map forest fire-prone areas[10]. However, the 'fire risk' in the present study reflects both the likelihood of ignition and the risk of likely spread. The slope factor which influences the spread of fire, thus increasing the fire risk has been incorporated in the present model. An interesting feature of this model is that it explains the important fact that, with the low availability of inflammable material, the probability of the fire in the forest would be low, irrespective of other factors being favourable. Table 3 describes the resultant fire risk zones and the corresponding degree of fire risk.

Finally the fire risk zone map, was compared with the actual sites disturbed by the fire. It was observed that fire occurrence shows a definite pattern. It was found that the starting points of fire were concentrated in areas adjacent to settlements, roads, trails, etc. It was interesting to note that most of the points representing the history of past fires occurred on the very high and high risk zones predicted from the present model (Table 3). Out of 17 sites previously burnt during 1985–1993, 41.49% of the total burnt area fell in the high and moderately high risk zones, while 31.95% fell in the moderate risk zone. This agreement between the predicted risk areas and the actual affected sites was assumed to be a major test for the reliability of the present approach.

The annual incidence of forest fire often causes irreversible damage to the environment, loss of regeneration status and even at times total loss of the vegetation cover along with the increase in the rate of soil erosion. It is therefore imperative to keep regular record of all the important factors influencing the forest fire in order to enable planners to draw up protection programs. The approach to this is to prepare fire-prone zone maps of the study area, which would indicate the probability of the fire incidence and extent of its spread. The resulting risk map would help authorities in taking remedial measures against fire incidence.

The present approach combining field observations, remote sensing and GIS seems to be reliable and satisfactory for fire risk zone mapping. The work can also be carried out on other commercial GIS softwares like ArcInfo and Modular GIS environment (Intergraph – MGE). The present approach does not account for the data on aspect, fire weather and many of the remotely sensed data of fine resolution. More interesting and reliable results can be obtained when the data on these aspects will be available.

1. Matson, M. and Holben, B., *Int. J. Remote. Sens.*, 1987, **8**, 509–516.
2. Bolin, B., Doos, B. R., Jager, V. J. and Warrik, R. A., *The Greenhouse Effect, Climatic Change and Ecosystems*, Scope 29, 1987.
3. Miller, W. and Johnston, D., Pecora X symposium, 1985, pp. 305–314.
4. Muirhhead, K. and Cracknell, A. P., *Int. J. Remote Sens.*, 1985, **6**, 827–833.
5. Matson, M., Schneider, S. R., Aldridge, B. and Satchnell, B., NOAA Technical Reports, NESDIS, Washington, DC, 1984.
6. Tiwari, A. K., in *Wildlife Habitat Evaluation Using Remote Sensing Techniques* (eds Kamet, D. S. and Panwar, H. S.), Indian Institute of Remote Sensing and Wildlife Institute of India, Dehradun, 1986.
7. Champion, H. G. and Seth, S. K., *A Revised Survey of the Forest Types of India*, Manager of Publications, Govt. of India, New Delhi, 1968, pp. 100–101.
8. Kandya, A. K., Kimothi, M. M., Jadhav, R. N. and Aggarwal, J. P., Scientific note SAC/RSAG-LRD/SN/02/93, 1993.
9. Chuvieco, E. and Congalton, R. G. *Remote. Sens. Environ.*, 1989, **29**, 147–159.
10. Deeming, J. E., Burgan, R. L. and Cohen, J. D., *The National Fire Danger Rating System*, US Department of Agriculture, Forest Service, Ogden, 1978.
11. Brown, A. A. and Davis, K. P., *Forest Fire: Control and Use*, McGraw-Hill, New York, 1973.
12. Artsybashev, E. S., *Forest Fire and their Control*, Oxonian, New Delhi (First ed. in Russian, 1974), 1983.
13. Gupta, R. K., *The Living Himalayas*, Today and Tomorrow's Publishers, New Delhi, 1983, vol. 1, p. 378.
14. Lorimer, C. G., in *Introduction to Forest Science* (ed. Young, R. A.), John Wiley, New York, 1983, pp. 357–377.

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Biochemical degradation of the cuticular membrane in an early Cretaceous frond: A TEM study

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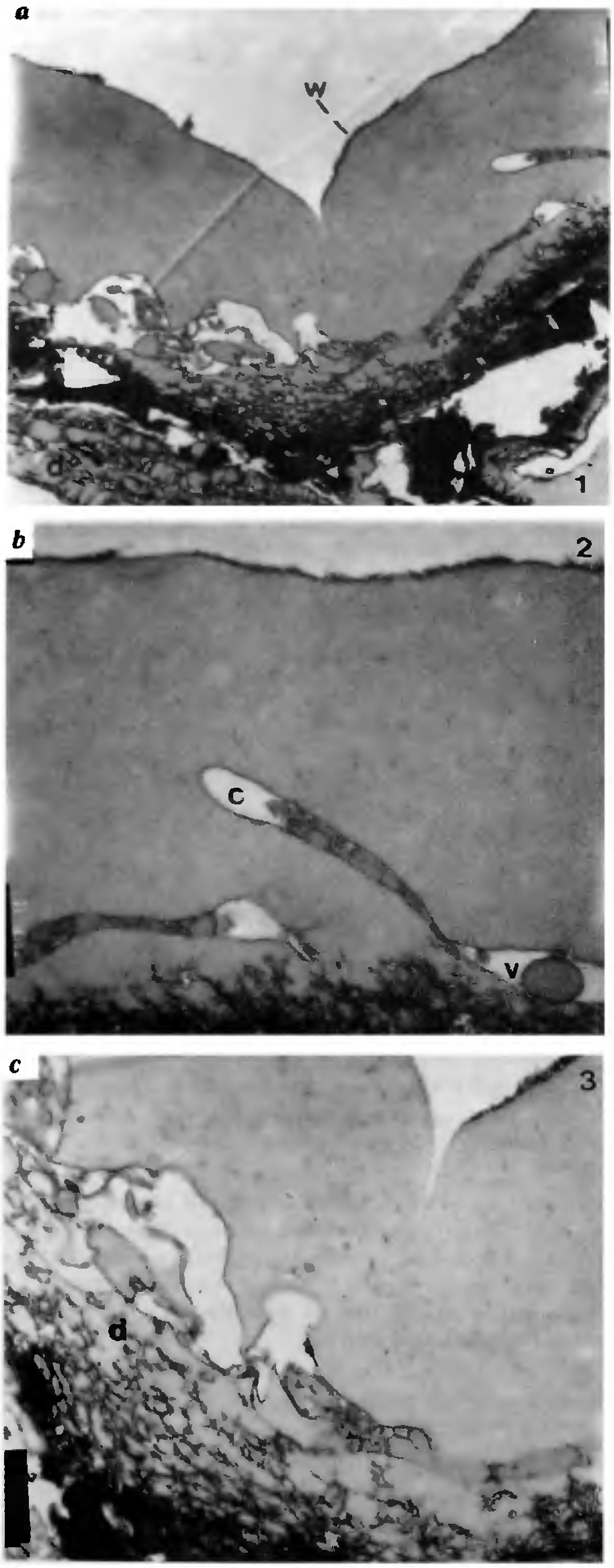
Ultrastructure of the cuticle of a fossil pteridospermous leaf *Thinnfeldia indica* has been investigated under the TEM. The cuticle of the leaf, which is infested with fungal hyphae, shows various stages of degradation, possibly due to activity of an enzyme secreted by the fungal hyphae.

AERIAL parts of the terrestrial plant body are generally covered by a thin continuous layer – the cuticular membrane or the cuticle. The cuticular membrane comprises an inner layer of cellulose encrusted with cutin, and an outer cuticularzied layer or the cuticle proper. The cuticular membrane is covered on the outer side by an irregular deposit of semi-crystalline or crystalline material[1]. Cutin is an insoluble high-molecular weight, complex lipid polyester[2,3].



Considerable data has been generated on the structure, chemical composition and organization of the cuticular membrane. On the basis of ultrastructural variation, the cuticular membrane in the extant plants investigated so far has been classified under six types[3]. Some of these cuticle types have also been recorded in fossil plants[4–6]. However, hardly any data is available on the development of the cuticular membrane, or its degradation due to activity of phytopathogens in plant fossils.

In order to know the changes in the structural configuration of cuticular membrane in an infested fossil leaf, *Thinnfeldia indica* Feistmantel, a pteridospermous leaf collected from the Early Cretaceous Sivaganga Formation in the Cauvery Basin was chosen as a case study. Epiphyllous fungal remains have earlier been recorded on this leaf[7]. The preparation of the sample for ultrastructural studies was carried out as outlined in an earlier paper[6].

The transverse section of the cuticular membrane of *T. indica* shows, under the light microscope, an apparent variation in its thickness as observed in some fossil leaves studied earlier[6]. The ultrathin sections of the leaf when observed under the transmission electron microscope show a sort of irregular deposition on the outer surface of the cuticular membrane (Figure 1 *a*–'w'). This deposit is interpreted as that of osmiophilic bodies which are lipophilic in nature, and possibly represent the epicuticular wax. Below the zone of irregular osmiophilic bodies is a homogeneous layer, the internal fine structure of which is mainly amorphous with a matrix of uniform density (Figure 1 *a*–*c*). Below the amorphous layer is a 'disturbed zone' which at places shows irregular aggregations of compactly-arranged 'bodies' (Figure 1 *a*, *c*–'d') that have a density similar to that of the matrix of the amorphous zone. These 'bodies' that may represent membrane-bound vesicles (Figure 1 *b*–'v') are in different sizes. At places the membrane-bound vesicles apparently seem to fuse with the sub-cuticular layer (Figure 1 *a*–'f'). Because of the fusion of the matrix the membrane left behind is electron dense, compressed and irregular. Elongated cave-like cavities (Figure 1 *a*, *b*–'c') are randomly present in the inner zone of the amorphous layer abutting on the 'disturbed' zone. These cavities are to a great extent loosely filled with discrete elements similar to the membrane-bound vesicles composing the 'disturbed' zone. Elsewhere, the inner margin of the amorphous layer is variously indented (Figure 1).

The membrane-bound vesicle-like structures seen in the 'disturbed' zone at places seem to merge with the sub-cuticular layer as if contributing to the development

Figure 1 *a*–*c*. *Thinnfeldia indica* Feistmantel. Transmission electron photomicrographs of ultra-thin sections of the leaf showing details of the cuticle. ***a***, ×10,400; ***b***, ×21,000; ***c***, ×21,000. (c – cave-like cavities; d – disturbed zone; f – vesicles apparently fusing with the sub-cuticular layer; v – membrane-bound vesicles; w – remnants of wax deposits.)

of this layer. A similar process of cuticular development has been reported on the glandular trichomes of *Cannabis sativa*[8]. The probability of such a process taking place in a mature leaf, however, is extremely low. The presence of fungi on the leaf surface, on the other hand, indicates that the 'disturbed zone' could have been formed due to biochemical activity of the fungi.

In the leaf investigated, the surface of the leaf exposed to atmosphere shows fertile structures of Ascomycetes and hyphae of Deuteromycetes. Extant fungi are known to secrete cutin-hydrolysing enzyme(s). Cutinase – a serine hydrolase – has been purified from the extracellular fluid of fungi grown on cutin[9]. The process of fungal degradation of polyesters has been outlined in detail by Kolattukudy[2]. Though no direct evidence is available, it is assumed that one such cutin-hydrolysing enzyme released by the fungal hyphae inside the leaf tissue of *Thinnfeldia indica* leaf might have triggered the chemical degradation of the cuticular membrane. This could have changed the flat smooth topography of the inner surface of the amorphous layer to the one with indentations and formed cave-like cavities leading to the formation of the 'disturbed zone'. That no such degradation is seen on the outer surface of the amorphous layer shows that in the present case enzymatic penetration of the cuticle may not be involved. This is further confirmed by the fact that at places the fungal hyphae seem to enter the leaf through stomata[7].

1. Baker, E. A., in *The Plant Cuticle* (eds Cutler, D. F., Alvin, K. L. and Price, C. E.), Academic Press, London, 1982, pp. 139–166.
2. Kolattukudy, P. E., *Science*, 1980, **208**, 990–1000.
3. Holloway, P. J., in *The Plant Cuticle* (eds Cutler, D. F., Alvin, K. L. and Price, C. E.), Academic Press, London, 1982, pp. 1–32.
4. Archangelsky, S. and Taylor, T. N., *Am. J. Bot.*, 1986, **73**, 1577–1587.
5. Archangelsky, S., Taylor, T. N. and Kurmann, M. H., *Bot. J. Linn. Soc.*, 1986, **92**, 101–116.
6. Maheshwari, H. K. and Bajpai, U., *Palaeobotanist*, **45**, in press.
7. Bajpai, U. and Maheshwari, H. K., *Palaeobotanist*, 1988, **36**, 210–213.
8. Mahlberg, P. G. and Kim, E.-S., *Am. J. Bot.*, 1991, **78**, 1113–1122.
9. Lin, T. S. and Kolattukudy, P. E., *Biochem. Biophys. Res. Commun.*, 1976, **72**, 243.

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First report of fossil dinoflagellates from the west coast of India and some observations

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Fossil dinoflagellates are reported for the first time from the west coast of India. These are recovered from two cores collected from the offshore of Mangalore. *Spiniferites pachydermus* is the dominant species in both the cores. *Spiniferites mirabilis* is abundant in the surface samples while *Operculodinium centrocarpum* is constrained to certain depths of the core only and *Lingulodinium machaerophorum* is restricted to the near shore core, *Spiniferites bentorii, S. ramosus* and *Tuberculodinium vancampoae* are restricted to offshore core.

DINOFLAGELLATES are mainly marine, unicellular biflagellate algae. They are characterized by a simple life cycle which involves a vegetative stage and an encysted stage. They are generally spherical to ellipsoidal or elongate, ranging in size from 25 to 250 µm. The variety of functions attributed to cysts include species dispersal, bloom initiation, bloom termination and survival through adverse conditions[1,2]. Fossilized dinoflagellates cysts have been used extensively in stratigraphic palynology[3] and its importance in palaeoceanography is briefed by Jain[4]. These fossils are abundant in marine clays, shales, siltstones, or mudstones. This paper forms the first published report of fossil dinoflagellates from the west coast of India.

Two cores were collected from the offshore off Mangalore, west coast of India (Figure 1). These cores were recovered in PVC pipes by gravity coring without disturbing the sequence of materials. The length of the nearshore core (CN) is 0.57 m, collected from a water depth of 11.4 m and at a distance of about 3.75 km from the coast. The length of the offshore core (CO) is 0.35 m, collected from a waterdepth of 50.9 m and at a distance of 35.50 km from the coast. Sample numbers CN1 to CN4 represent the nearshore core samples and CO1 to CO7 represent the offshore core samples.

Many methods of palynologic preparation have been published over the years[5,6]. The basic principle here is the removal of inorganics and unwanted organics from the original sample, thereby ensuring the concentration of palynomorphs. The different stages involved in the

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