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BOTANICAL PERSPECTIVE ON THE QUATERNARY

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ABSTRACT

The paper discusses the botanical perspective of the Quaternary research in the light of phenomenal and revolutionary progress ushered in by the oceanic research of deep sea cores and long uninterrupted terrestrial sequences. It is suggested that the botanical parameter should be equipped sufficiently and the dynamic nature of climatic requirements of plant species must be taken into consideration for past inference of environmental syndromes and for its overall applicability so that the consumer disciplines are not misled.

Key-words — Quaternary botany, Climatology.

सारांश

क्वाटरनरी का वनस्पतिक स्वरूप – विष्नु-मित्र

परिघटनात्मक एवं उग्र-परिवर्तनशील प्रगति को ध्यान में रखते हुए समुद्र के गहरे क्रोड़ों के अन्वेषण तथा लम्बे अविच्छिन्न पार्थिव अनुक्रमों द्वारा क्वाटरनरी युगीन अनुसन्धान का वनस्पतिक स्वरूप विवेचित किया गया है। यह प्रस्तावित किया गया है कि वनस्पतिक स्वरूप पर्याप्त सम्पन्न होना चाहिये तथा वातावरणीय संलक्षणों के अतीत-कालीन अनुमान एवं सम्पूर्ण उपयोगिता के लिए पादप जातियों की जलवायवी आवश्यकताओं की पविर्तनशील प्रकृति को भी ध्यान में रखना चाहिये ताकि अन्य उपभोक्ताओं को भ्रांति न हो सके।

INTRODUCTION

IN the investigation of the Quaternary the botanical parameter concerns itself with the building up of the history of flora, the reconstruction and alterations in the past forest communities in response to climatic, edaphic and biotic factors. Evidence, Time and Space, the three aspects of any historical approach are equally applicable to this parameter. In this respect the botanical parameter becomes interdependent upon the other sister and diverse disciplines and like them it has its own technicalities and limitations. The conclusions arrived at by this should be adjudged and assessed along with those of the others. The various kinds of biota among plants and animals do not behave alike in their response to climate (Coope, 1975, 1977) or in their rates of evolution and migration (Repenning, 1978). Much conflicting inference in literature is due to this fact. For instance, the climatic amelioration indicated by pollen at 13,000 years ago in England is shown to be earlier at 13,500 years BP by the coleopteran evidence (Coope & Pennington, 1977). The beetle evidence suggests a more wooded zone during the Fladbury interstadial and Late Weichselian deposits at Colney Health than the pollen evidence (Godwin, 1974, p. 36).

The unevenness between the biological and physical data on past climates suggests inadequacy of the data with these two parameters. How carefully the three components, Evidence, Time and Space, of the approach have been handled by these parameters and to what extent the consumer disciplines have been misled requires to be looked intq ? It is perhaps due to individual specialists or groups tending to regard their field as the corner stone for others which Butzer (1975) terms as Particularism.

REVOLUTIONARY FEATURES OF RECENT RESEARCH

Any change in the fundamental outlook concerning event sequences, geomorphology, geophysics, palaeoclimatology and biogeography has far reaching implications upon the botanical parameter for its interdependence upon these for Time and Space the two important components of historical approach. Its own independent contribution concerns Evidence.

The last decade particularly has witnessed phenomenal and revolutionary progress in Quaternary research comparable to that of the Plate-tectonic theory in the geological sciences (Bowen, 1979). Its influence upon our concepts and models that have reigned supreme in Quaternary research for several decades is staggering and salutary. The recent researches on the stable isotopes from deep sea cores first demonstrated by Emiliani in 1955 and on long uniterrupted terrestrial sequences such as Macedonia and the lake of Fuquene Bogota, Columbia (Van der Hammen *et al.*, 1971; Wijmstra, 1978), Lynch Crater, Queensland (Kershaw, 1975) and Lake Biwa, Japan (Horrie, 1976) have compelled us to reconsider, modify or abandon our concepts and models. A realisation has emerged concerning the inadequacy of the terrestrial deposits for the building up of the event sequences for the entire Quaternary. The attempts at synthesis of data (West & Haag, 1976) have given new directions to our ever fluctuating concepts and thought. The revolutionary features of recent research are summarised below from articles of Wright, Davis, Butzer, Mann published in Ecology of the Pleistocene (West & Haag, 1976) and from other literature.

The duration of the Pleistocene has now been pushed back to 2-3 million years. Against the four glacial periods separated by three long interglacials (the Alpine model), fresh evidence has been discovered of as many as 16 different glacials each of much longer duration about 50,000-1,00,000 years separated by interglacials which lasted for about 10-20,000 years (Kukla *et al.*, 1972). Against the earlier notion that the glacials were cool and wet, the fresh evidence reveals that they were long periods of cold and dry climate interrupted by shorter episodes of interglacials. Owing to discontinuities and lack of isotopic dates the terrestrial records for glacials have been found to be incomplete in contrast to the long uninterrupted ocean cores.

The discovery of glacial deposits in the Late Tertiary dated to 4-10 million years in the foot-hills of the St Elias Mountains of the Yukon in Antarctica cautions us against the use of climatic change as a criterion to define the Plio-Pleistocene boundary (Wright, 1976). It tends to support the traditional method of defining it by the extinction of certain taxa such as marine mollusca and foraminifera. The extinctions are suggested to be related to a major palaeomagnetic reversal (Hays, 1971).

Insects and microforams have been found to be climatically more sensitive than plants. Against the earlier belief that all glacial advances result from a climatic cause, a nonclimatic cause like surging has been found to be responsible for some of these (Wright, 1976). The migration of vegetational belts in response to climate earlier believed to have followed a linear movement of boundaries over vast distances was restricted to local areas. During this movement some members of vegetation were lost and some fresh ones acquired. Migration or invasion of individual tree taxon into a stable community was not necessarily due to a single climatic record. Gleason's individualistic concept (Wright, 1976) for the independent behaviour of constituents rather than their interdependent behaviour within a plant community even under relatively stable climate seems to be supported by modern progress. Solid evidence from biostratigraphy and geochronology suggesting regional trends and similarities is therefore highly essential for the palaeoclimatic inference than from incomplete and distorted pollen profiles.

Many modern analogues of environment of past vegetation do not exist today and our interpretation of past vegetation and environment are therefore conjectural, intuitional and based upon untenable and weak grounds. There is considerable lack of data on the biology, ecological requirements and competitive roles of plant species. Being brief and unstable episodes the interglacials did not allow the ecosystem equilibrium to be attained.

Recent research further shows that the climate changed suddenly and was of a great magnitude at the end of a Glacial (Dansgaard *et al.*, 1971; Denton, 1974; Davies, 1976). As many migrating species could not respond rapidly unusual communities developed which were invaded later (after hundreds of years) by competitively superior species. Temperatures rose rapidly between 15,000-10,000 years. The reversals observed between 15,000-10,000 yrs in Europe did not arise from shifts in the atmospheric circulation rather they were caused by the secondary affect of excessive break-up of shelf ice in the north Atlantic during general wastage of the ice sheet (Mercer, 1969).

The interglacial communities contained different spectrum of genera or the same genera in variable abundance in different interglacials. Apart from the brief span of the present interglacial, it has been found to be relatively an highly atypical event (Davies, 1976).

The assemblage floras, comprising the basis for floristic history and correlation, have been found to lack stratigraphical sophistication. They should not be considered to be controlled by climate. They should be distinguished by the first appearance or extinction of taxa. More interglacials existed than hitherto believed has also been discovered by palynologists. Three Eemian type interglacials are now recognized in northwest Europe (Turner, 1975; Kukla, 1977; West, 1977; Bowen, 1979). The stable isotopic analysis of deep ocean cores has shown greater complexity of Pleistocene than by the study of terrestrial deposits and their correlation (Bowen, 1978, 1979).

The study of past and present general atmospheric circulation, an independent parameter has produced dependable results for past climates against the uneven inference of past climates from the biological and physical data. The evaluation of the sea surface temperatures and salinities for January and July is an important step in this regard together with a similar attempt from the surface of the earth on continents. Encouraging success has been obtained for January 18,000 years BP (Climap, 1976).

In the history of biota, that of man particularly during the Quaternary, is of considerable importance in particular regard to the environmental background to his evolution, his socio-economic and behavioural patterns, the causes leading to his emergence as a land tiller and the modifications of his original pursuits of gathering, hunting and fishing into pastoralism and eventually his interaction with and conquest of natural phenomena. Provisional correlation of the archaeological data with the deep sea framework (de Lumley, 1975) have added substantially to our understanding. The history of man's exploitation and continued interference with nature since the Holocene altithermal between 8,000-4,000 years ago is giving glimpse of future scenario based on Quaternary data (Kellog, 1978; Vishnu-Mittre & Rajagopalan, 1979).

BOTANICAL APPRAISAL OF REVOLUTIONARY FEATURES

The history of Quaternary research is replete with fluctuation of concepts. Nonetheless the recent revolutionary change is far greater in its magnitude than before. It is certain that this ongoing process of change in concepts would continue with the pace of research. Conflicts and difference of opinion characterise the present progress as they did the earlier ones. In fact, the recent progress has expanded the earlier models of Quaternary research than creating new ones for a stratigraphical stable oxygen isotopes in the calcite tests of foraminifera from the oceanic deep cores. Of these Emilianis' model (Emiliani, 1955, 1966) was a model of sinusoidal temperature change but Broecker and van Donk (1970) realized it as saw-toothed in nature. All models are characterised by rigidity which influences thoughts and concepts so that the data are to be arranged into rigid pegeonholes the components of a model. Further they condition the interpretation of new data within the framework of a model, the flexibility of which is lost or never considered. This explains the fate of the earlier models and it is most likely that the expanded models provided by the oceanic record may be further expanded or replaced by the future research.

Whatever be the progressive state of research at present, some conflicts between the terrestrial and astronomic record are inexplicable. In Milankovitch chronology the interval based upon radiation, minimum at 25,000 years ago, is believed to be glacial but pollen and soil analyses determine it as an interstadial (the Formdalian in central and south-east America). The oceanographers consider here a lag of 7,000 years between the climatic impetus 25,000 yrs ago and the ocean response 18,000 yrs ago. The palaeoclimatic curve for two Indian Ocean cores shows that 41,000 yrs climatic cycle did lag behind variations in axial tilt by about 8,000 yrs but the 23,000 climatic cycle lagged systematically behind variations in procession (Imbrie & Imbrie, 1979). This interesting geological puzzle remains inexplicable (Wright,1979). Further about 10,000 yrs span for an interglacial as indicated by the radiation curves (Wright, 1979) or by the oceanic deep core studies is not supported by the counting of annual laminae in lake deposits which indicate that the last interglacial lasted for 15,000-30,000 yrs. Howsoever, revolutionary progress in the number and duration of glacials and interglacials has been brought out by studies of long and uninterrupted ocean cores, it must not be overlooked that these cores may have been affected by rates of sedimentation which are difficult to detect. The minor palaeomagnetic reversals observed in them have been found difficult to correlate with the palaeomagnetic sequence of dated volcanic rocks.

It is not that the ecosystem equilibrium was never attained because the interglacials were brief and unstable episodes. A plant community is like a living entity determined by its dominant genera and within it being continuously affected by the ecesis, expansion and decline of its subordinate individual members. It is only after the decline of the dominant members that the equilibrium is upset followed by a new equilibrium now dominated by some other members. The continuous dominance of some taxa is highly suggestive of attainment of equilibrium, howsoever, shortlived it may be. The former oak woods have been found to have continued for several thousand years even though the other constituents have varied both qualitatively and quantitatively. Each pollen zone (pollen assemblage) based upon codominance of taxa would indeed be suggestive of an ecosystem attaining equilibrium. The birch woods, pine woods, oak woods, and shola forest are all forest ecosystems, and the grassland is an ecosystem of open communities. Likewise there are desert ecosystem, freshwater and marine ecosystems, howsoever, shortlived their equilibrium may be.

It would be largely admitted that the modern analogues of past vegetation communities have not been discovered in spite of extensive studies of modern pollen spectra in various parts of the world. Comparable modern pollen spectra showing thorn forest with abundant *Artemisia* for the Rajasthan desert, showing oak woods with dominant *Artemisia* for the Kashmir Valley and for codominance of oaks with grasses for the Kathmandu Valley have so far not been found in South Asia. In the absence of these our reconstruction of past climates therefore has been indeed largely conjectural.

The migration of plant communities or taxa even in south Asia as indicated by the pollen diagrams constructed so far (Vishnu-Mittre, 1979a, 1979b) has been found over short distances as elsewhere. The oak woods during the later part of last glacial migrated into the Kathmandu Valley from the surrounding mountains and similar short distance postglacial shifts in plant communities occurred in the Kashmir Valley. Evidence has yet to be obtained of the extent of eastwest or westward migration of oak woods in the subtropical and temperate Himalaya. The typical thorn forest represented by *Calligonum polygonoides* did not move out of the Rajasthan desert into Gujarat or Uttar Pradesh and *Holoptelea integrifolia* did not move out of Gujarat into Rajasthan and Uttar Pradesh, during the Holocene times. Some members of dry deciduous forest from the north-east of Rajasthan or western Uttar Pradesh migrated north-east across Ganga River into Pratapgarh-Allahabad region (Vishnu-Mittre, 1979b). Likewise the shola forest at Ootacamund has been found to have migrated over short distances in local areas (Vishnu-Mittre & Gupta, 1971).

The short distance migration of plant communities and taxa in local areas seems to have emerged as a reality during the Quaternary. It has a far reaching implication particularly concerning the time and establishment of the present phytogeographical provinces. Were they established in late Tertiary times or during early Pleistocene times ? It raises an important question in Indian phytogeography concerning the time when the Himalayan element reached, if at all it did, the peninsular mountains. At least during the last 40,000 yrs no such evidence has been obtained.

However, the present broad patterns of vegetational development in different climatic regimes indeed have undergone evolution depending upon the time and advent of the migration of new taxa. The first immigration of Pine into the Himalaya is subsequent to *Cedrus*. Did the latter act as a coloniser of open vegetation prior to immigration of Pine ? Both *Abies* and *Picea* immigrated subsequent to that of Pine. The earliest evidence available reveals that they competed with each other and with the other conifers and their association with oaks was acquired later.

In the past riverain plant successions in Gujarat, indications of *Holoptelea integrifolia* along with *Acacia* as a member of the first seral stage in contrast to its present appearance in the third seral stage are observed in the two pollen diagrams (Vishnu-Mittre, 1969a).

Salvadora is a much later immigrant in Rajasthan desert nearly after 5,000 yrs ago. The presently recognized *Salvadora* and *Prosopis cineraria* climax community is a recent historical development. Seen in this historical perspective, the botanical parameter can provide considerable fresh and valuable information to the plant ecologist and sociologist about the changing patterns of vegetation and ecological behaviour of its individual constituents.

The alpine model of fourfold glaciation has equally influenced the geologists and geomorphologists in South Asia and the attempts of accommodating fresh data within the framework of the Alpine Model are continued. The botanical parameter has indicated that the situation has been more complex than considered hitherto (Vishnu-Mittre, 1973a). The so-called First Interglacial below the earliest undisputed massive glacial deposits referred to II Glaciation by de Terra and Paterson (1939) has been found on pollen analysis comprising three temperate and two cool phases with the third in the overlying glacial deposit. The three temperate phases each equivalent of an interglacial after the site names are Sedauian, Nichahomian and Botapathrian. The beginning of the Pleistocene was not coeval with the glacial phase (Vishnu-Mittre, 1973a). In the light of these indications the stratigraphical sophistication accompanied by intensive pollen analytical studies must be carried out.

At about 30,000 radiocarbon yrs the immigration and expansion of shrubby vegetation in grassland savannah at Ootacamund in the peninsular India and expansion at this time of Juniper community in the alpine steppe accompanied by a biogenic deposit in alpine Ladakh (Bhattacharya & Vishnu-Mittre, 1979); savanization at Ootacamund following the decline of Shola forest and the formation of meandre lakes in Rajasthan and southern Uttar Pradesh about 11,000 radiocarbon yrs ago; formation of the black cotton soil, activisation of the sand dunes in Rajasthan, flooding of the coastal regions in Bengal and Gujarat, shifts in vegetational belts (oak woods replacing chirpines in west Himalaya), immigration of *Prosopis cinerariea* across the Ganga Yamuna Doab, migration of the *Holoptelea* community in the vicinity of the Nal Lake and of the mangrove communities nearly 39 km north of the Sunderbans in Bengal between 7,000-5,000 radiocarbon yrs and the eustatic sea rise between 6,000-5,000 radiocarbon yrs are the interesting and significant televerberations over long distances in South Asia. The submergence in the Bengal basin dated between 5,000-3,500 radiocarbon yrs and submerged forests in the Bombay docks may be contemporary. The pre-7,000 yrs marine influence at the Nal Lake near Ahmedabad is equally interesting. The factors responsible for these might well be climatic and tectonic or others working together or in isolation. Indeed, there have been environmental syndromes causing these televerberations.

The lack of corresponding analogues of past environments and the highly inadequate knowledge of the climatic requirements of modern floristics have created stumbling blocks in our attempts to build up the past syndromes. The efforts towards inference from fossil pollen of the habitat of individual taxa or climatic inference from the shifts in recognizable phytogeographical groups (Rossignolstrick & Duzer, 1979), appear to be based upon highly insufficient base data. Have the habitats of the plants remained static throughout the Quaternary ? Recent progress has shown how misleading has been our reliance upon the insufficient but fixed base data to interpret the past environmental syndromes. The successive and rapid fluctuations of several glacial and interglacial episodes during the Quaternary must have brought about evolution in the preference of plants for the changing habitat (discussed ahead).

The inference of past climates is usually expressed in the averages of temperature and precipitation in comparison to those of the present. This implies that these are considered static. The range in both temperature and precipitation has the flexibility to accommodate any variables that the evolution may bring about. It must have been contracting or expanding in keeping with the alterations in the climatic requirements of a plant species. The precipitation rhythm for *Calligonum polygonoides* in western India ranges from 100-140 mm and the gross average would be 120 mm. Was its average or the minimum or maximum precipitation responsible for its ecesis, expansion or decline during the Holocene in Rajasthan desert ? Or was the edaphic factor responsible because the species is psammophytic ? Or else both the factors along with the range in temperature and the number of dry months in a year worked in conjunction with one another.

How uncertain we are on the factors determining the migration, expansion and decline of the present day taxa ? This uncertainty increases as we go far back in time. Through such uncertain data the extent the non-botanist consumer disciplines have been misled must be realised. The model of Holocene precipitation changes constructed by Bryson (1975) upon the insecure data from the Rajasthan pollen profiles (Singh *et al.*, 1974) is unsupported by the plant ecological studies in Rajasthan (Gaussen *et al.*, 1972; Meher-Homji, 1977; Vishnu-Mittre, 1974a, 1974b, 1979a).

It is important to consider together the biological and the astronomical data in the light of models constructed of general circulation patterns of the atmosphere (CLIMAP, 1976) placing more reliance upon the guidelines of the independent variables of the atmosphere and of the astronomical record for the inference of palaeoclimates. These variables are independent of the ice-age earth's oceanography, geomorphology and biogeography. Any inference of the past climate must be tested on the touchstone of these independent variables before it is accepted. Our proceeding backwards from the fixed points insufficiently known today has misled us. Butzer's Trewartha scheme (Butzer, 1976) is an encouraging blend of the biological and astronomical data.

Lytle Webb's cautionary note that the palaeoclimatic interpretations of pollen from archaeological samples and resulting chronologic interpretations should be considered tentative and with great care until our understanding is increased (Webb, 1978) ought to be taken seriously by those engaged in pollen analysis of archaeological samples.

IS BOTANICAL PARAMETER SUFFICIENTLY EQUIPPED ?

The botanical parameter is largely based upon the morphology of the plant remains and their qualitative and quantitative evaluation with reference to the modern plant species. Very often the modern comparable data is based upon a single or a few plant specimens in contrast to the subfossil data derived from populations. Not only the study of populations is not undertaken but geographical variations are also ignored. Recent research has drawn attention to the importance of these (Thorpe, 1976; Saxena & Vishnu-Mittre, 1977; Birks, 1978).

The identity in quite a few cases is no more than provisional, tentative or unqualified. Comparative studies are often not extended to modern highly polymorphic aggregates of a species occurring upon different habitats to any of which fossil material is impossible to refer to as in case of *Thallictrum minus* (Godwin, 1974). Fossil seeds or pollen may be smaller than modern ones as in *Arabis stricta* from Alleröd or larger as in *Rorippa microphyllum* (Godwin, 1974).

The incapacity in several cases of separating modern ecospecies from their pollen or seed; the persistent occupation of a site by a species in the wake of change in local ecological conditions and over-all climate (as in *Saxifraga*); the plasticity of a species occupying varied environments as of *Hippophae rhamonoides* from Atlantic Norway across European coasts, central Europe to temperate Asia and Himalaya; the differential behaviour of taxa in the past, for instance elm increasing before oak or elsewhere after it and similarly that of *Carpinus*, *Corylus*; large excess of four porate over 5 porate pollen of *Alnus* in the past are some interesting examples from among quite a few which can be picked up from literature (Godwin, 1974). Such instances are usually explained through circular arguments and assumptions based upon inadequate knowledge of the behaviour and ecological requirements of the modern taxa.

DYNAMIC NATURE OF CLIMATIC REQUIREMENTS OF PLANTS

It would be highly unreasonable to believe that the past plants had not responded to the quick and repeated alterations in environments. If they had, then their ecological requirements must also have evolved. The morphographic change in subfossil pollen, seed, etc. is usually not discernible and where detected is not considered because all our comparative data base is the extant species and their present day climatic requirements. The use of this data base to infer past climates implies that the climatic requirements of plants are considered static and unchangeable during the last 2-3 million years of the Quaternary. It is owing to this that the pollen or seeds of thermophillous species found in glacial deposits or of low land plants at high altitude or vice-versa are considered derived. The dynamic process of evolution especially in regard to the climatic requirements of plants is overlooked.

The Lower Karewa leaf impressions referred to Lithozone 4 of Interglacial by de Terra and Paterson (1939) reveal a mixture of plant species distributed today from low to alpine altitude which then was much lower. Further, the ecological heterogeneity is observed in *Betula utilis* and *B. alnoides*, *Acer oblongum* and *A. pentapomicum*, *Trapa natans* and *T. bispinosa*, etc. the remains of which are found together (Vishnu-Mittre, 1965). Circular arguments may be pressed here to former occurrence of varieties of habitats or the identifications may be questioned. But the botanical evidence seen in the background of geological evidence reveals that the present day ecological diversity and altitudinal delimitations of these taxa has evolved after the mountains were uplifted during or after the II Glaciation.

The formation of unusual communities in the past interglacials with different spectrum of genera or the same genera in varying proportions in contrast to the extant comparable though not identical plant communities may be ascribed to their ecological requirements different from their supposed modern counterparts. The cases of strange and different behaviour during ecesis, expansion and decline of past individual taxa are the other indications supporting the thesis that the climatic requirements have undergone change during the Quaternary.

PALAEOETHNOLOGY AND LAND USE

For nearly 99% of man's evolution he has been a gatherer and hunter and has led mobile existence. In the technology of food acquisition the human food gatherers and the modern chimpanzees are very much alike feeding on fruits, leaves, blossoms, seeds, stems, bark, resin, honey, insects, eggs and meat (Mann, 1972). Besides several different wild plants, 15 species of mammals are known to be caught and eaten (Teleki, 1973). Besides, the chimpanzees are known to eat galls, termites, ants, grubs and caterpillars. Most modern human gatherer hunter societies except in temperate and arctic regions subsist primarily on vegetable foods and hunting providing a smaller though constant supply of meat (Mann, 1976). Likewise enormous information has been gathered on wild plants used for various purposes by primitive human communities existing today in various parts of the world. Against this, meagre information has been brought out concerning early cultivars and their progenitors from the Quaternary by the botanical parameter (Vishnu-Mittre, 1968, p. 88). Some valuable information from the protohistoric and early historic periods indeed of the consumption of some wild plants has become available from the examination of stomach contents or faeces of man (Callen, 1963; Bryant, 1974). Seeds of wild plants are sometimes found with or without remains of crops suggesting intentional gathering for multifarious uses (Helbaek, 1963; Savithri, 1976; Vishnu-Mittre, 1978).

The development of gatherer-hunter into a pastoralist and husbandsman and the emergence of peasantry in human history continue to be conjectural (Reed, 1977; Vishnu-Mittre & Tewari, 1978). The Iversenian hypothesis (Iversen, 1941) has indeed given a new dimension to the interpretation of early episodes of shifting cultivation from the pollen diagrams but its applicability remains to be demonstrated outside Europe particularly in regions (Africa & South Asia) where shifting cultivation has continued till the present day. Pollen evidence has failed in the Middle East, the centre of domestication of crops (van Zeist, 1967).

The most serious limitation observed is in the overlap of pollen of both wild and cultivated grasses (Hamilton, 1972; Vishnu-Mittre, 1973b). Whereas Hamilton attributes the cereal type fossil pollen to disturbed habitat, Vishnu-Mittre (1976) sees in it the indication of former occurrence and cultivation of non-conventional cultivars such as *Coix lacryma-jobi* on historical evidence of its large scale cultivation in the immediate past and its restricted cultivation by some tribals today. The recovery of fairly large-sized cereal type pollen from the last glacial and later deposits from Iran and South Asia prior to commencement of farming (van Zeist, 1976; Vishnu-Mittre, 1979a, 1979b) further complicates the situation. The pollen of millets, usually associated today with shifting cultivation, is much smaller than the usually accepted conventional cereal pollen size (40-50 μm or above) and its distinction from that of other wild grasses is not possible by the usual means adopted.

The shifting cultivation in an area is usually of 15-30 yrs duration as observed in most parts of the world today but against this a cycle of clearance, occupation and regeneration at a site has been dated by radiocarbon from 150-300 yrs (Godwin, 1974, p. 468). Turner's three dimensional pollen diagrams (Turner, 1969) enable not only help in locating the local and regional patterns of clearances affected at different times but also suggest phases of development from shifting to settled agriculture.

The evidence of charcoal remains undecisive whether it was natural or man-made. However, circular arguments are advanced for the assumption that it was man-made hence indicative of the slash and burn practice. Every slash and burn practice may not necessarily indicate shifting cultivation. In the desert of Rajasthan continuous records of charcoal dating from 10,000 radiocarbon yrs and waning and disappearing after 3,000 yrs could have another and perhaps more appealing interpretation than that of shifting cultivation. The regular annual burning of grasslands is a usual practice in desert areas of the world to allow growth of tender grasses to be grazed by the domesticated animals. The stiff-stemmed and stiff-leaved perennial grasses are usually not browsed because their piercing awns and burrs would injure the delicate mucus membranes of sheep and goat. Here the slash and burn practice is indicative of animal husbandry rather than of plant husbandry.

Pollen evidence has indeed to be stretched through circular arguments to arrive at a particular inference for which there may be more than one alternatives. The overlap of cereal type vs. wild grass pollen is also suggestive of the immigration into the area of such wild grasses which produce pollen equal to or larger than the usual cereal type and provides a means towards the history of grasses.

Most unequivocal evidence for palaeoethnobotany comes from seeds, fruits or caryopses of cereals and other food, oil and fibre crops and the culture plants associated with them. Enormous information has been gathered from their remains in archaeological context from the various centres of domestication recognised by cytogeneticists. Supported by radiocarbon dates and archaeological context, the information on the origin of crops and their subsequent diffusion from the centres of domestication is most valued by archaeologists and anthropologists, and by the agriculturists for the reconnaisance it has brought to light with cytogenetics also (Savithri & Vishnu-Mittre, 1979). In this respect some renowned cytogeneticists and agriculturists such as N. I. Vavilov, G. L. Stebbins. J. R. Harlan, E. Anderson, P. C. Mangelsdorf, G.W. Beadle, T.T. Chang, Charles B. Heiser, Sir Joseph Hutchinson, C.P. Darlington, Janaki-Ammal and the others have evinced keen interest and involved themselves in archaeobotanical research (Savithri & Vishnu-Mittre, 1979; Reed, 1977).

THE PALAEOBOTANIST

The archaeobotanical or palaeoethnobotanical researches have largely confirmed the recognized centres of origin for the cultivated plants though the boundaries for some of them have been found formerly more extensive than recognised today. The Fertile Crescent extended to Greece in southern Europe (Jarman, 1972) and to western part of the Indian subcontinent for barley and wheat (Jarrige, 1979).

Rice has posed more difficulties for its remains by ordinary means of identification cannot be referred to wild or cultivated strain. The oldest Thailand records of rice from Non Nok Tha and the Banyan Valley Cave from south-east Asia, being of wild strain (Chang, 1976), the pre-7,000 yrs records from South Asia have recently been determined through scan microscopy to comprise wild and cultivated rice (Vishnu-Mittre, Savithri & Sharma, 1979). The gap has now been filled and the Hindustan Centre in South Asia has been proved to be a centre for the domestication of rice.

The oldest records so far known of some millets such as *Sorghum*, *Pennisetum*, and more or less contemporary of *Eleusine coracana*, the cytogenetically established African crops, in South Asia dating from about 3,600 yrs ago (Vishnu-Mittre, 1977) and likewise the oldest records of African *Lagenaria cicineraria* in Mexico dating from 9,000 yrs (Pickersgill & Heiser, 1977) have indeed raised eyebrows. Their spread from Africa into South Asia and into the New World may have taken place at much earlier date (Pickersgill & Heiser, 1977). The botanical parameter has indeed failed so far to bring out the history of root crops.

REFERENCES

Bhattacharya, A. & Vishnu-Mittre (1979). Biological radiocarbon evidence for fluctuations in Weichselian Glaciation in Ladakh. *Abstract Symp. on Evolutionary Botany & Biostratigraphy, Calcutta*: 26.

Birks, H. & John, B. (1978). Geographical variation of *Picea abies* (L) Karsten pollen in Europe. *Grana*, **17** (3): 149-160.

Bowen, D. Q. (1978). *Quaternary Geology: A Stratigraphic Framework for Multidisciplinary Work*. Pergamon Press.

Bowen, D. Q. (1979). Geological perspective on the Quaternary. *Progress in Physical Geogr.*, **3** (2): 167-186.

Butzer, K. W. (1975). Geological and ecological perspectives on the Middle Pleistocene, pp. 857-874 in Butzer, K. W. & Issac, G. Ll. (Eds) — *After the Australopithecines*. The Hague, Mouton.

Butzer, K. W. (1976). Pleistocene climates. *Geosci. Man*, **13**: 27-44.

Broecker & van Donk, J. (1970). Insolation changes, ice volumes and O^{18} record in deep sea cores. *Geophys. space phys.*, **8**: 169-198.

Bryant, V. M. Jr. (1974). Prehistoric diets in south-west Texas: The Coprolite evidence. *Amer. Antiquity*, **39**: 408-470.

Bryson, Reid A. (1975). The lessons of climatic history. *Environmental Conserv.*, **2**: 163-170.

Callen, E. O. (1963). Diet as revealed by Coprolites, pp. 186-184 in D. Bothwell & E. Higgs (Eds)— *Science in Archaeology*. New York.

Chang, T. T. (1976). The origin, evolution, cultivation, dissemination and diversification of Asian and African rices. *Euphytica*, **25**: 425-441.

Climap (1976). The surface of Ice Age Earth. *Science*, **191**: 1131-1137.

Coope, G. R. (1975). Climatic fluctuations in north-west Europe since the last Interglacial, indicated by fossil assemblages of Coleoptera, in Wrigh, A. E. & Moseley, F. (Eds)— *Ice Ages: Ancient & Modern. Geol. Jour.* (*Special issue*), **6**: 153-68.

Coope, G. R. (1977). Fossil coleopteran assemblages as sensitive indicators of climatic changes during the Devensian (Last) Cold Stage. *Phil. Trans. R. Soc.*, **B280**: 313-40.

Coope, G. R. & Pennington, W. (1977). The Windermere Interstadial of the Late Devensian. *Phil. Trans. R. Soc.*, **B280**: 337-339.

Dansgaard, W. S., Johnsen, S. J., Clauden, H. B. & Langway, C. C. (1971). Climatic record revealed by the Camp Century Ice Core, pp. 37-56 in Turekian, K. K. (Ed.)— *The Late Cenozoic Glacial Ages*. Yale Univ. Press.

Davies, M. B. (1976). Pleistocene biogeography of temperate deciduous forests. *Geosci. Man*, **13**: 13-26.

de Lumley, H. (1975). Cultural evolution in France in its palaeoecological setting during the Middle Pleistocene, pp. 745-807 in Butzer, K. W. & Issac, G. Ll. (Eds)— *After the Australopithecines*. The Hague, Mouton.

Denton, G. H. (1974). Quaternary glaciation of the White River Valley, Alaska, with a regional synthesis for the northern St Elias Mountains, Alaska and Yukon territories. *Geol. Soc. Amer. Bull.*, **5** (85): 871-892.

de Terra, H. & Paterson, T. T. (1939). *Studies on the Ice-Age in India and Associated Human Cultures*. Washington.

Emiliani, C. (1955). Pleistocene temperatures. *Jour. Geol.*, **63**: 538-578.

Emiliani, C. (1966). Palaeotemperature analysis of Caribbean cores and a generalized temperature curve for the last 4,25,000 years. *Jour. Geol.*, **74**: 109-126.

Gaussen, H., Meher-Homji, V. M., Legris, P., Blasco, F., Delacourt, A., Gupta, R. K. &

TROY, J. P. (1972). Notice de la Rajasthan. *Trav. Sci. Tech. l' Inst. Francais de Pondicherry*, Ser. no. **12**: 1-154.

GODWIN SIR HARRY (1974). *History of British Flora*. 2nd Edn., Cambridge Univ. Press.

HAMILTON, A. C. (1972). The interpretation of pollen diagrams from Highland Uganda. *Palaeoecology of Africa and of the Surrounding Islands and Antarctica*, **7**: 45-149.

HAYS, J. D. (1971). Faunal extinctions and reversals of the earth magnetic field. *Geol. Sci. Amer. Bull.*, **5** (82): 2433-2477.

HELBAEK, H. (1963). Palaeoethnobotany, in D. Bothwell & E. Higgs (Eds)— *Science and Archaeology*. New York.

HORRIE, S. (1976). *Palaeolimnology of Lake Biwa and the Japanese Pleistocene*. Vol. **4**. 1-836 pp.

IVERSEN, JOHN (1941). Land occupation in Denmark's Stone Age. *Danm. Geol. Unders. II Rekke*, **66**: 1-68.

IMBRIE, JOHN & IMBRIE, K. P. (1979). *Ice Age Solving Mystery. N.J.* Enuslow, Short Hills.

JARRIGE, J. F. (1979). Excavations at Mehergarh (Baluchistan): Their significance for understanding the background of Harappan civilization. *Proc. Seminar Harappan Civilization, Srinagar, Kashmir* (in press).

JARMAN, H. N. (1972). The origin of wheat and barley cultivation, pp. 15-26 in E. S. Higgs (Ed.)— *Papers in Economic Prehistory*. Cambridge. Univ. Press.

KELLOG, W. W. (1978). Is mankind warming the earth ? *Bull. Amer. Scient.*, February: 11-19.

KERSHAW, A. P. (1975). Late Quaternary vegetation and climate in northern Australia. *Quat. Studies R. Soc., New Zealand*: 181-188.

KUKLA, G. J. (1977). Pleistocene land sea correlations. *Earth Sci. Rev.*, **13**: 307-374.

KUKLA, G. J., MATHEWS, R. K., & MITCHELL, J. M. (1972). The present interglacial: How and when will it end. *Quat. Res.*, **2**: 261-265.

MANN, ALAN (1972). Hominid and cultural origins. *Man*, **5** (7): 379-386.

MANN, ALAN (1976). Ecology of early man in the Old World. *Geosci. Man*, **13**: 61-70.

MEHER-HOMJI, V. M. (1977). History of the dry deciduous forests of western and central India, pp. 109-126 in Agrawal, D. P. & Pande, B. M. (Eds)— *Ecology and Archaeology of Western India*. New Delhi.

MERCER, J. H. (1969). The alleröd oscillation: A European climatic anomaly. *Arctic Alpine Res.*, **5** (1): 227-234.

PICKERSGILL, B. & HEISER, CHARLES, B. JR. (1977). Origins and distribution of plants domesticated in the New World tropics, pp. 803-835 in Charles A. Reed (Ed.)— *Origins of Agriculture*. The Hague.

REED, CHARLES A. (1977). *Origins of Agriculture*. The Hague.

REPENNING, C. A. (1978). Faunal exchanges between Siberia and North America — Evidence from Quaternary land mammal remains in Siberia, Alaska and the Yukon Territory. *Amer. Quat. Assoc. (Abstracts), Biennial Meet., Edmonton, Alberta*: 56-77.

ROSSIGNOL-STRICK, M. & DUZER, D. (1979). West African vegetation and climate since 22,500 BP from Deep-sea core palynology. *Pollen spore*, **21** (1 & 2): 105-134.

SAXENA, A. K. & VISHNU-MITTRE (1977). Pollen morphology of *Mimosa rubicaulis* Lamk. and *Mimosa hamata* Willd. *Geophytology*, **7** (2): 217-221.

SAVITHRI, R. (1976). Studies in archaeobotany together with its bearing upon socio-economy and environment of Indian protohistoric cultures. *Ph.D. Thesis*. Lucknow University, India.

SAVITHRI, R. & VISHNU-MITTRE (1979). Reconnaisance between cytogenetics and archaeobotany. *Proc. Symp. Evolution. Botany & Biostratigr., Calcutta*: 9.

SINGH, G., JOSHI, R. D., CHOPRA, S. K. & SINGH, A. B. (1974). Late Quaternary history of vegetation and climate of the Rajasthan desert, India. *Phil. Trans. R. Soc.*, **B267**: 467-501.

TELEKI, GEZA (1973). The omnivorous chimpanzees. *Scient. Amer.*, **5** (228): 32-42.

THORPE, R. S. (1976). Biometric analysis of geographic variations and racial affinities. *Biol. Rev.*, **51**: 407-452.

TURNER, C. (1975). The correlation and duration of Middle Pleistocene interglacial periods in northwest Europe, pp. 259-308 in K. W. Butzer & G. Ll. Issac (Eds)— *After the Australopithecines*. The Hague.

TURNER, J. (1969). Post-Neolithic disturbance of British vegetation, pp. 97-116 in D. Walker & R. G. West (Eds)— *Studies in the Vegetational History of the British Isles*. Cambridge Univ. Press.

VAN DER HAMMEN, T., WIJMSTRA, T. A. & LAGWIJN, W. H. (1971). The florecord of the Late Cenozoic Europe, pp. 391-424 in K. K. Turekian (Ed.)— *The Late Cenozoic Glacial Ages*. New Haven, Yale Univ. Press.

VAN ZEIST, W. (1967). Late Quaternary vegetational history of western Iran. *Rev. Palaeobot. Palynol.*, **2**: 301-311.

VISHNU-MITTRE (1965). Floristic and ecological reconsiderations of the Pleistocene plant impressions from Kashmir. *Palaeobotanist*, **15** (1 & 2): 157-175.

VISHNU-MITTRE (1968). Protohistoric records of agriculture in India. *Trans. Bose Res. Inst.*, **31** (3): 87-106.

VISHNU-MITTRE (1973a). The Lower Karewas, pp. 160-167 in: *Palynology of Pleistocene & Holocene. Proc. III Internat. Palynol. Conf., Novosibirsk, U.S.S.R.*, 1971.

VISHNU-MITTRE (1973b). Cereal vs. non-cereal grass pollen and the inference of past agriculture, pp. 24-32 in: *Pollen & Spores Morphology of the Recent Plants. Proc. III Internat. Palynol. Conf., Novosibirsk*, 1971.

VISHNU-MITTRE (1974a). Plant remains and climate from the Late Harappan and other chalcolithic cultures of India — A study in inter-relationships. *Geophytology*, **4** (1): 46-53.

VISHNU-MITTRE (1974b). Late Quaternary palaeobotany-palynology in India — An Appraisement, pp. 16-51 in Vishnu-Mittre (Ed.)— *Late Quaternary Vegetational Developments in Extra-European Areas*. Birbal Sahni Institute of Palaeobotany, Lucknow, India.

VISHNU-MITTRE (1976). Possible significance of pre-Neolithic cereal type pollen in south Asia. *Proc. IV Internat. Palynol. Conf., Lucknow (Abstract)*.

VISHNU-MITTRE (1977). Changing economy in ancient India, pp. 569-588 in R. Charles A. (Ed.)— *Origins of Agriculture*. The Hague.

VISHNU-MITTRE (1978). Origins and history of agriculture in the Indian subcontinent. *Jour. Human Evol.*, **7**: 31-36.

VISHNU-MITTRE (1979a). Environment of early man in northwest India: Palaeobotanical evidence, pp. 20-65 in S. R. K. Chopra (Ed.)— *Man in Northwest India*. New Delhi.

VISHNU-MITTRE (1979b). The environment of early man in the Upper Gangetic Plain. *Proc. Seminar Recent Trends in the Study of Plant Structure* (*Abstract*), *Allahabad*: 58-59.

VISHNU-MITTRE & GUPTA, H. P. (1971). The origin of shola forest in the Nilgiris. *Palaeobotanist*, **19** (1): 110-114.

VISHNU-MITTRE & RAJAGOPALAN, G. (1979). Socio-economic development — Historical perspective and future implications. *Sci. Soc.*, **2** (4): 135-148.

VISHNU-MITTRE, SAVITHRI, R. & SHARMA, G. R. (1979). World's earliest record of rice from district Allahabad. *Proc. Seminar Recent Trends in the Study of Plant Structure* (*Abstract*): 59.

VISHNU-MITTRE & TEWARI, P. K. (1978). Origin of peasantry in the Indian subcontinent. *The East. Anthropol.*, **31** (3): 217-227.

WEBB, JAMES LYTLE (1978). Pollen analysis in south-western archaeology, pp. 13-28 in P. Grebinger (Ed.)— *Discovering past behaviour. Experiments in the Archaeology of the American Southwest*. New York.

WEST, R. G. & HAAG, W. G. (1976). Ecology of the Pleistocene: A symposium. *Geosci. Man*, **13**: 1-76.

WEST, R. G. (1977). East Anglia, in: *X INQUA Congr. Guide Book*, Bowen D. Q. (Ed.) — *Geol. Abstracts*. Norwich.

WIJMSTRA, T. A. (1978). Palaeobotany and climatic change, pp. 25-45 in J. Gribbin (Ed.)— *Climatic Change*. Cambridge.

WRIGHT, H. E. JR. (1976). Pleistocene ecology — Some current problems. *Geosci. Man*, **13**: 1-12.

WRIGHT, H. E. JR. (1979). A geological puzzle. *Science*, **204**: 751-753.