (3-5%) and Cerealia (2%) are met with in a decreasing trend in contrast to preceding pollen zone. On the other hand, Cheno/Am (4-15%), Cyperaceae (2-12%) and Tubuliflorae (3-10%) show an increasing trend. *Artemisia* (1-5%) remains more or less static. *Potamogeton* (3-5%), *Typha* and Dinoflagellate cysts become more sporadic. Fern spores (monolete 5-10% and trilete 7-20%) maintain their high frequencies. *Pinus* (8-21%) declines considerably in this zone.

DISCUSSION

The pollen analytical investigation of a 4.90 m deep trench profile exposed at Sirmuri Tal, Sirmur District (Himachal Pradesh) has provided some important pollen proxy data for reconstructing the changing vegetational scenario and climatic events in the region during late-Holocene. The pollen sequence generated has demonstrated that around 2800 to 1800 years BP, the open mixed vegetation chiefly comprised of grasses together with good proportion of sedges, Chenopodiaceae/Amaranthaceae, *Artemisia*, etc. existed in the region. A few tree taxa such as *Mallotus*, *Emblica officinalis*,

Holoptelea, *Grewia*, *Shorea robusta*, Meliaceae, etc. and thickets of *Strobilanthes*, *Viburnum*, Oleaceae and Fabaceae grew scantily in the open vegetation. In general, the overall vegetational mosaic reflects that the region was under cool and dry climatic regime during this phase. The presence of fragmentary charcoals in high concentration in the sediments envisages the occurrence of fire in the region, which is often associated with drier climate. The lake did occur, but it was small in expanse as evidenced from the meagre presence of aquatic taxa such as *Potamogeton*, *Lemna* and *Typha*. The sediments comprising clay with fine sand also seem to be accumulated in a pond or small lake on the riverside plain. The geomorphological study of Trans-Yamuna segment of the Western Doon valley (Philip & Sah, 1999) has shown that the lake sedimentation commenced about 4000 years BP. The area in the vicinity of the lake was under the impact of anthropogenic activities, more particularly agricultural practices as deciphered by the frequent representation of culture pollen taxa viz., Cerealia, Caryophyllaceae, Chenopodiaceae/Amaranthaceae, *Artemisia*, etc. during this time.

The abundance of *Pinus* pollen in the sediments could be attributed to its transportation by wind or water from nearby mountains where chirpine forests probably occurred profusely.

Between 1800 to 400 years BP, the mixed tropical deciduous forests got established as a consequence of improvement in *Emblica officinalis*, *Grewia*, *Mallotus*, Meliaceae, etc. as well as simultaneous invasion of moist deciduous trees such as *Terminalia*, *Adina cordifolia* and *Syzygium* in the region. The shrubby vegetation comprising, *Viburnum*, *Aspidopterys* and *Melastoma* also flourished well. Thus, the increased diversity in the forest floristics reveals that the area experienced more precipitation, which led to the prevalence of moist climatic condition during this phase. This is also manifested by the low charcoal concentration in the sediments. Furthermore, in response to increased precipitation in the region, the lake also had wider spread than before as indicated by the first record of Dinoflagellate cysts in good numbers and improvement in aquatic taxa viz., *Potamogeton* and *Typha*. This is also substantiated by the presence of sticky clay as well as the bands of peat and fine sand in the upper part of lithocolumn during this phase. Local and historical information indicates that a lake at Sirmuri Tal was breached in 1082 AD or about 900 years ago (Philip & Sah, 1999).

With the inception this phase, the expansion of agricultural practices also took place in the region, which is inferred by the better representation of the culture pollen taxa viz., Cerealia, Chenopodiaceae/Amaranthaceae, *Artemisia* and Urticaceae. The remnants of the palace of king of Sirmur located near Sirmur Tal Village and legends associated with palace also reveal the acceleration of anthropogenic activities, particularly agricultural practice in the region as a consequence of increased human population around 1082 AD or 868 years BP [Gazetteer of Sirmur State, 1934 (reprinted 1996)].

The increased frequencies of *Pinus roxburghii* imply that the chirpine forests grew more luxuriantly in the adjoining subtropical belt during this time.

Later on, around 400 years BP and onwards the forests became sparse as well marked by the reduced frequencies of most of the tree taxa viz., *Terminalia*, *Emblica officinalis*, *Adina cordifolia*, *Mallotus* and *Syzygium*. Likewise; the shrubby vegetation, in general, also turned more scanty. Hence, the overall decline in the forest constituents might have occurred under the impact of deterioration of climate, which most probably became cool and dry during this phase. However, the illicit and selective felling of arboreals, particularly trees by the local inhabitants cannot also be ruled out. The ground vegetation remained almost identical in composition, as it was earlier, however, the expansion of sedges and Chenopodiaceae/Amaranthaceae and a corresponding decline in aquatic elements as well as Dinoflagellate cysts signify that the gradual transformation of lake into swamp commenced by this time. The land tenure records of 100 years show that the Giri River gradually migrated southward due to fluvial dynamics and tectonic activity (Philip & Sah, 1999). This change in the river course led to the choking of water source to Sirmuri Tal, which ultimately got vanished in due course of time. The agricultural practice continued in the region at a more or less same pace, as before, since most of the culture pollen taxa do not exhibit any conspicuous change in their representation during this phase.

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