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Palaeovegetation and climatic variations in the Parvati Valley, Himachal Pradesh, India since last deglaciation

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ABSTRACT

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Pollen proxy records from 1.2 m deep sediment profile from Tundabhuj, Parvati Valley (H.P.) reveals that between 15,260 and 13,280 yr BP, the sub–alpine belt supported alpine–scrub vegetation dominated by *Betula* and thermophillous broad–leaved allies viz. *Quercus*, *Corylus* and *Carpinus*, interspersed with meadows comprising grasses, Asteraceae, *Impatiens*, etc. under a warm and moderately moist climate. The dry scrubby element, *Juniperus* occurred in restricted pockets on the sunny mountain slopes. The frequent record of conifers such as *Pinus* cf. *wallichiana*, *Cedrus*, *Abies* and *Picea* implies the proximity of the temperate belt to the study site. Around 13,280 to 7,340 yr BP, the considerable expansion of *Betula* and broad–leaved allies and a simultaneous reduction in *Juniperus* elucidate the replacement of alpine scrub forests by temperate *Betula*–broad–leaved forest in response to onset of a relatively warm and more–moist climate. This change occurred by the upward shift of the timber line as reflected by the improvement in the conifers. The climate deteriorated and turned cold and dry around 7,340 to 5,030 yr BP as manifested by the abrupt reduction in the alpine–scrub vegetation and meadow constituents. Subsequently, between 5,030 and 2,000 yr BP this region witnessed a warm and moist climate again as evidenced from moderate expansion in the alpine–scrubs and conifers. Since 2,000 yr BP onwards deterioration in climate is demonstrated by the depletion in *Betula* and broad–leaved associates and substantial increase in *Juniperus* and *Ephedra*.

Key–words—Vegetation shifts, Palaeoclimate, Pollen, Parvati Valley, Himachal Pradesh.

अंतिम विहिमनदन से पार्वती घाटी, हिमाचल प्रदेश, भारत में पुरावनस्पति एवं जलवायवी परिवर्तन

अंजलि त्रिवेदी, एम.एस. चौहान एवं अनुपम शर्मा

सारांश

टुंडाभुज, पार्वती घाटी (हिमाचल प्रदेश) के 1.2 मीटर गहरी अवसाद परिच्छेदिका से प्राप्त परोक्षी अभिलेख उद्घाटित करते हैं कि 15,260 और 13,280 वर्ष पूर्व के मध्य कोष्ण व साधारण आर्द्र जलवायु के अंतर्गत घास एस्टेरेसी, *इंपेशिएन्स* (गुलमेंहदी) इत्यादि सन्निहित घास के मैदानों से अंतःप्रकीर्ण *बेतुला* व तापरागी चौड़ी पत्ती युक्त उपवर्ग अर्थात *क्वेरकस, कॉरीलस* व *कार्पिनस* से प्राबल्य उप–अल्पाइन क्षेत्र ने अल्पाइन कुंज वनस्पति को संबल प्रदान किया। उज्जवल पर्वत ढालों पर सीमित पुंजकों में शुष्क झाड़दार घटक *जूनीपेरस* उगे। शंकुवृक्षों जैसे कि *वाल्लिचिएना* तुल्य *पाइनस* सीड्रस, *एबीज* व *पिसिया* के नित्य अभिलेख अध्ययन स्थल में शीतोष्ण क्षेत्र के सामीप्य का संकेत देते हैं। 13,280 से 7,340 वर्ष पूर्व, *बेतुला* और चौड़ी पत्ती उपवर्ग का काफी विस्तार तथा *जूनीपेरस* में साथ–साथ ह्वास कोष्ण एवं अति–आर्द्र जलवायु के सापेक्ष के प्रारंभ की अनुक्रिया में शीतोष्ण *बेतुला* चौड़ी पत्ती वन से अल्पाइन कुंज वनों का प्रतिस्थापन स्पष्ट करते हैं। यह परिवर्तन वृक्ष सीमा के उपरिगामी परिवर्तन से हुआ जैसा कि शंकुवृक्षों में उन्नयन से प्रतिबिंबित है। 7,340 से 5,030 वर्ष पूर्व जलवायु बिगड़ गई तथा शीत व शुष्क हो गई जैसा कि अल्पाइन–कुंज वनस्पति एवं घास के मैदान घटकों में यकायक पतन से प्रकट है। तदंतर, 5,030 से 2000 वर्ष पूर्व इस अंचल ने पुनः कोष्ण एवं आर्द्र जलवायु प्रदर्शित की जैसा कि अल्पाइन कुंज एवं शंकुवृक्षों में साधारण विस्तार से साबित है। 2000 वर्ष पूर्व से *बेतुला* व चौड़ी पत्ती संबद्धों में अवक्षय तथा *जूनीपेरस* व *एफेड्रा* में समृद्ध वृद्धि से जलवायु में खराबी प्रदर्शित है।

सूचक शब्द—वनस्पति परिवर्तन, पुराजलवायु, पराग, पार्वती घाटी, हिमाचल प्रदेश।

INTRODUCTION

ENOUGH data have been generated on the vegetation succession, climate change and lake level fluctuation during the Quaternary Period on broader time scale from the subtropical and temperate belts in different sectors of Garhwal Himalaya (Chauhan *et al.*, 1997; Chauhan & Sharma, 2000; Sharma *et al.*, 2010) and Kumaon (Vishnu–Mittre *et al.*, 1967; Gupta, 1977; Chauhan & Sharma, 1996; Kotlia *et al.*, 1997, 2010), western Himalaya and Himachal Pradesh (Sharma & Singh, 1974a, b; Sharma & Chauhan, 1988) and Jammu & Kashmir (Singh, 1964; Vishnu–Mittre & Sharma, 1966; Sharma & Vishnu–Mittre, 1968; Gupta *et al.*, 1984; Sharma *et al.*, 1985; Trivedi & Chauhan, 2008, 2009) in northwest Himalaya, based on the pollen evidence from the lacustrine deposits. However, the subalpine and alpine belts with a large number of potential lakes/bogs for the Quaternary palaeoclimatic studies have hitherto not got adequate attention on this aspect, barring the sketchy proxy records retrieved from Takche Lake (Mazari *et al.*, 1996) and Sithikhar Bog (Chauhan *et al.*, 2000) from Spiti region and Naychhudwari Bog (Chauhan, 2006) from Parvati Valley in Himachal Pradesh and Tipra River Bank Glacier in Garhwal region (Bhattacharyya & Chauhan, 1997), revealing the changing vegetation scenarios, surge of glaciers/ tree line in response to short–term climatic variability during the last 2 millennia or so. In the present paper, an attempt has been made to extend such studies in the sub–alpine belt (transition between temperate & alpine zones) of Parvati Valley with the view to brings about more proxy signals on the vegetation shifts and climatic oscillations broader time scale since deglaciation, which has been noticed globally *ca*. 19,000 to 1,700 yr BP (Naidu & Govil, 2010). The present study has been through the pollen analytical investigation of 1.2 m thick sediment profile from Tundabhuj Lake, lying at an elevation of *ca*. 11,000′ amsl.

CLIMATE AND VEGETATION

The study area, in general is characterized by severe cold and dry climate and remains covered with thick sheet of ice during the almost round the year. The annual mean maximum

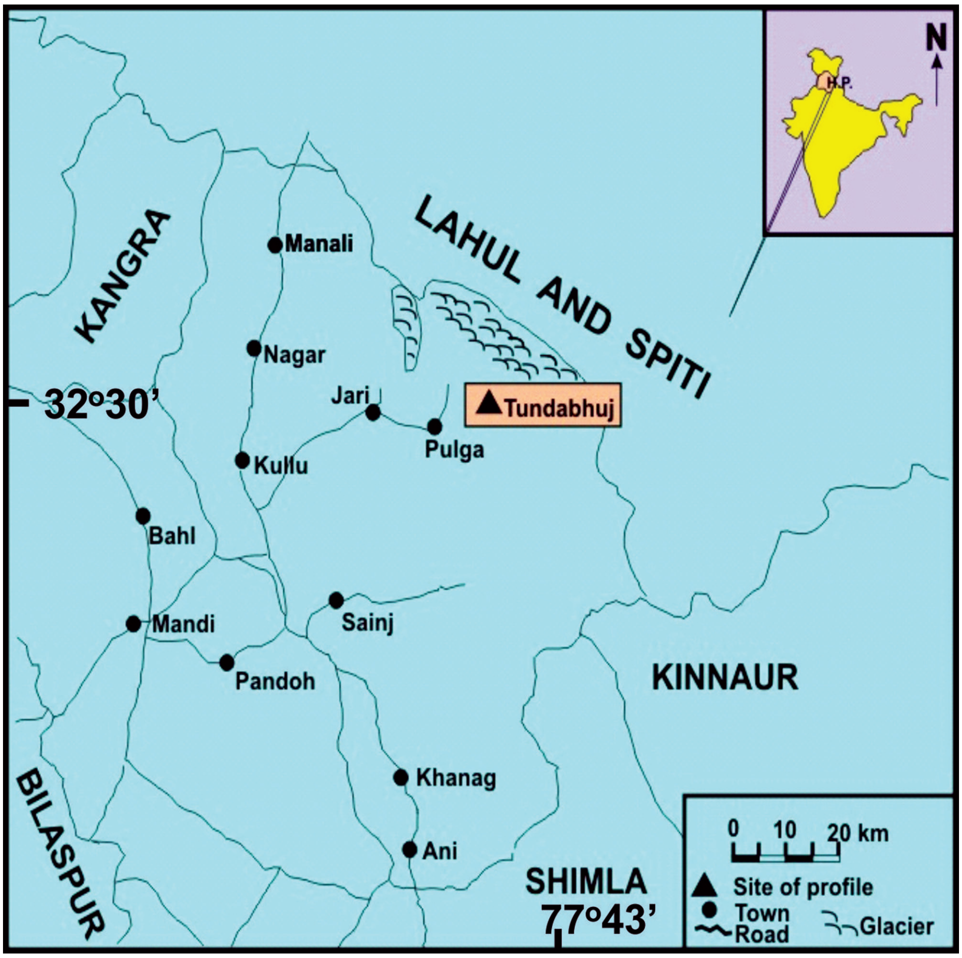

Fig. 1—Map showing the investigation site in Parvati Valley (H.P.).

and minimum temperatures range from 11.72ºC to –6.97ºC and 10.51ºC to 9.54ºC respectively. The monthly mean temperature generally remains above 0ºC during the summer months. The January and February are the coldest months of the year. The summer monsoon commences from mid–June and continues till mid–September. The precipitation occurs during major part of the year, i.e. from October–March is in the form of snowfall; however, during the monsoon period the average rainfall in the region is 230.5 mm.

The vegetation of the Tundabhuj proper is alpine scrub type. Most of the trees, viz. *Betula utilis*, *Alnus nepalensis*, *Corylus* sp., *Rhododendron* spp., *Quercus semecarifolia*, *Salix daphnoides* and *Crataegus cranulata* are gnarled and present in pockets. The herbaceous complex, sprinkled with scrubs, comprises Poaceae, *Artemisia* sp., *Potentilla* sp., *Zerbera* sp., *Meconopsis aculeata*, *Geranium nepalense*, *Pedicularis pectinata*, *Thalictrum foliosum*, *Impatiens thomsonii*, *Polygonum filicaule*, *Ranunculus hirtellus*, *Anemone obtusiloba*, *Sedum ewersii*, *Primula denticulata*, *Aster* sp., *Viola* sp., etc. However, in shady and moist hill slopes *Impatiens balsamina*, *Polygonum filicaule* and *P. cognatum* can be seen widely during the post monsoon period. The shrubby elements, viz. *Cotoneaster microphylla*, *Rosa macrophylla*, *Crataegus crenulata*, etc. are common. On the bouldery dry sunny mountain slopes, *Berberis chirtria*, *Ephedra gerardiana* and *Juniperus communis* occur in restricted areas.

The lower southern hill slopes are engaged by the pure or mixed vegetation of temperate coniferous forests principally composed of *Abies spectabilis*, *Picea smithiana*, *Cedrus deodara* and *Pinus wallichiana*. The moist valleys along the Parvati River are characterized by the occurrence of mixed broad–leaved woodlands of which *Alnus nitida*, *Quercus semecarpifolia*, *Betula utilis*, *Rhododendron campanulatum*, *Ulmus wallichiana*, *Salix elegans*, etc. are the key elements.

MATERIAL AND METHOD

Tundabhuj Lake is situated about 38 km northeast of Manikaran in Kullu District between 77º43' long. & 32º30' lat. at about 3600 m amsl on the right bank of Parvati River (Fig. 1). The lake is glacial in nature and currently it is in the form of a small pond on the flat ground at the base of Tundabhuj Glacier. It is about 30 m in circumference and contains little quantity of water during the post–monsoon ice free season. The higher reaches are characterized by the chain of snow–clad mountains. Topographically, the vicinity of the lake is marked by the stretch of flat meadow studded with bouldery high slopes, whereas the valleys contain the huge moraine deposits transported by the glaciers.

A 1.2 m deep trench was dug out on the eastern margin of the lake and a total number of 21 samples were collected for pollen analysis at an interval of 5 cm from surface to100 m depth and at10 cm intervals from 100 to 120 cm depth. In addition, 2 bulk samples were taken at larger intervals for the radiometric dating from upper and lower horizons of the trench.

Table 1

Depth	Lithology
0–50 cm	Clayey sand with abundant rootlets
15–50 cm	Clayey sand with few rootlets
50–120 cm	Sandy clay with rootlets and charcoal pieces

The sediment profile is chiefly composed of clay and sand with rootlets and charcoal pieces in variable proportions. The depth–wise stratigraphic details are set out as Table 1:

For this trench profile two radiocarbon ages have been determined and these are 2,720 ± 70 yr BP (BS–2566) at 20–30 cm depth and 9,320 ± 180 yr BP (BS–2570) at 70–80 cm depth. A sediment accumulation rate of 132 years/cm has been calculated for this sediment profile, based on the above ^{14}C dates. Assuming the constant accumulation of sedimentation rate, more ages, i.e. 15,260 yr BP at 120 cm depth, 13,380 yr BP at 105 cm depth, 7,340 yr BP at 75 cm depth, 5,030 yr BP at 42.2 cm depth and 2,000 yr BP at 15 cm depth have been extrapolated and interpolated for the Tundabhuj sediment profile for the temporal demarcation of vegetation shifts and contemporaneous climatic episodes in the sub–alpine belt of Parvati Valley since deglaciation.

The standard procedure of pollen analysis (Erdtman, 1943), using 10% aqueous KOH, 40% HF solutions and acetolysing mixture (9 : 1 ratio of acetic anhydride and concentrated sulphuric acid) was followed to extract the pollen/spores from the sediments for microscopic examinations.

POLLEN ANALYSIS

All the samples analysed from the trench profile were very productive in pollen/spore content. The pollen sum ranges from 300 to 450, which exclude the pollen of aquatic plants and ferns due to their origin from the local sources. The percentage frequencies of the recovered pollen taxa (Pl. 1) were calculated from the pollen sums for their representation in the pollen spectra and diagram. The plant taxa categorized as trees, shrubs, herbs and ferns are arranged in the same manner in the pollen spectra and pollen diagram. Further the tree taxa are put in an order of their altitudinal distribution.

Description of pollen diagram:

The pollen diagram from Tundabhuj Lake has been divided into five different pollen zones (TBL–I, TBL–II, TBL–III, TBL–IV & TBL–V), depending upon portray of arboreals

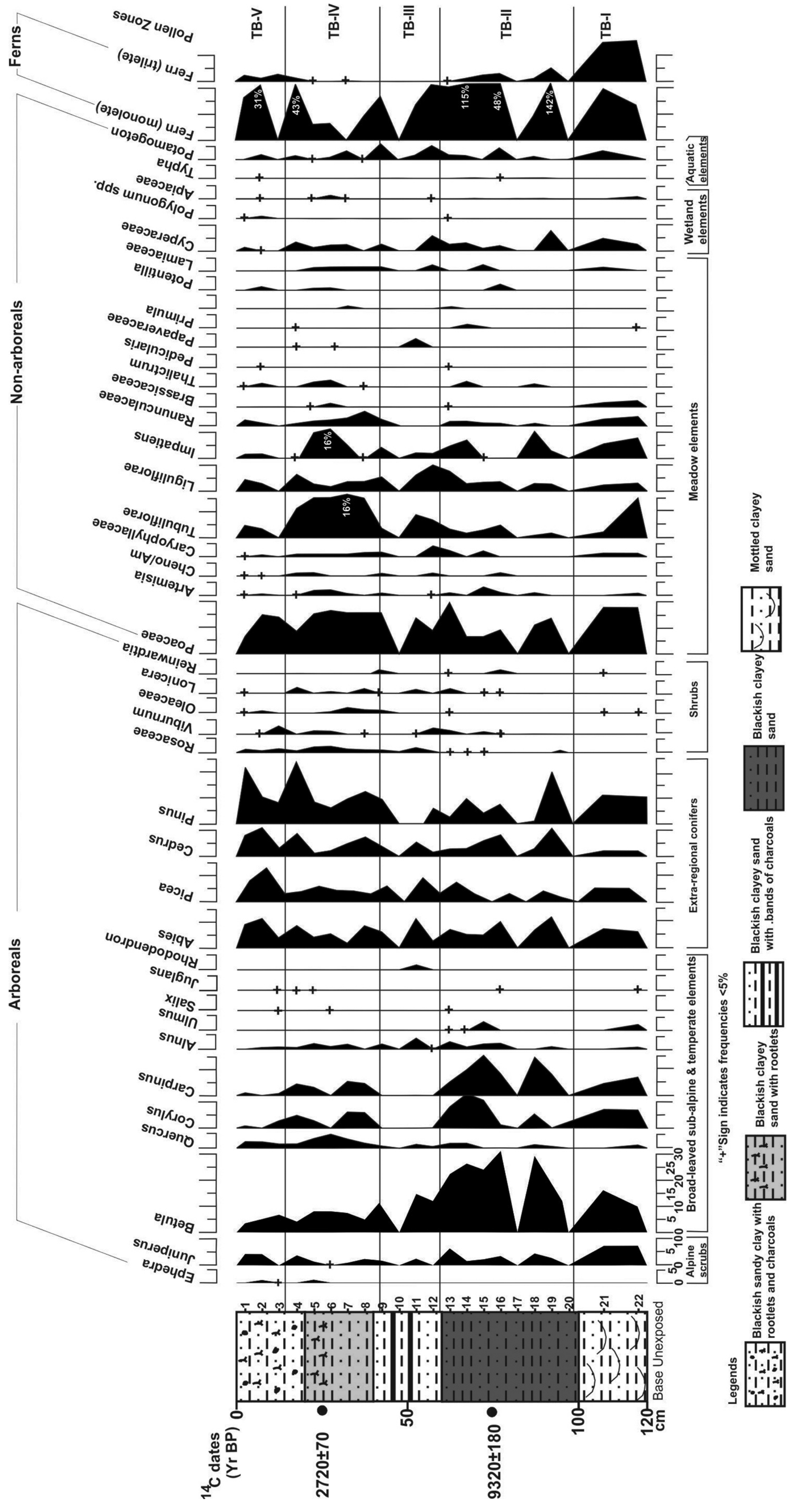

Fig. 2—Pollen diagram from Tundabhuj, Kullu District (H.P.).

and non–arboreals (Fig. 2). The pollen zones are designated by the initials 'TBL' after the name of investigation site and are numbered from bottom to top.

Pollen Zone TBL–I (120–105 cm): Betula–Quercus–Corylus–Pinus–Abies–Juniperus–Poaceae–Fern Assemblage

This pollen Zone covering the time frame of 15,260 to 13,280 yr BP is characterized by the high frequencies of broad–leaved elements, viz. *Betula* (10–16%), *Corylus* (7–8%) and *Carpinus* (7–4%). *Juniperus* (8–9%) has also good frequencies. Among the temperate conifers, *Pinus* cf. *wallichiana* (10–12%), *Abies* (5–7%) and *Picea* (4–5%) are met with consistently in moderate values, whereas *Cedrus* (2–3%) is lowly present. Poaceae (20–18%) followed by Tubuliflorae (2–15%), *Impatiens* (4–8%), Liguliflorae (2–3%) and Brassicaceae (1–2%) are the major constituents among the non–arboreals. Lamiaceae, *Artemisia* and Caryophyllaceae are encountered in reduced values. Cyperaceae and Apiaceae represent the marshy vegetation. *Potamogeton* is the lone representative of aquatic vegetation and recorded consistently. The fern spores (monolete 10–18% & triletes 10%) are retrieved frequently.

Pollen Zone TBL–II (105–75 cm): Betula–Corylus–Carpinus–Pinus–Abies–Juniperus–Poaceae–Liguliflorae–Impatiens–Fern Assemblage

This pollen Zone with solitary radiocarbon date of 9,320 ± 180 yr BP and encompassing the time bracket of 13,280 to7,340 yr BP is marked by the much increased frequencies of *Betula* (20–30%), *Corylus* (5–10%) and *Carpinus* (13–15%), whereas *Alnus* (1–3%), *Ulmus* (2%) and *Quercus* (1–2%) also have somewhat increased frequencies compared to the preceding pollen zone. However, *Juniperus* (2–5%) is recorded constantly in reduced values. Temperate conifers like *Abies* (7–10%), *Pinus* cf. *wallichiana* (5–20%), *Cedrus* (2–10%) and *Picea* (2–5%) also show improved values, though in fluctuating trend. Among the non–arboreals, Poaceae (8–20%) maintains its dominance as earlier. Tubuliflorae (1–3%), Liguliflorae (2–3%) and *Impatiens* (5–7%) are consistently recorded in moderate values. Others such as Ranunculaceae, *Thalictrum*, *Potentilla* and Lamiaceae (2% each) are sporadic. The marshy element, Cyperaceae (2–5%) remains almost same as in the preceding pollen zone. *Polygonum* sp. turns up for the first time in one sample only in the upper part of this pollen zone. *Potamogeton* is recovered consistently. Monolete fern spores (5–20%) are marked by much enhanced values; however, the triletes spores (1–3%) decline sharply.

Pollen Zone TBL–III (75–42.2 cm): Abies–Picea–Betula–Alnus–Juniperus–Poaceae–Liguliflorae–Impatiens–Fern Assemblage

This pollen Zone with the temporal range of 7,340–5,040 yr BP demonstrates the sharp decline of broad–leaved taxa comprising *Betula* (15–10%) and *Quercus* (1%), whereas *Alnus* (1–3%) is steadily present in reduced frequencies. Similarly, *Juniperus* (2%) also has much reduced values than in the Pollen Zone TBL–II. *Ephedra* (1%) appears for the first time. The temperate conifers such as *Abies* and *Picea* (3–5%) each) do not portray any marked change. On the other hand *Pinus* cf. *wallichiana* (7–5%) and *Cedrus* (4%) are noticed in reduced frequencies. Among the non–arboreals, Poaceae (13–16%) and Tubuliflorae (7–2%) decline in this zone. However, Liguliflorae and *Impatiens* also have lower frequencies than before. *Artemisia*, Cheno/Am Papaveraceae and *Potentilla* become more sporadic than in the preceding pollen zone. Cyperaceae (2%), the only representative of marshy vegetation, is scantily encountered. *Potamogeton* is met with constantly. Fern spores decline considerably.

Pollen Zone TBL–IV (42–15 cm): Abies–Picea–Betula–Alnus–Juniperus–Poaceae–Liguliflorae–Impatiens–Fern Assemblage

This pollen Zone with lone ^{14}C date of 2720±70 yr BP covering a time bracket of 5,030 to 2,000 yr BP reveals the consistent improvement in *Betula* (5–7%), *Quercus*, *Corylus* and *Carpinus* (2–5% each). *Alnus* (2%) is also steadily recovered, though in low frequencies. *Pinus* cf. *wallichiana* (7–25%), *Picea* (3–5%), *Abies* and *Cedrus* (3–8% each) are recorded in considerably higher values throughout. Likewise, Poaceae (10–15%) followed by Tubuliflorae (5–15%), *Impatiens* (2–10%), Liguliflorae (2–5%) and Ranunculaceae (2–8%) are retrieved with much increased frequencies as compared to Pollen Zone TBL–III. Similarly, *Thalictrum, Potentilla* and Lamiaceae also exhibit improvement than the preceding pollen zone. The marshy taxa, viz. Cyperaceae and Apiaceae are also better represented in this pollen zone. Fern monolete spore are preponderant in contrast to earlier zone, whereas trilete spores are meagrely noticed.

Pollen Zone TBL–V (15–0 cm): Pinus cf. wallichiana–Abies–Picea–Betula–Quercus–Juniperus–Ephedra–Poaceae Fern Assemblage

This pollen Zone encompassing the temporal range of 2,000 yr BP to present brings out the severe decline in most of the broad–leaved elements such as *Betula* (2–5%) together with *Quercus* (1.5–2.5%) have relatively reduced frequencies than in the preceding pollen zone. On the other hand *Corylus*, *Carpinus* and *Alnus* (1% each) are scanty. *Juniperus* (1–2%) is encountered with somewhat higher frequencies. *Ephedra* reappears after a lapse during the previous pollen zone. The temperate conifers *Abies*, *Picea*, *Cedrus* and *Pinus* cf. *wallichiana* are recovered constantly with much improved frequencies. Grasses (5–15%) as usual dominate, the other herbs, viz. Tubuliflorae, Liguliflorae, *Impatiens*, *Potentilla* and *Thalictrum*, which exhibit much lower values. The wetland taxa such as Cyperaceae and *Polygonum* spp. are met with in reduced values compared to the preceding pollen zone. *Potamogeton*, the sole representative of aquatic flora, also decline sharply. Fern trilete spores retain the high frequencies, whereas monolete spores are meagre.

DISCUSSION AND CONCLUSIONS

Pollen proxy data generated through the investigation of 1.2 m deep trench profile from Tundabhuj Lake, Parvati Valley (H.P.) has unfolded five distinct phases of vegetation shifts, lake–level fluctuation and glacier/tree line shifts owing to coeval climatic change in the sub–alpine belt of Himachal Pradesh since the deglaciation, which commenced around 19,000 to 17,000 yr BP on global scale (Naidu & Govil, 2010). The pollen sequence reflects that between 15,260 and 13,280 yr BP, the sub–alpine belt of Parvati Valley supported alpine–scrub vegetation largely constituted of *Betula* and its thermophillous broad–leaved allies, viz. *Quercus*, *Corylus* and *Carpinus*, interspersed with wide stretches of meadows comprising mainly grasses, Asteraceae, *Impatiens*, etc. By comparing the vegetation scenario with the modern analogue on pollen–vegetation dealt elsewhere in the text, it could be deduced that the region experienced a warm and moderately moist climate than that prevails today. The dry scrubby element–*Juniperus* grew in restricted pockets on the adjoining sunny mountain slopes. The presence of pollen of aquatic plant–*Potamogeton* denotes the prolonged existence of lake in the region. This period of a favourable climate falls within the time limit of deglacial phase, which is noticed globally between 14,000 to 12,000 yr BP ((Rawat *et al.*, 2010). The frequent record of conifers such as *Pinus* cf. *wallichiana*, *Cedrus*, *Abies* and *Picea* depicts the close proximity of the temperate belt from where their pollen got transported by the upthermic winds to the investigation site. Ferns flourished luxuriantly in moist and damp a situation, which is well demonstrated by the frequent encounter of monolete and trilete spores in the sediments.

Around 13,280 to 7,340 yr BP, the substantial expansion of alpine–scrub vegetation dominated by *Betula* together with other common broad–leaved associates, viz. *Corylus, Carpinus* and *Alnus* and simultaneous improvement in the prominent meadow elements such as *Impatiens*, *Potentilla*, Asteraceae and Lamiaceae, besides grasses suggests that the region was under a relatively warm and more–moist climate. The xerophillous element–*Juniperus* further got restricted into smaller pockets on adjoining dry mountain slopes as well corroborated by the simultaneous reduction in its frequencies during this phase. The lake assumed a slightly wider stretch in response to further improvement in the climate as clearly portrayed by the rising trend of aquatic element–*Potamogeton* and wetland elements–sedges. The increasing trend of *Pinus* cf. *wallichiana*, *Cedrus*, *Abies* and *Picea* brings out the upward shift of temperate coniferous forests/tree line and retreat of glaciers during this period because of prevalence of more favourable climatic condition in the region. The latter part of this phase of favourable climate corresponds to some extent with the early part of Period of Climatic Optimum (Bradley, 1999), which has been noticed globally between 9,000 to 4,000 yr BP. This is also supported by the multiproxy signals from Phulera Lake in the Kumaun Himalaya (Kotlia *et al*., 2010), via magnetic susceptibility ~8,200 to ~6,000 yrs BP, and also documented by marine foraminifera studies (Naidu & Govil, 2010).

The abrupt depletion in *Betula* and scanty presence of broad–leaved taxa, *Alnus* and *Quercus* as well as disappearance of other associates as stated in the preceding phases for a relatively shorter period, i.e. around 7,340 to 5,030 yr BP elucidates that the alpine–scrub vegetation got confined into small patches and became much sparse in response to deterioration of climate, which turned cold and dry. By this time, the temperate conifers and meadow constituents also declined on account of onset of adverse climatic condition in the region. The glaciers and tree line might have descended to lower elevations. The prevailing dry climatic condition induced the repeated fire incidence in the region as evidenced from the presence of distinct intercalated bands of charcoals at the depth of 40–60 cm in the trench profile encompassing this phase.

PLATE 1

(Bar on Fig. 1 represents magnification of rest of the photographs) ⟶

1. *Abies*
2. *Pinus*
3. *Picea*
4. *Alnus*
5. *Cedrus*
6 *Betula*
7. *Corylus*
8. *Juglans*
9. *Quercus*
10, 11. *Juniperus*
12. Tubuliflorae Type I
13. Tubuliflorae Type II
14. *Artemisia*
15. *Ephedra*
16, 17. Cheno/Am
18. Caryophyllaceae
19. *Impatiens*
20. Brassicaceae
21. Ranunculaceae
22. Poaceae
23. Cyperaceae
24. Fern monolete
25. Fern trilete

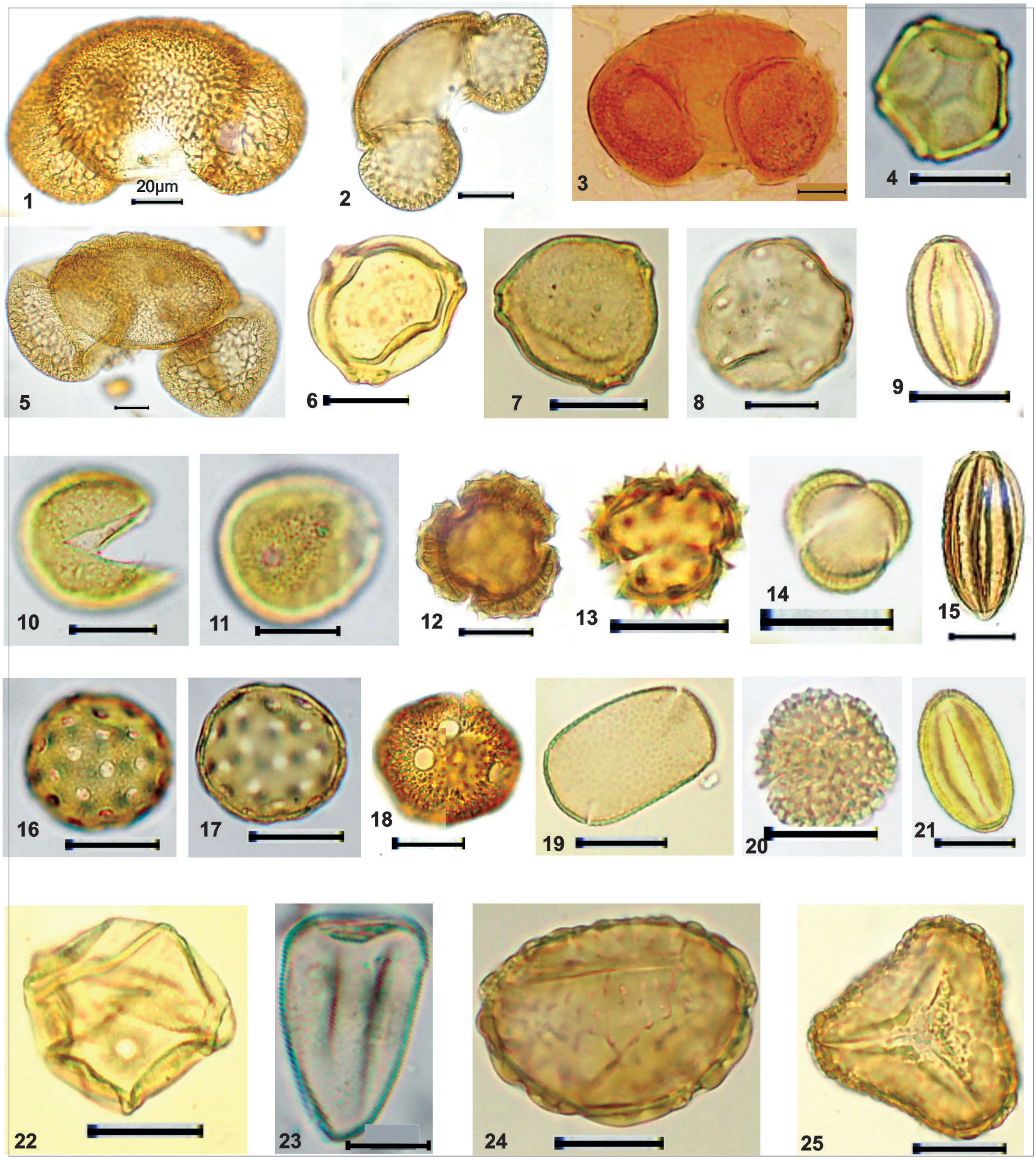

PLATE 1

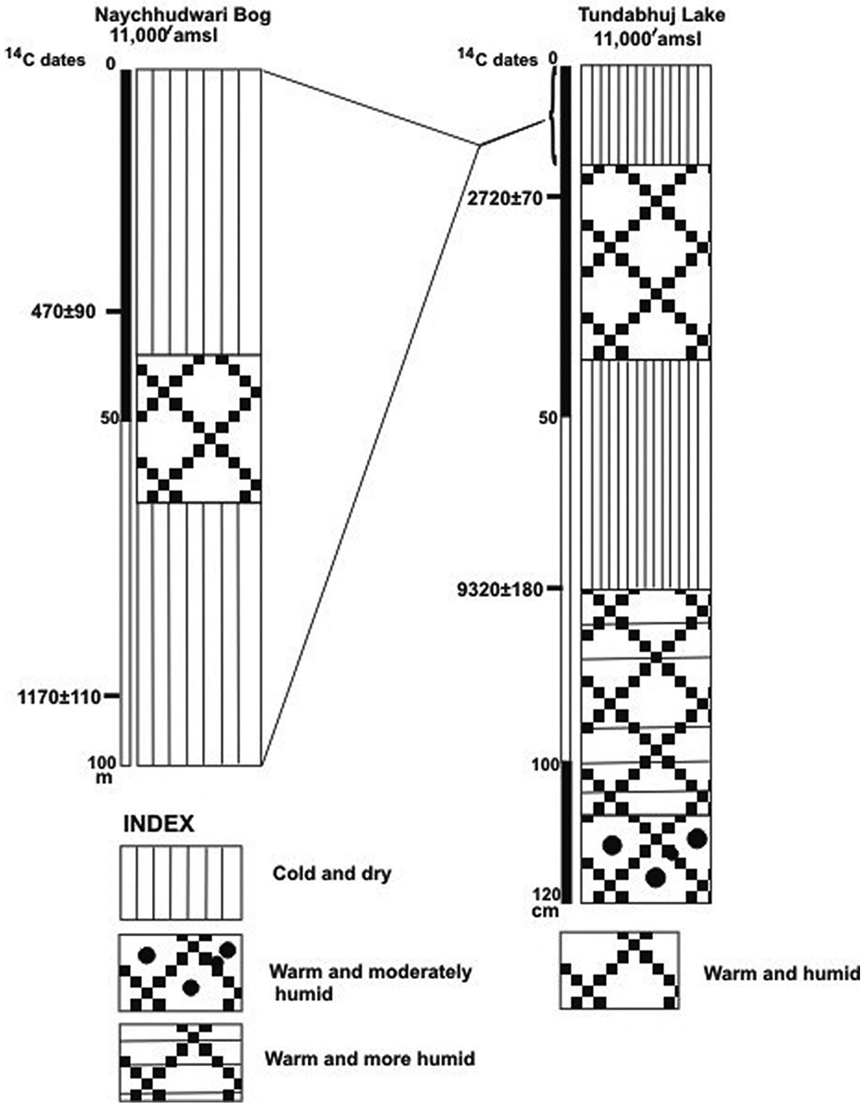

Fig. 3—Correlation of pollen sequences investigation from Kullu District (H.P.).

Around 5,030 to 2,000 yr BP, the region experienced a warm and moist climatic condition again, which was of relatively low intensity in terms of monsoon precipitation compared to the phase preceding the previous one and consequently a moderate expansion of *Betula* and accompanying other warmth–loving broad–leaved elements such as *Quercus*, *Corylus* and *Carpinus* took place. The temperate conifer forests might have shifted to somewhat higher elevations with the advent of favourable climatic conditions as manifested by the increased frequencies of its prominent coniferous and broad–leaved constituents. The ground flora also flourished profusely and became more diversified as obvious from the much improvement in graminods and other elements such as Asteraceae, *Impatiens*, *Artemisia*, *Thalictrum*, etc., the major ingredients of alpine meadow.

Since 1,950 yr BP onwards, an apparent deterioration in climate took placed and consequently alpine–scrub vegetation turned much feeble and sparse as clearly demonstrated by the sharp decline in *Betula* together with its thermophillous and broad–leaved associates *Quercus*, *Corylus*, *Carpinus* and *Alnus*. This is also supported by the simultaneous increase in *Juniperus* and *Ephedra,* which thrive well on the dry sunny steep sloped mountains in western Himalaya.

Thus, the pollen based proxy records from 1.2 m deep sediment profile from Tundabhuj Lake has unfolded five distinct phases of vegetation shifts and climate change in the sub–alpine belt of Parvati Valley in Himachal Pradesh since the deglaciation. During the time lapse of 15,260 to 13,280 yr BP, this region enjoyed a warm and moderately humid moist climate as deciphered by the presence of *Betula* dominant alpine–scrub vegetation. Around 13,280 to 7,340 yr BP the much expansion of *Betula* and associated broad–leaved taxa implies the initiation of a warm and relatively warm and more–moist climate in response to prevalence of active monsoon precipitation. The glaciers receded and tree line also shifted to higher elevations due to favourable climate. Between 7,340 to 5,030 yr BP the region witnessed a brief spell of cold and dry climate and as a result of this the glaciers advanced to lower altitudes. This is well demonstrated by the sharp decline in the alpine–scrub vegetation. Later on, the mild expansion of *Betula* scrub vegetation and much expansion of meadow elements occurred with the advent of warm and moist climate again around 5,030 to 2,000 yr BP. Since 2,000 yr BP onwards, the region has witnessed deterioration in climate which turned cold and dry.

On correlation of the pollen sequences from the Parvati Valley, it has been observed that the top phase (Pollen Zone TBL–IV) of Tundabhuj pollen sequence covering the time bracket of 2,000 yr BP fits well to larger extent in terms of temporal range with that of Nachhudwari Bog (Chauhan, 2006), located about 5 km east and at 600 m higher altitude (i.e. 4200 m amsl) in contrast to present investigation site (Fig. 3). However, the pollen data from 1m deep shallow core Nachhudwari Bog has provided an elaborated picture of the high resolution vegetation shifts and climatic trend since 1,300 yr BP (Chauhan, 2006), which could not have deciphered in Tundabhuj sequence due to much compressed nature of the sediments, hence a lesser number of samples could be analysed for the said time period. It is, therefore, presumed that the pollen proxy records from the Naychhudwari Bog have supplemented the information concerning the intermittent short–term climatic variability in the Parvati Valley, depicting three clear phases of climate, i.e. warm and moist between 1,300 and 750 yr BP, warm and more–humid around 750 to 450 yr BP and cold and dry since 450 yr BP onwards, based on the changing vegetation scenarios during the last 1.3 millennia.

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