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A major change at ca. 3500 years BP in the vegetation of the Western Ghats in North Kanara, Karnataka

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The palynological study of a marine core off Karwar, Karnataka, near the estuary of the Kalinadi river, reveals a major vegetational change, at ca. 3500 years BP. This is of significance in tracing Late Holocene evolution of the vegetation of the Western Ghats in North Kanara. This change is represented by a well-marked fall in the quantity of pollen from both evergreen and deciduous forests accompanied by a rise in the number of savanna pollen. The cause of such a noteworthy break may be linked to reduction of humid conditions.

THE Western Ghats which form a relatively narrow chain of mountains along the west coast of Peninsular India are now covered by a more or less continuous strip of forests. Some of these forests are primary formations such as the famous Silent Valley or the Bagwati Reserve forest which are very well preserved. The present vegetation is mostly reduced to disturbed evergreen forests or even to secondary and degraded stages.

The palynological study of a marine core taken off Karwar, North Kanara, Karnataka, has enabled reconstruction of the evolution of the inland vegetation in this region. The core, SK 27 B/8, 4. 8 m long, was collected by *R. V. Sagar Kanya* in the inner part of the continental shelf, at a depth of 22 m (14° 49'.43 N × 73° 59'.37), off the wide estuary of the Kalinadi river. This is one of the most important rivers flowing from the Western Ghats to the Arabian Sea. Its drainage basin, the largest in the central part of the Western Ghats, is the result of captures extending the basin eastwards. Thus the Kalinadi river drains not only the Western Ghats but also a part of the western side of the Karnataka Plateau (Figure 1). The sediments deposited in the cored site are directly supplied by the Kalinadi river; hence their pollen and spore content, for the major part, are directly linked to the vegetation covering its drainage basin.

This drainage basin now extends into several bioclimatic zones mainly related to the monsoon regime and the topography[1], marked by the great western escarpment of the Ghats and further east, by the Karnataka Plateau. The average elevation ranges from 600 to 800 m, the highest point, near Londa, culminating at 1025 m. The lower part of the Kalinadi valley lies deep in the plateau bordered by steep slopes.

The present vegetation of the Kalinadi catchment basin[2,3] mostly consists (Figure 2) of disturbed forests,

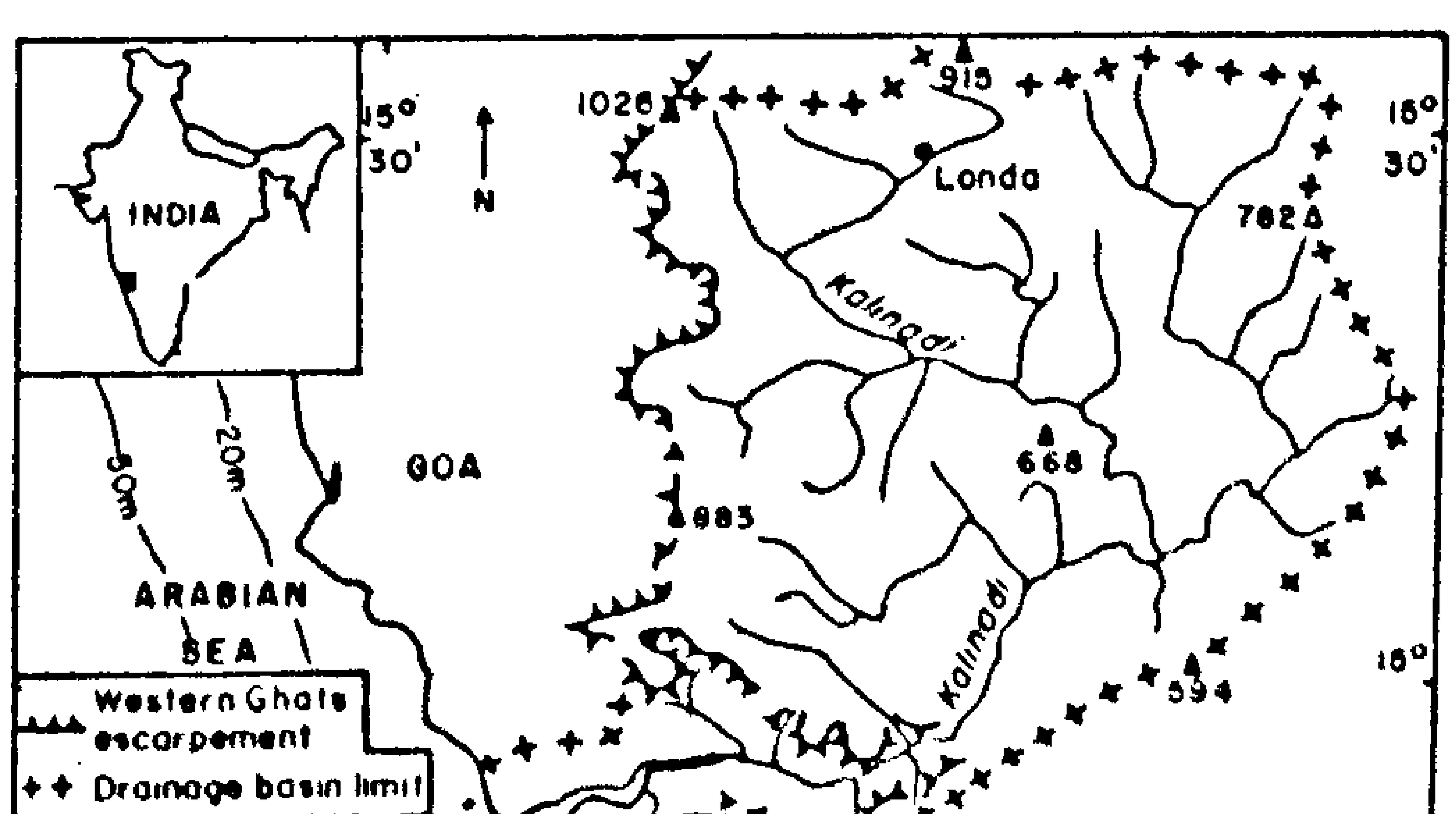

Figure 1. Drainage basin of Kalinadi river and location of the core SK 27 B/8.

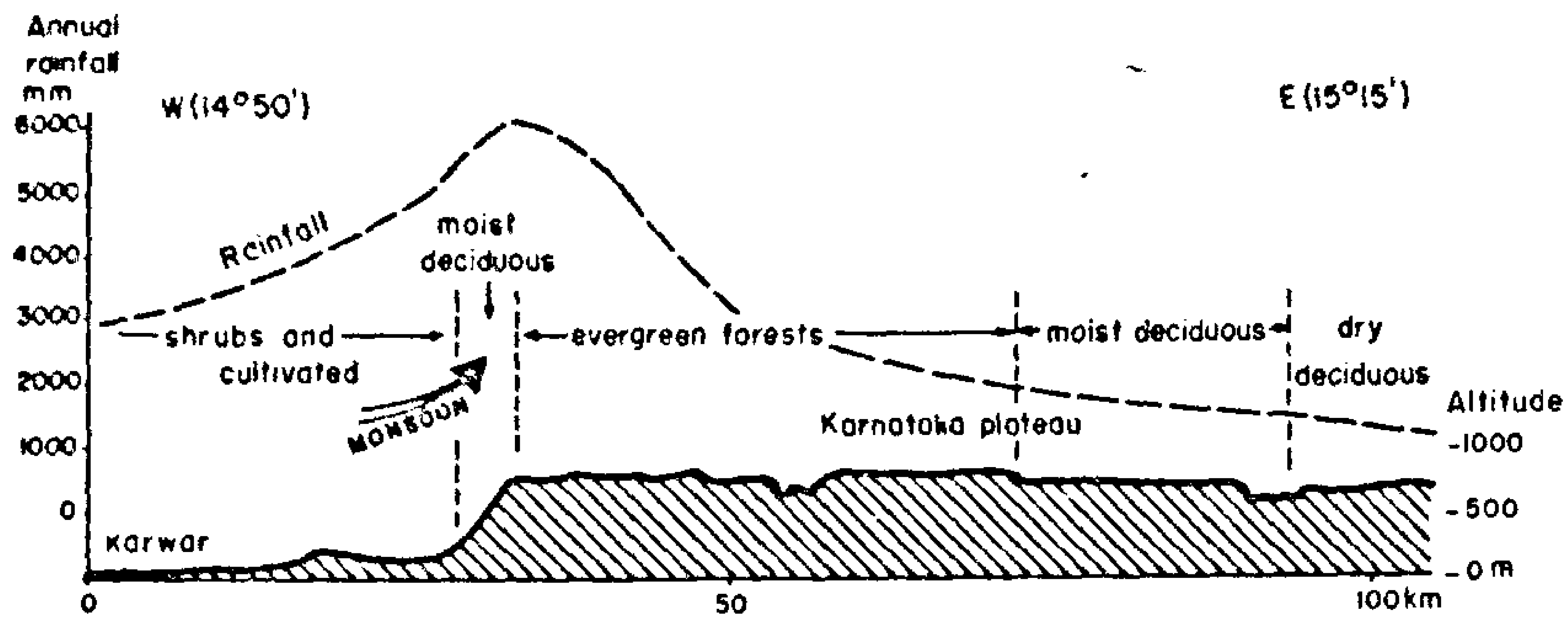

Figure 2. Transect along the Kalinadi drainage basin: relief, rainfall and forest formations.

divided into several types according to the bioclimatic zones. There are secondary and degraded stages of evergreen and semi-evergreen forests in the western part of the Karnataka Plateau. The medium elevation type (*Memecylon umbellatum–Syzygium cumini–Actinodaphne angustifolia*) occurs on the higher region of the Plateau, in the north. Moist deciduous forests (*Lagerstroemia microcarpa–Tectona grandis–Dillenia pentagyna* type) are found towards the east and beyond, where the rainfall becomes still lower, and dry deciduous forests (*Anogeissus latifolia–Tectona grandis–Terminalia alata* type) make their appearance. The slopes bordering the low Kalinadi valley and the western escarpment are covered by woodlands and savanna woodlands of moist deciduous forests. In the coastal region, thickets, tree savannas and scattered shrubs are mixed with cultivated lands in the best areas.

^{14}C datings

Four samples have been analysed:
- 130–135 cm: 2220 ± 40 years BP (Gif-8168)
- 140–145 cm: 2020 ± 40 years BP (Gif-8169)
- 300–305 cm: 3510 ± 60 years BP (Gif-8170)
- 442–450 cm: 4325 ± 65 years BP (Gif-8167)

Hence, the core 27B/8 may be considered as reprentative of the last five millennia.

Pollen and spores diagram

Only the continental components have been considered to construct the pollen and spore diagram (Figure 3), leaving out marine and littoral microfossils. The diagram is split into two distinct sequences:

Sequence 1 : from ca. 4500 to 3500 years BP

Evergreen forests. Pollen markers recorded:

- Core evergreen forests: *Aglaia roxburghiana, Holigarna, Mangifera, Ardisia, Arenga, Artocarpus, Bischofia javanica, Calophyllum, Caryota urens, Dipterocarpu Dysoxylum, Elaeocarpus, Hopea, Lophopetalum wightinum, Mimusops, Myristica, Agrostitachys indica,* Aracea *Arisaema, Elaeagnus kologa, Entada, Cocculus, Cycle Tinospora,* Piperaceae, *Toddalia asiatica, Ventilag Calamus, Garcinia, Ixora brachiata, Zanthoxyllum*;
- Openings and edges: *Macaranga, Mallotus, Trem Allophyllus, Leea indica, Aporosa indica, Maesa indica*
- Also present in deciduous forests: *Alstonia, Diospyro Syzygium.*

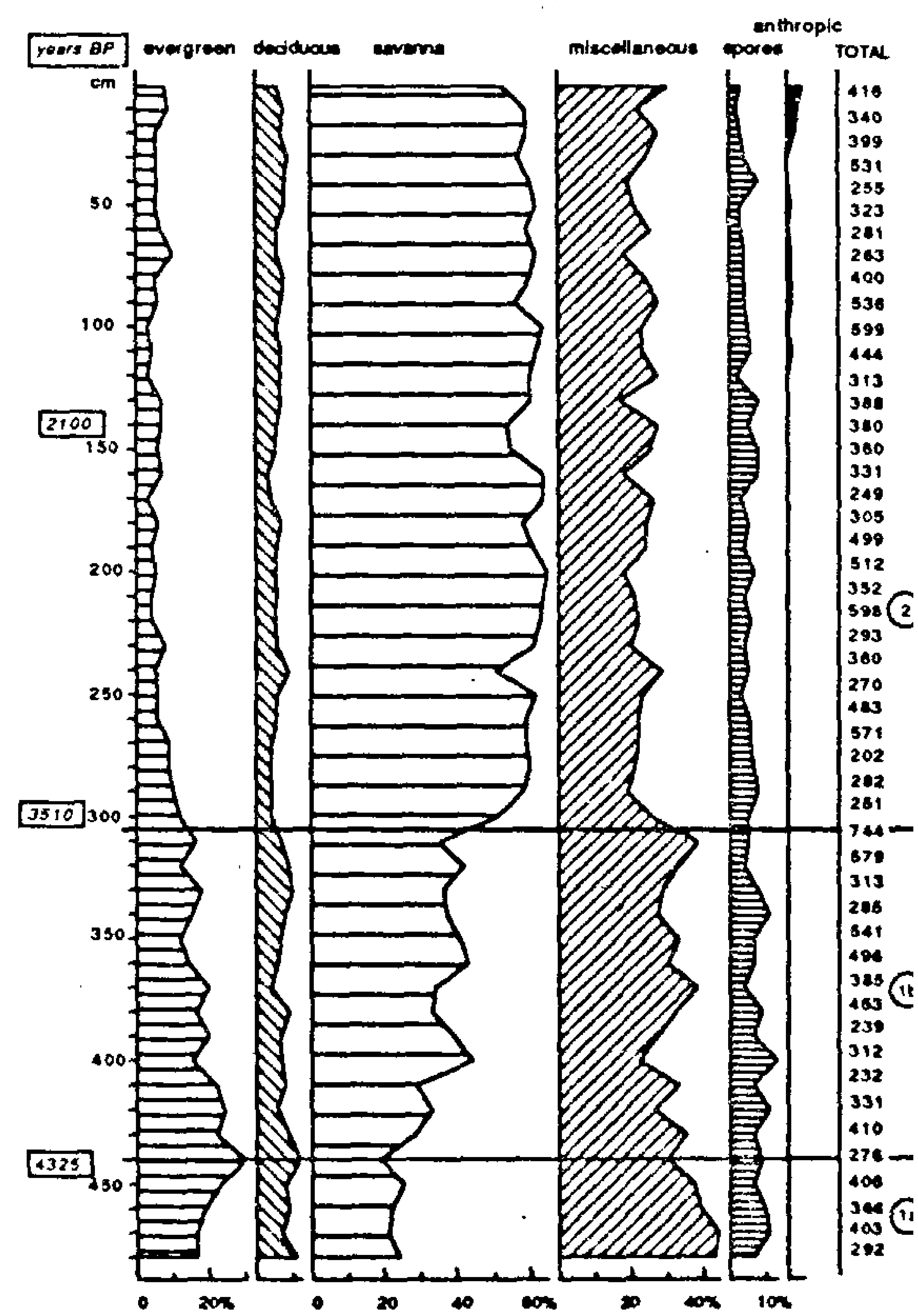

Figure 3. Core SK 27 B/8: pollen diagram of inland vegetati (mangrove excluded).

The representation of the evergreen forests increases from 17 to 30% in a short sub-sequence (la: 480 to 440 cm); above this, its values decrease regularly to 10% at 300 cm (sub-sequence 1 b).

Deciduous forests. Main pollen markers: Combretaceae–Melastomataceae, *Acacia, Xylia, Buchamania, Butea, Lannea, Rhus, Anogeissus, Bombax malabaricum, Bridelia, Celtis, Dillenia, Evodia, Garuga pinnata, Haldina, Helicteres isora, Holoptelea, Lagerstroemia, Radermachera, Randia rugulosa, Schleichera, Shorea, Xeromphis.*

–Sub-sequence la: percentages always greater than 8%;

–Sub-sequence lb: mean percentages around 6 to 7%.

Savannas (and deciduous forests p.p.). Poaceae, the main component of this group, grows mainly in savannas but may also occur in deciduous forests as commonly observed in the southern part of the Western Ghats, while in the Kalinadi basin, the herbaceous undergrowth is always poorly developed in deciduous forests. Other taxa with small representation have been recorded: *Careya arborea, Emblica, Gardenia gummifera, Gnidia glauca, Dodonea,* Capparidaceae, *Grewia, Crotalaria, Phyllanthus, Ziziphus.*

–Sub-sequence la: percentages around 22%;

–Sub-sequence lb: the values increase to 35%.

Miscellaneous. In this group are merged all the components with too large ecological requirement or geographical distribution to be included in one of the previous vegetation groups, as well as the unidentified pollen. Hence, this group has practically no palaeogeographical significance. However, some changes may be noted:

–Sub-sequence la: rates decreasing from 40 to 30%;

–Sub-sequence lb: rates varying around 30%.

Spores of Pteridophytes. Sub-sequences la and lb are not distinguishable: the percentages vary irregularly from 7 to 13%.

Sequence 2: from ca. 3500 years BP to present

All the percentages vary from those of the sequence 1, the limit between the two sequences being well marked by a very short transitional zone.

The main distinction from sequence 1 is a sharp increase, from 35 to about 60%, of the savanna pollen represented essentially by Poaceae accompanied by a general decrease of all the other groups. Calculation of the absolute number of pollen grains by gram of sediment confirms the occurrence, for all the groups, at 300 cm, of this break which, therefore, is not an artefact due to the mode of calculation by percentages.

During sequence 2, the climate conditions remained without any major change until now. Nevertheless, some minor modifications affecting the palynologica diagram during the more recent period (which may be estimated to a few centuries), may be noted.

A drier climate from ca. 3500 years BP

The interpretations of the pollen and spore diagram are based on the generally accepted facts that herbaceous formations such as savannas require less humidity for their growth than forest formations, particularly evergreen forests. From this statement, the well marked climatic change occurring at ca. 3500 years BP, can be interpreted as due to the relatively quick onset of drier conditions. This is confirmed by several other observations from the core 27 B/8, all the indicators showing the same trend: the evidence of a drier climate during the younger period:

– *Mangrove forest palynology.* It is well known[4] that an alteration of the intensity of humid conditions results in a reduction in the development of mangrove forests. Thus, in the core 27 B/8, at 350 cm, the quantity of pollen released by the mangrove forests decreases abruptly.

– *Stable carbon isotope, $\partial^{13}C$.* For terrestrial plants, $\partial^{13}C$ is characterized by low values, whereas in marine microplankton it is always higher[5]. Therefore, any decrease of the continental inputs in coastal sediments raises the value of this isotope and, indeed, such an increase is recorded in 27 B/8 where the values below 350 cm are lower than −23%, and going up to −22 above the limit of 350 cm and even −21% higher.

– *Sedimentation rate.* The rate of sedimentation is much lower in the recent period (7 cm/100 years) than during the 4500–3500 year period (18 cm/100 years). Such a decrease once again confirms the alteration of the humid conditions after 3500 years BP, resulting in slower erosion process and consequently in a reduction of the quantity of sediments discharged into the sea by the river.

Comparison with Late Holocene climates in Rajasthan desert

The climatic evolution of Rajasthan during the Late Holocene is well known from the numerous palynological works of Singh *et al.*[6] and their reappraisal by Bryson[7]: a wet period ending abruptly at ca. 3600 years BP is followed by 'the long drought', and then the establishment of the present conditions. At Didwana Lake[8], the same climatic history was reconstructed for the Late Holocene. With another method of study, Krishnamurthy *et al.*[9] arrived at a similar result.

Therefore, in spite of the great distance separating Karwar from Rajasthan, the similarity of the results is striking. The interpretations of these authors to explain the climatic variations in Rajasthan, particularly the models of monsoon regimes emphasizing the variations in wind direction, may be applied for explaining the evolution observed in Karwar also where the climate is controlled by the same pattern of southwest monsoon.

The Recent period

The upper part of the core is marked by several features, of faint amplitude, but worth mentioning: (i) above 110 cm, some pollen of anthropogen origin are recorded such as the introduced *Casuarina, Eucalyptus, Mimosa pudica*; (ii) the small increases of the values of the evergreen forests from 80 cm to the top due mainly to the genera *Syzygium* and *Calamus*; (iii) the slightly higher values of the deciduous forests above 60 cm due to the large Combretaceae group; (iv) the diminution of the Poaceae above 50 cm, from 62 to 53%.

These changes might be the result of a recent development of the forests, which, contrary to the generally accepted idea, in some places are now spreading on land previously covered by savannas.

Conclusion

The obvious changes affecting the palynological markers of the vegetation covering the basin of the Kalinadi river at ca. 3500 years BP have been confirmed, and hence strengthened, by the preliminary palynological and chronological studies of another marine core, SK 44/13, collected nearby, in the same area off shore Karwar.

Human interference cannot be assessed from palynological data to explain the degradation of the forests at present. These changes are probably the result of a climatic change corresponding to the establishment of drier conditions. The climate of Rajasthan, like that of the Western Ghats, belongs to the same southwest monsoon pattern. Since a similar climatic evolution has affected both Karwar region and Rajasthan, following the same chronology, a common factor is implied. According to recent climatic models completed in Rajasthan, this climatic evolution is linked to the monsoon regime and more particularly to wind direction.

The same climatic evolution has been described in several regions in Africa where from 7000 to 3500 years BP the climate was more humid and hotter than now, whereas from 3500 years BP to Recent, humidity and temperature were decreasing[10]. From this, could a global climatic change occurring at 3500 years BP be considered?

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