VEGETATION AND CLIMATIC CHANGES IN NEPAL HIMALAYAS. I. VEGETATION AND CLIMATE IN NEPAL HIMALAYAS AS THE BASIS OF PALAEOECOLOGICAL STUDIES

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The ecological bases of palaeoecological studies are discussed to establish the method to infer the past vegetation and climate in the Himalayas. The most conspicuous characteristic of Himalayan vegetation is that different altitudinal zonation of vegetation types is found on southern and different exposures of the mountain slopes. The vegetation types on the northern slopes in West Nepal Himalayas are presented as an example. This contrast is observed from the Sub-Himalayas to the Higher Himalayas and also in the Himalayan sectors other than Nepal Himalayas. The complexity of pollen diagrams obtained from Himalayas is attributed to this feature. When Himalayan pollen diagram is interpreted, the topography of the area surrounding the sampling site, therefore should be considered with reference to the depositional environment, floral richness, the presence of entomophilous plants, identification of Quercus etc. to choose the key plant for the reconstruction of the past climate.

Key Words: Palaeoecology; Climatic Change; Nepal; Pollen; Altitudinal Vegetation Zone

INTRODUCTION

Fossil records can tell us the climatic changes which controlled the plant community structure in a given geological time. The pollen analysis is one of the most important means to get reliable information for the reconstruction of the past vegetation and climate, though it has some serious limitations such as predominance of anemophilous plants, difficulties of identification of plant species, problems of pollen preservation, interpretation of sedimentary environment etc. Pollen diagrams obtained from the Himalayan region have shown some complicated features derived from characteristics of the vegetation in the Himalayas. The common method to infer the past vegetation, hence, the past climate, from the palynological data has not yet been established in the Himalayas. The accurate ecological background based on the knowledge of present vegetation is required to evaluate the proportional changes of the constituent pollen genera and/or species as well as the pollen assemblages.
Vegetation of Nepal Himalayas

Many botanists have explored Nepal Himalayas during the last one hundred and eighty years, but most of them were taxonomists. Since the work of Wallich and Don, botanical researches were carried out mainly on the plants of Central and East Nepal and our new knowledge of flora and vegetation of Nepal is derived from botanical and anthropological explorations and from botanists included in mountaineering expeditions after reopening of Nepal for foreigners in 1949. The flora of Nepal is still not adequately known as a whole, though the situation has been improved after the compilation, An Enumeration. The vegetation has been poorly investigated as yet in Nepal Himalayas as well as in the other sectors of the Himalayas. Dobremez has explored Nepal since 1968 and compiled vegetation maps of Nepal. Stainton described forests of Nepal and compared them with Champion's classification of forests. Though the latter is very informative, the Himalayan vegetation requires more attention.

It is profoundly important to carry out palaeoecological studies that the vegetation differs on different aspects in the Himalayas. The vegetation of the south-facing slope is remarkably different from that of the north-facing slope in the Himalayas. At an altitude of 3300m in West Nepal, for instance, the north-facing slopes are covered by Abies spectabilis forest. This contrast is very different from the vegetation distribution with which one is familiar in Japan and the other humid areas without a conspicuous dry season. This contrast seems to be found from Sub-Himalayas (Siwalik Range) to the Higher Himalayas (the Great Himalayas). Though the Himalayan system extends over 2,400km with a variety of environments and vegetation types, it is likely that this is generally seen in the other sectors of the Himalayas.

Fig. 1 shows the Map of Nepal the sites (Fig. 1). Fig 2 shows the vertical distribution of the main forest types in the area north of Nepalganj, West Nepal. In Fig 2, the south-facing slopes of the Siwalik Range are covered with subtropical deciduous forest consisting of Anogeissus latifolia, Terminalia tomentosa with some evergreen species like Semecarpus anacardium, Buchanania latifolia, whereas its north-facing slopes are occupied by sal forests. Above these, oak forests including Quercus lanuginosa, Quercus incana, Rhododendron arboreum etc., are seen up to c. 2,400m on the southern slopes, but on the northern slopes there are completely different forests, temperate evergreen mixed broad-leaved forests in which lauraceous species like Litsea, Neolitsea Machilus, Dodecadenia occur along with Ilex Symplocos etc. On the south-facing slopes above the oak forest Quercus semecarpifolia forests are distributed from 2,300m to the timberline at an altitude of 3,800m, and then alpine meadow occurs with alpine juniper scrub which is distributed sparsely. On the north-facing slopes, Abies spectabilis forest is common above the temperate evergreen mixed broad-leaved forest and Picea smithiana is often mixed with Abies spectabilis. Betula utilis forests are seen at 3800 to 4000 above the coniferous zone and then alpine meadow occurs. Cedrus forms pure stands mostly on the south-facing slopes and
occurs mingled with *Picea smithiana* and *Pinus excelsa* on the north-facing slopes in Jumla area. *Quercus dilatata*, though not common, occurs at 2,300 to 2,900m forming pure stands on the south-facing slope and mixes with *Picea smithiana* on the north-facing slope.

There are different forest types at the same altitude on the south-facing and north-facing slopes as shown in Fig. 2. Generally the vegetation on the west-facing slopes is similar to that on the north-facing ones and that on the east-facing slopes to that on the south-facing ones. Oak forests of different kinds cover the southern slopes up to the timberline above the subtropical forest. It is also seen that the vegetation and flora become simpler westward in Nepal.

These facts should be given attention to reconstruct the past vegetation in the Himalayas.

**Mountain Climate in Nepal Himalayas**

The climatological records show that East Nepal receives more annual rainfall than West Nepal, but winter precipitation increases as one goes westward, and there is a second precipitation peak in winter which is attributed to snowfall. Jumla received an annual average rainfall of 888mm during 1971–1982. *Cedrus deodara*, one of representative western elements, is not distributed in the area with more rainfall than 1,000mm in Nepal.

We monitored temperature at an altitude of 3,150m on different exposures surrounding the Rara lake in West Nepal from June, 1983 to May, 1984 (Tabata et al., unpublished). The annual fluctuation of temperature is shown in Fig. 3.

The difference of monthly mean maximum temperatures between south-facing and north-facing slopes is 0.9 °C in July, but that is 6.5 °C in January. The
difference of 6.5 °C is comparable to that of 1,300m in altitude, when the temperature lapse rate is 0.5 °C/100m.

The difference between monthly mean maximum and minimum temperatures on the southern slope ranges from 8.7 °C in July to 12.9 °C in January, while that on the northern slopes is from 7.6 °C in July to 6.6 °C in January. These data show that the environmental conditions of the north-facing slope are milder than those of the south-facing slope. The north slope is generally more
shady and moist than the south slope except the mountain range just adjacent to the Tibetan plateau.

RECONSTRUCTION OF PAST VEGETATION AND CLIMATE

The pollen diagrams from the Himalayas are too complicated to infer the past vegetation and climate without an adequate knowledge of the present vegetation and flora. We are led to different vegetation reconstruction in some cases.

Depositional Conditions

The first thing to be considered is the depositional conditions, because the genera which can be used as the key genera in the case of lacustrine deposits cannot be useful in deposits of fluvial or fluvio-lacustrine nature. Especially the fluctuation of water plants concurrent with upward-fining sedimentary sequences might be attributed to very local environmental changes, like ponds and/or marshes formed by river meandering and their filling-up. Therefore, the values of water plants are not always connected with changes in precipitation. The interpretation of sedimentary environment, such as the work carried out by
Tandon et al\textsuperscript{28} in the Karewa Group, helps ecologists exclude local elements and infer regional vegetation.

The pollen contamination from older deposits is possible in the case of fluvo-lacustrine deposits, because the variation of carbon dates\textsuperscript{29-30} shows that wooden materials were derived from the older deposits. Though this is one of serious limitations in pollen analysis, it is necessary to try to exclude extrinsic pollen carefully when pollen diagrams are interpreted.

\textit{Topography}

The vegetation distribution is quite different on different exposures of the slope in Himalayas as mentioned above. It is not likely except in some cases that only one type of vegetation occupies all exposures, as long as the information on the present vegetation is valid. In this sense a single combination of genera dominating in a pollen zone would not mean reconstruction of the past vegetation. Therefore it is of importance to depict configuration of the area surrounding the sampling site where pollen might have derived from, when the past vegetation and climate are inferred. The reconstruction of vegetation should be done with reference to the depositional environment, the configuration and the present vegetation pattern, and then the key genera or species in pollen assemblage to infer the past climate should be decided.

\textit{Floral Richness or Species Diversity}

As the climate gets colder or drier, there is a tendency that species diversity is reduced. Floral richness is considered to be one of useful features to infer the past climate. When the Pleistocene vegetation in the Kathmandu Valley was reconstructed, this principle was adopted.\textsuperscript{30}

\textit{Oaks and Insect-Pollinated Plants}

\textit{Quercus} is one of the most important components of pollen assemblages in the Himalayas and it forms oak forests of different kinds upward above subtropical zone, up to the timberline on the southern slopes. In temperate zone the northern slopes are generally covered by temperate evergreen broad-leaved mixed forests mainly consisting of lauraceous trees and insect-pollinated plants whose pollen are absent or represented by very low values in the deposits, while the southern slopes have oak forests. The pollen diagram in this zone is represented significantly by \textit{Quercus} and the pollen assemblage is different from the real vegetation to a large extent. It is therefore difficult to infer the altitudinal zone of the past vegetation and climate without identification of oak species. The identification of oak species by scanning electron microscope (SEM) is recommended to infer the past climate. \textit{Quercus semecarpifolia} was discriminated from the other three species by SEM.\textsuperscript{31} It is also necessary to reconstruct the vegetation on the north-facing slopes from low values of insect-pollinated plants, though the relationship between the value in the pollen diagram and the forest size of the insect-pollinated plants
has not been studied in details. This idea was applied in our pollen analytical study.

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