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LATE HOLOCENE CLIMATE AND VEGETATION CHANGE IN THE DZUKO VALLEY, NORTH EAST INDIA

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ABSTRACT

Pollen analysis of the ten moss cushion samples as well as one 1.3 meter deep sedimentary profile from the Dzuko valley has revealed the short term vegetation and climatic alterations in the region for the last 1600 years. The pollen study of the sedimentary profile has revealed three palynozones since 1600 yrs BP. An open land vegetation consisting largely of pollen from dwarf bamboo (*Sinarundinaria rolloana*) along with *Primula, Anemone* and *Rubus* interspersed with scattered cool-loving arboreals like *Magnolia, Symplocos, Ilex, Carya,* Lauraceae and *Rhododendron,* used to grow in the vicinity of the study area during 1600 yrs BP under cool and humid climate, similar to the prevailing present-day temperate conditions. The vegetation turned out to be comparatively warmer during 980 yrs BP as evidenced by the appearance of mixed tropical-subtropical plant assemblage, namely *Emblica*, Sapotaceae, *Elaeocarpus*, Meliaceae, *Lagerstroemia,* Ericaceae and Oleaceae. However, from 450 yrs BP onwards, a combination of Poaceae-Bambusoideae pollen as well as broad-leaved arboreals, especially *Quercus, Elaeocarpus* and Combretaceae along with highland conifers have appeared, indicating increased warm and humid conditions followed by a slightly drier conditions at the upper column due to increased values of *Ephedra* and *Artemisia.*

Keywords: Vegetation and climate changes, Late Holocene, Palynology, Dzuko valley, N.E. India

INTRODUCTION

The Dzuko Valley is one of the rich biodiversity hot spots in North East India. The valley is situated at the border of Nagaland and Manipur states, northeast India at an altitude of about 2400 masl (Lat. 25^0 33.375" N and Long. 94^0 04.58" E) (Fig.1). At first sight, this valley gives an impression of the well-known 'Valley of Flowers' in the Garhwal Himalaya of northern India during April to September. Due to extreme cold conditions during October to February, most of the plant taxa cannot thrive well except the growth of an endemic temperate dwarf bamboo viz., *Sinarundinaria rolloana.* Therefore, the valley in this season is known as "Valley of Bamboo". The other main attraction of the valley is the beautiful, rare and endemic lilly named *Lilium mackliniae* which comes to full bloom during June and July (Mao and Kataki, 1994). The altitudinal location of the valley and its interesting characteristics – a partial wetland ecosystem combined with subalpine features and bounded by a temperate forest ecosystem on the higher ridges (Japfu Hill Range) - make it extremely rich in biodiversity.

The valley has a low-lying plain covering an area of about 27 sq. km., criss-crossed by four streams which all form a zig-zag river and flow to Paren and down to Assam plain. The nonarboreal vegetation mainly consists of elements of temperate to subalpine nature (Champion and Seth, 1968; Kanjilal *et al.*,1982) and the dominant species are *Lilium mackliniae, Euphorbia sikkimensis, Aconitum nagarum, A. elwesii, Anaphalis margaritacea, Potentilla fulgens, P. polyphylla, Rubus nepalensis, Thalictrum foliosum, T. virgatum, T. reniforme, Bistorta emodi, Heracleum wallichii, Swertia cordifolia, S. angustifolia,* Grasses, etc. The marshy vegetation is composed of *Caltha palustris, Blyxa ambertii, Carex alta, C. fusiform, Gentiana sikkimensis* and *Genarium himalayana.*

The surrounding hilly areas are dominated by temperate to subalpine forests. The dominant arboreal species are *Rhododendron arboreum, R. fulgens, R. elliottii, Ilex dipyrena, Betula utilis, Lithocarpus pachyphylla, Juniperus recurva, Lyonia ovalifolia, Vaccinum dunalianum, Gaultheria griffithiiana, G. hookeri, Magnolia campbelii, Quercus lamelosa, Symplocos dryophila, Taxus wallichiana, Tsuga brunoiana, Illicium simonsii*, etc.

SOIL AND CLIMATE

The soil is brown to black in colour due to richness in humus and the rock types exposed in the valley belong to the Disang Formation of Eocene age. It consists of splintery shale intercalated with thin sandstone bands and is highly prone to erosion. The temperature in the valley ranges from a minimum of -3^0 in January to a maximum of 32^0C in September. Relative humidity ranges from 45 to 90% in different seasons. Rain is maximum during May and August.

So far, no palynological database is available from Dzuko valley. Therefore, it is aimed to deduce pollen/vegetation relationship and palaeoclimatic oscillations with respective vegetation successions from such a remote, geologically fragile terrain.

MATERIAL AND METHODS

Out of 10 samples of the moss cushion, the first five were procured from the dry upland valley area and the rest (6-10) from the submerged area along the streams (Fig.1). Total 13 soil samples were studied at the interval of 10cm each from 1.3 meter sedimentary profile. The said profile was procured by trenching method. Sediments were chemically processed using standard acetolysis method (Erdtman, 1943) and 200-315 pollen grains per sample were counted. The plant elements have been categorized into nonarboreal, local arboreal, highland taxa, ferns and fungal remains including spores and other fruiting bodies which are included in the pollen sum to interpret the pollen spectra and diagram (Figs. 3, 4). The group "Poaceae-

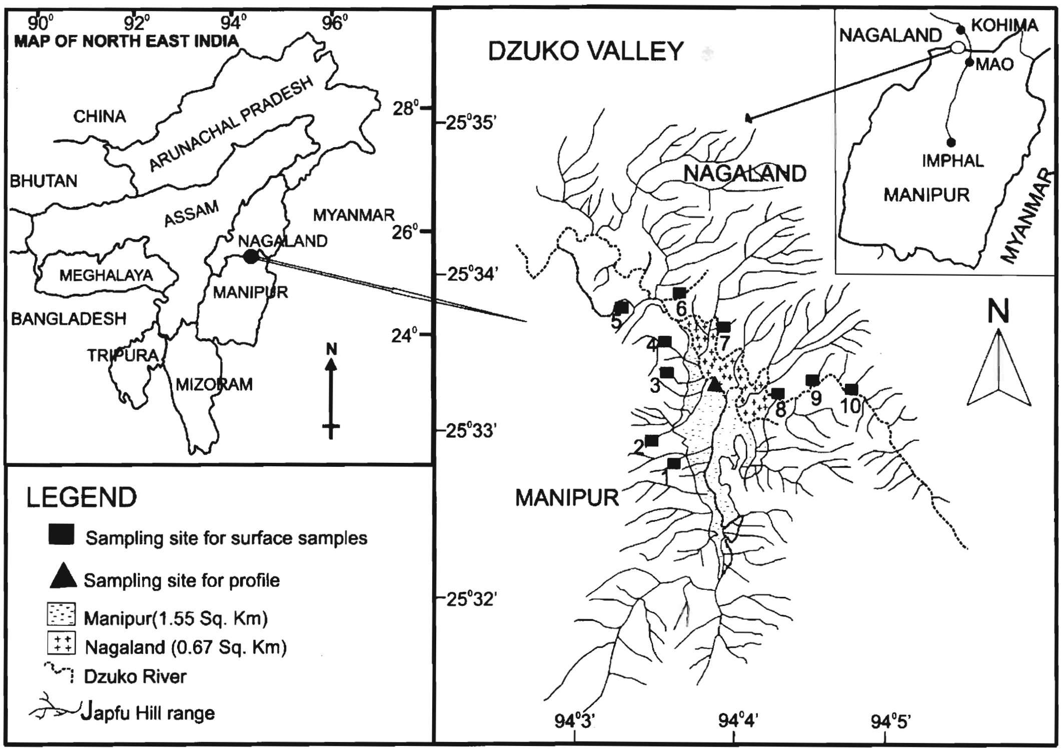


Fig. 1. Location map of the Dzuko valley showing the sampling site.

Bambusoideae" in the text refers to the unique combination of both wild grass pollen (20-40μm) and dwarf bamboo pollen (>40μm) recovered from the sediment. The pollen sequence in the diagram is subdivided into three pollen zones, viz., DZ-I, DZ-II and DZ-III, the prefix DZ representing the Dzuko Valley (Faegri and Iversen, 1989).

The C^{14} dating was carried out at Birbal Sahni Institute of Palaeobotany, Lucknow. The sediment was manually cleaned, sieved and subjected to hydrochloric acid to remove any carbonate component. After repeated rinsing and pH-checking, the sediment was combusted in the continuous flow of oxygen. The resulting carbon dioxide was collected and converted to acetylene and then to benzene using standard catalyst and procedures. The counting was done in a Liquid scintillation counter (Quantulus 1220). Due to very less carbon content in the sediment, only 2 samples were found potential for dating. Two dates i.e. 450±70 yrs BP at 50-60cm (BS-2580) and 980±110 yrs BP at 80cm (BS-2581) were determined. The approximate rate of sedimentation calculated on the basis of the above dates is 0.85 mm/yr. Assuming a constant rate, the calibrated C-14 age of 980±110 years BP for 80 cm deep sample, when linearly extrapolated to a depth of 130 cm, suggests that the deepest sample is about 1600 yrs old.

RESULT AND DISCUSSION

Pollen/vegetation relationship

The palynological study of 10 samples of the moss cushion, 5 each from the dry upland valley and along streams, reflects a reasonably good pollen assemblage matching the present-day vegetation. The pollen spectra show predominance of nonarboreals over the arboreals. The major nonarboreals (25-30%) comprise Poaceae-Bambusoideae, Ranunculaceae, Tubuliflorae, *Strobilanthes*, Polygonaceae,

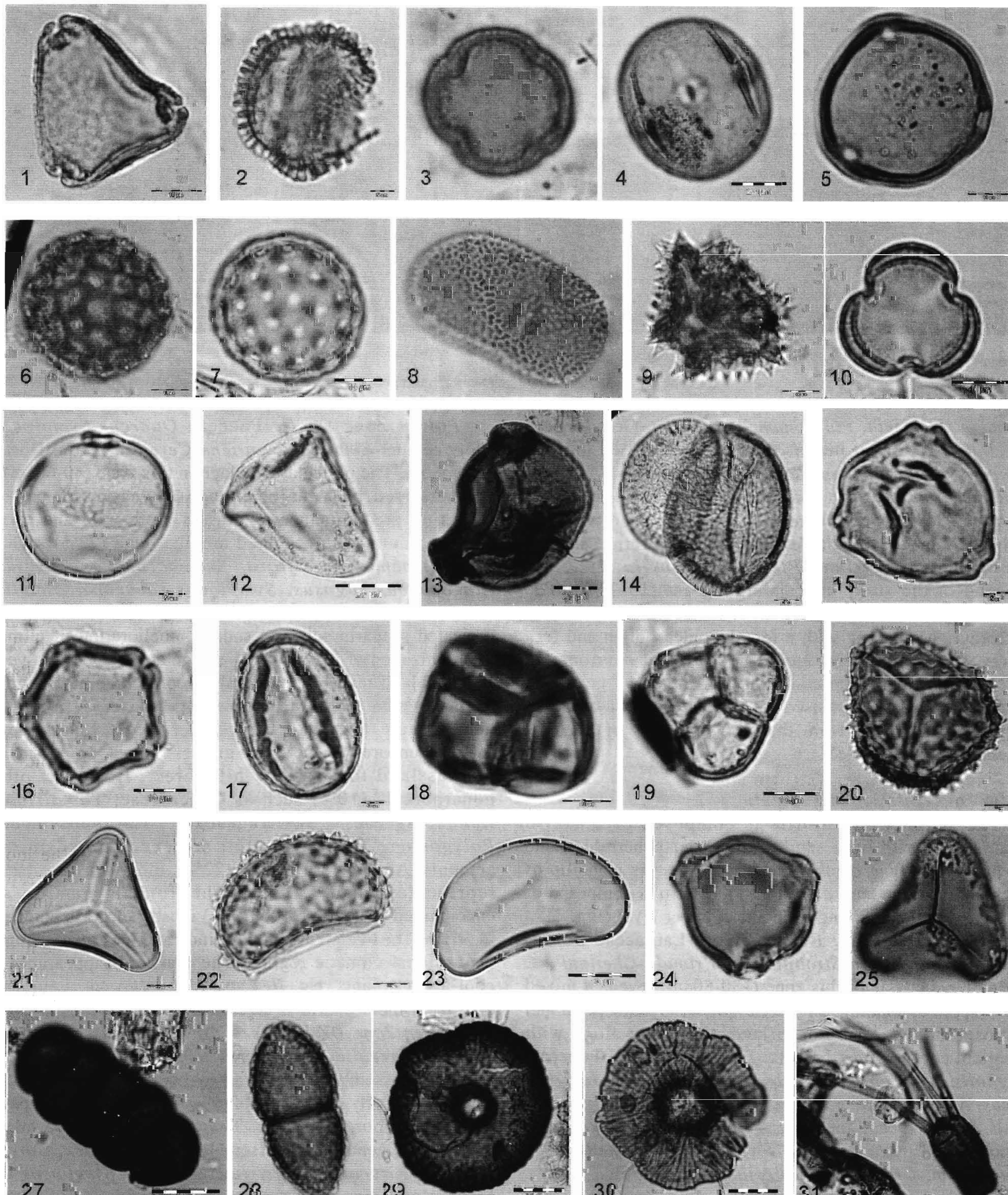
EXPLANATION OF PLATE I

(All figure x 1200)

1. ***Symplocos dryophila***
2. ***Ilex dipyrena***
3. ***Emblica officinalis***
4. ***Madhuca indica***
5. ***Carya alba***
6. ***Polygonum serrulatum***
7. ***Amaranthus spinosus***
8. ***Impatiens balsamina***
9. **Tubuliflorae**
10. ***Artemisia vulgaris***
11. **Bambusoideae**
12. ***Cyperus rotandus***
13. ***Ludwigia repens***
14. ***Pinus khasiana***
15. ***Betula utilis***
16. ***Alnus nepalensis***
17. ***Quercus lamelosa***
18. ***Rhododendron arboreum***
19. ***Erica cinerea.***
20. ***Lycopodium japonica***
21. ***Cyathea gigantia***
22. ***Polypodium vulgare***
23. ***Dryopteris flixmax***
24. ***Betula*** pollen with perforations near aperture
25. Partly degraded *Cyathea* spore with branched wedge shape perforations

27. ***Meliola*** sp.
28. ***Diplodia*** sp.
29-30. **Microthyriaceae**
31. ***Tetraploa*** sp.

Plate I



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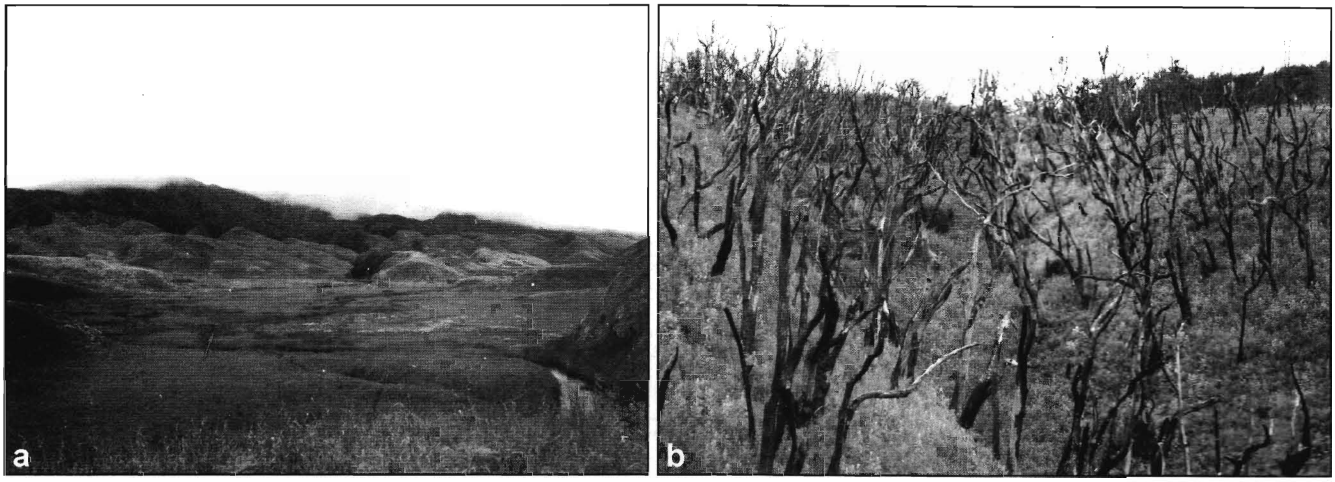

Fig. 2. (a) A view of the Dzuko valley, (b) Burnt stumps of *Rhododendron* spp.

Rosaceae, *Rubus*, etc. The marshy taxa include *Carex*, Liliaceae, *Ludwigia*, *Polygonum*, *Heracleum*, Gentianaceae and *Impatiens*. The major arboreals (15-20%) include *Quercus*, *Symplocos*, *Ilex*, *Elaeocarpus*, *Carya*, *Rhododendron*, etc. The conifers are represented by *Pinus*, *Picea* and *Tsuga* as the representative of highland taxa (20-25%). The presence of a few high altitude ferns such as *Cheilanthus*, *Athyrium*, *Pteris stenophylla*, etc., not growing in the study area, is significant (15-20%). The presence of fungal remains (15-25%), especially Microthyriaceae along with a few degraded pollen and fern spores strongly suggests humid depositional environment (Bera *et al.*, 2008). The comparative pollen data generated from the study have been used for the interpretation of pollen diagram constructed from this area in terms of the past vegetation and climate.

History of vegetation and climate

The sedimentary profile is composed of blackish organic clay with little sand. The rootlet penetrable zone reaches up to 20cm depth, whereas 20-80cm is made up of black organic clay and the rest up to 130 cm is composed of black organic clay having little silt at lower level (Fig. 3).

Pollen Zone DZ-I: Bambusoideae-Lauraceae-*Carya-Rhododendron-Tsuga-Strobilanthes-Primula-Cheilanthus*. The pollen analysis of this zone (130-80cm) revealed mixed pollen/spore assemblage of Pteridophyte, Gymnosperm and Angiosperm suggesting open land vegetation along with important cool-loving arboreals (15%), viz., *Ilex*, Lauraceae, *Magnolia*, *Quercus, Rhododendron*, Oleaceae, *Juglans*, *Ulmus*, *Alnus*, *Betula,* etc. The highland taxa include (20%) *Pinus*, *Tsuga*, *Picea*, *Salix*, etc. The fern spores (15%), both monolete and trilete, namely *Davallia*, *Pteris*, *Cheilanthus*, *Lycopodium*, *Cyathea*, *Microlepia*, *Athyrium*, etc., signify the prevalence of humid conditions. Nonarboreals (35%) are composed mainly of dwarf bamboo pollen (Bambusoideae 15%) followed by pollen of Asteraceae, Cyperaceae, *Impatiens*, *Strobilanthes*, *Primula*, *Anemone*, Chenopodiaceae, Rosaceae, Apiaceae, etc. They indicate open land vegetation. Fungal remains (15%). are largely composed of Microthyriaceae along with other grass pathogens such as *Diplodia*, *Alternaria*, *Tetraploa*, etc. The mixed assemblage of vegetation strongly indicates cool and humid climatic regime since about 1600 years BP (Fig. 5).

Pollen Zone DZ-II: Poaceae-*Quercus-Symplocos-Elaeocarpus-Emblica-Impatiens-Cerealia*-Tubuliflorae-*Dryopteris*. The pollen assemblage in this zone (80-60cm) is characterized by a major change in vegetation pattern reflecting predominance of grasses, both wild and dwarf bamboo, along with scattered arboreal taxa (22%) such as *Lagerstroemia parviflora, Semecarpus anacardium*, *Elaeocarpus rugosus*, *Symplocos racemosa*, *Emblica officinalis*, Oleaceae, Sapotaceae, Meliaceae, etc. The projected scenario suggests sudden amelioration of climate in colonization of savannah type vegetation since 980 years BP. Highland taxa (18%) are also represented at a slightly higher value than the preceding phase. Among the nonarboreals, the dwarf bamboo declined to the value of 5% as compared to the other grasses, indicating expansion of grassland towards the hill forest. However, other nonarboreals (10%) such as Cyperaceae, Tubuliflorae, Ranunculaceae, Saxifragaceae, Caryophyllaceae, *Polygonum*, *Impatiens*, etc., are encountered in low amounts. Among fern spores (22%), monoletes are better represented than triletes. The fungal remains are encountered at good profile (23%) mostly of grass pathogen in origin. The overall assemblage indicates a warm and humid depositional climatic regime. The drastic disappearance of cool-loving plants, e.g. *Ilex* sp., *Magnolia*; sp., Lauraceae etc., from the scenario is significant.

Pollen Zone DZ-III: Ilex-Careya-Quercus-Artocarpus-Dillenia-Cerealia-Xanthium-Artemisia-Microthyriaceae. The pollen assemblage (60-0cm) in this zone is characterized by comparatively high value of arboreals (25%) as compared to the nonarboreals (18%). The invasion of more mixed arboreal elements in the assemblage, namely *Ilex*, *Careya*, *Quercus*, *Artocarpus*, *Syzygium*, *Dillenia*, *Symplocos* and Lythraceae suggests increasing trend for warm and humid conditions around 450 yrs BP. Among the highland taxa (22%), *Pinus* and *Juniperus* are the major taxa. Fern spores, especially monoletes (20%) along with marshy/aquatic elements such as *Ludwigia*, Ranunculaceae and *Nymphoides* are low in abundance in the lower part of DZ III. The appearance of *Ephedra* and *Artemisia* in the upper part indicates slightly drier climate in which lake may have become shallower and allowed to grow more moist loving

Table. 1: Grouping of ecologically characteristic plant taxa in and around the Dzuko valley (*Taxa are encountered in sediments).

Nonarboreal taxa (NAP)	Arboreal taxa (AP)	Ferns and fungal spore
Terrestrial herbs: **Sinarundinaria rolloana*, **Primula denticulata*, **Prunus nepalensis*. *P. acuminata*, **Potentilla fulgens*, *P. polyphylla*. **Rubus calycinus*, *R. paniculatus*, *R. nepalensis*, *Rosaceae, *Poaceae, **Anemone rivularis*, *Lilium mackliniae*, *Euphorbia sikkimensis*. **Aconitum nagarum*, *A. elswii*, *Anaphalis margaritacea*, **Thalictrum foliosum*, *T. virgatum*. *T. reniforme*, **Saxifraga ligulata*, *Selinum striatum*, *Bistorta emodi*, **Heracleum wallichii*. *Swertia cordifolia*, *S. angustifolia*, *S. pulchella*. *Rhodiola heterodonta*, *Oenanthe benghalensis*. *Ligularia dentata*, *Polygonatum verticillatum*. *Lantana camara*, **Eupatorium cannabinum*. *Blumea densiflora*, **Artemisia vulgaris*, *A. parviflora*, **Xanthium strumarium*, *Rumex acetosella*, **Amaranthus spinosus*, **Chenopodium album*, *Alternanthera sessilis*, *Satyrium nepalensis*, *Juncus planifolius*. **Ranunculus repens*, etc. **Marshy/aquatic:** *Caltha palustris*. *Blyxa ambertii*. *Carex alta*, *C. fusiform*, *Gentiana sikkimensis*, *G. tenella*, *G. quadrifaria*, *Genarium himalayana*, **Cyperus rotandus*, **C. corymbosus*, **Silene vulgaris*, **Polygonum serrulatum*, **Impatiens balsamina*, **Nymphoides peltata*, **Myriophyllum aquaticum*, **Trapa bispinosa*, *Typha latifolia*, **Nymphaea cristata*, *Jussiaea suffruticosa*, **Ludwigia repens*, etc.	**Local arboreals:** **Carya alba*, *Cinnamomum tamala*, *Lauraceae **Emblica officinalis*, *Adina cordifolia*, **Sideroxylon hookeri*, **Madhuca indica*, **Syzygium cumini*, **Semecarpus anacardium*, **Elaeocarpus rugosus*, *Grewia elastica*, **Melia azedarach*, **Lagerstroemia parviflora*, **Dillenia indica*, **Artocarpus chaplasha*, **Combretum acuminatum*, *C. pilosum*, **Careya arborea*, **Symplocos dryophila*, **Rhododendron arboreum*, *R.. fulgens*, *R. elliottii*, *Gaultheria griffithiiana*, *G. hookeri*, **Erica cinerea*, *Ericaceae, **Ilex dipyrena*, **Ephedra gerardiana*, **Betula utilis*, *Vitex negundo*, **Alnus nepalensis*, *Lithocarpus pachyphylla*, *Lyonia ovalifolia*, *Vaccinum dunalianum*, **Magnolia campbelii*, **Quercus lamelosa*, *Q. serrata*, *Morus alba*, *Sapindus rarak*. *Illicium simonsii*, **Ulmus lancifolia*, **Juglan regia*, *Melastoma malabathricum*, *Clerodendrum viscosum*, *Mallotus philippensis*, **Strobilanthes flaccidifolia*, *Jasminum laurifolium*, *J. attenuatum*, *J. heterophyllum*, *Olea dentata*, *Ligustrum compactum*, *Oleaceae, etc. **High land taxa:** **Pinus khasiana*, **Picea abies*, *Cedrus deodara*, *Taxus wallichiana*, **Tsuga brunoiana*, **Juniperus recurva*, *J. macropoda*, *Cryptomeria japonica*, **Salix excelsa*, etc.	**Ferns:** **Cheilanthus microphylla*, **Athyrium flix-femina*, **Pteris stenophylla*, *P. wallichiana* **Davallia denticulata*, **Lycopodium clavatum*, **Polypodium vulgare*, **Dryopteris flixmax*, *Lygodium japonica*, **Cyathea gigantia*, **Microlepia hancei*, *Osmunda claytonia*, *Gleichenia polypodioides*, *Ceratopteris thallicteroides*, etc. **Fungal spore:** *Microthyriaceae, *Nigrospora*, *Xylaria*, **Helminthosporium*, **Cookeina*, **Alternaria*, **Diplodia*, *Glomus*, **Tetraploa*, *Pleospora*, etc.

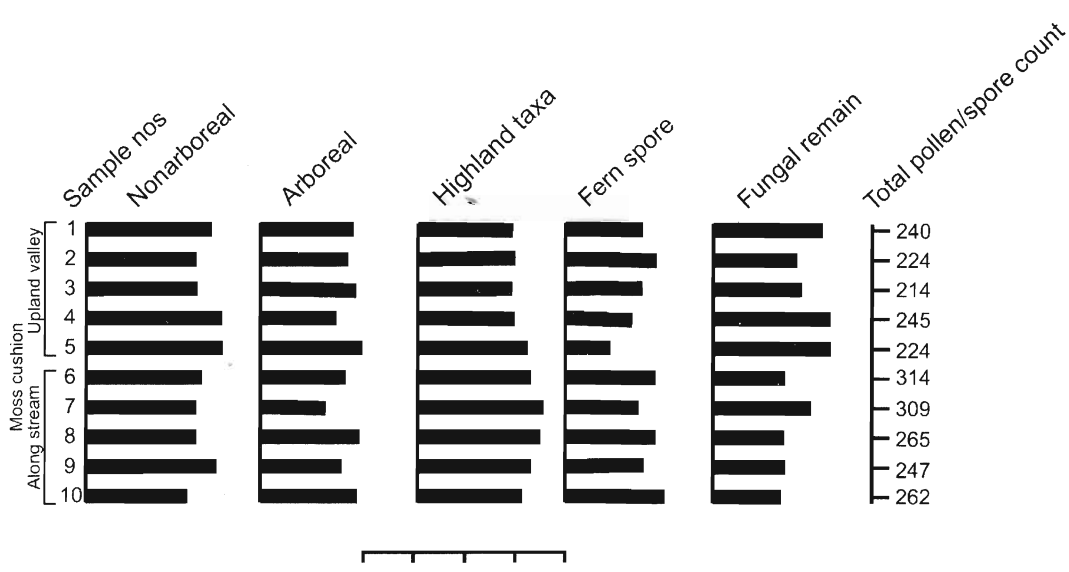

Fig. 3. Composite pollen spectra including fungal remains from the sediments of the Dzuko valley.

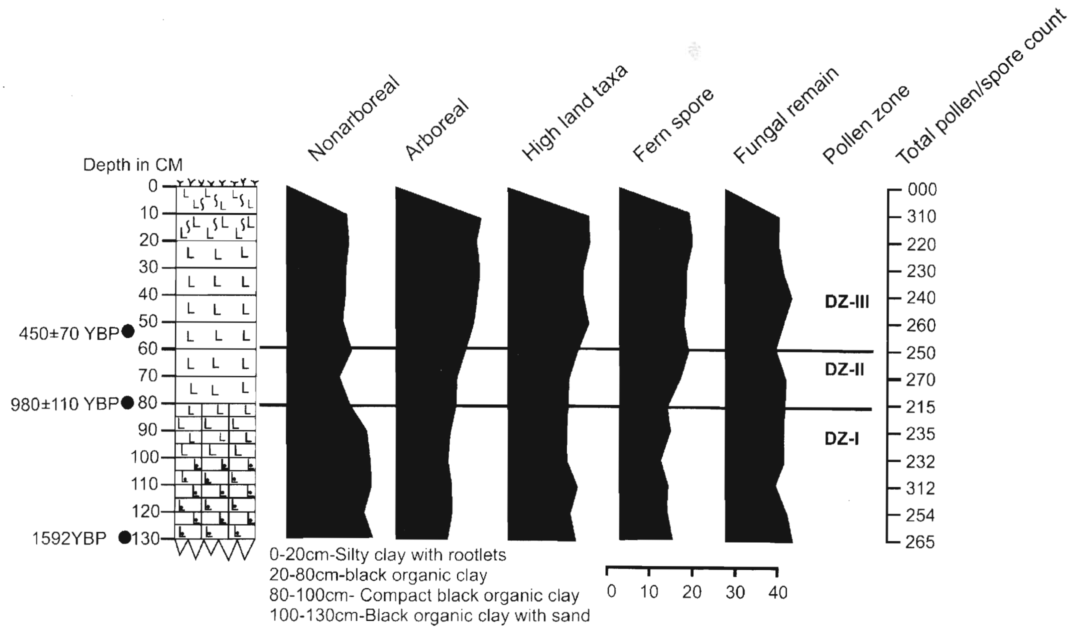

Fig. 4. Composite pollen diagram including fungal remains from sediments of the Dzuko valley.

plants. Though fungal remains are represented at a slightly lower value (15%), the predominance of Microthyriaceae supports more humid conditions. The study indicates that there may have been a condition for tree line shift towards high elevation as evidenced by the increase of both highland broad-leaved and local arboreals. This may be attributed to the reversal of climate towards more humid conditions.

Judging from the above pollen database, it is evident that there were three phases of climatic regimes ranging from cool and humid to increasing warm and humid conditions, though largely a temperate-subtropical vegetation prevailed throughout since 1600 years BP.

CONCLUSIONS

The change of vegetation sequences in the pollen diagram shows that some degree of climatic fluctuations did occur in this valley. The forestation phenomena were generally associated with decrease and increase of grasses and herbs along with other local elements. The diagram also shows that the lower part of the profile is represented by subtropical-temperate elements which tend to weaken slightly in the upper part, perhaps indicating that the climatic condition deteriorated and resulted in deforestation as evidenced by the loss of dwarf bamboos (dry brown patch) and burnt stumps of *Rhododendron* (Fig. 2 a, b). The nature of vegetation recorded in the valley could have been influenced by altitudinal factors or cooling impact from the neighboring Himalayan belt as evidenced by the occurrence of important cool-loving plants such as *Carya alba*, *Magnolia*, *Symplocos*, Lauraceae, *Juglan*, *Rhododendron*, etc. The other supportive data include the occurrence of a large number of ferns, which are of temperate origin and not growing around the study area. During the recent past, the natural forest of the area is being destroyed extensively by forest fire because of human intervention. All these have resulted in the rapid depletion of the rich flora of the area. The populations of several species are also facing threat to survival in their natural habitats, while a few are already on the verge of extinction (Mao and Gogoi, 2007). The situation has reached an alarming stage and it would be worse if immediate conservation measures are not taken. Our palynological database from this unique valley is a pioneering step to lead to many other multiproxy studies. Moreover, for eco-tourism development of the area, it is a prerequisite to have a detailed palynoflora map with a complete inventory of all the plants before we loose.

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