

Cuticular studies on the fossil leaves from Churia (Siwalik) sediments of Arjun Khola Sequence, western Nepal

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ABSTRACT

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Two fossil leaf impressions along with their cuticle, collected from Middle Siwalik (Upper Miocene) sediments of Arjun Khola Sequence, about 3 km north-west of Lamhi in Deokhuri District of western Nepal, have been identified on the basis of their morphological and cuticular features. They resemble closely with the modern taxa. *Sterculia coccinea* Jack. and *Diospyros toposia* Ham. of the Sterculiaceae and Ebenaceae respectively. The present distribution of the modern equivalent taxa of the fossils and the presence of fungal spores in their cuticle collectively indicate the prevalence of warm humid climate in the area during Upper Miocene.

Key words—Leaf impressions, Cuticles, Miocene, Angiosperm, Churia (Siwalik) Formation, Arjun Khola.

पश्चिमी नेपाल में अर्जुनखोला के चुरिया (शिवालिक) अवसादों से प्राप्त अशिमत पत्तियों का उपचर्मीय अध्ययन

महेश प्रसाद एवं एकनाथ गवजी खरे

सारांश

पश्चिमी नेपाल के देवखुड़ी जिले में लमही से लगभग 3 किमी. उत्तर-पश्चिम में अर्जुनखोला अनुक्रम के मध्य शिवालिक (उपरि मायोसीन) अवसादों से प्राप्त दो अशिमत पर्ण मुद्राश्म अपने आकारिकीय तथा उपचर्मीय लक्षणों के आधार पर अभिनिर्धारित की गई है। ये पर्ण मुद्राश्म स्टेकुलियाएसी एवं एबीनेसी कुलों के क्रमशः *स्टेकुलिया कोक्सीनिया* (जैक.) एवं *डायॉसपाइरस टोपोसिया* (हेम.) के आधुनिक वर्गकों के साथ निकट सदृशता रखती है। जीवाश्मों के आधुनिक समतुल्य वर्गकों के वर्तमान वितरण तथा अपने उपचर्म में कवकी बीजाणुओं की उपस्थिति उपरि मायोसीन के दौरान क्षेत्र में उष्ण-आर्द्र जलवायु की व्यापकता का सामूहिक रूप से संकेत करती है।

संकेत शब्द—पर्ण मुद्राश्म, उपचर्म, मायोसीन, आवृतबीजी, चुरिया (शिवालिक) शैलसमूह, अर्जुनखोला।

INTRODUCTION

IN Nepal the sediments of Siwalik Group are known as Churia Group after the Churia hills which is the extension of the Himalayan foot hills (Siwalik Hills). The Churia hills represent

clastic sediments of fresh water molasse that accumulated in a long narrow foredeep formed to the south of rising Himalaya in the third episode of Himalayan uplift during Middle Miocene. The Churia Group ranges in age from Middle Miocene to Middle Pliocene. The detail lithology and stratigraphy

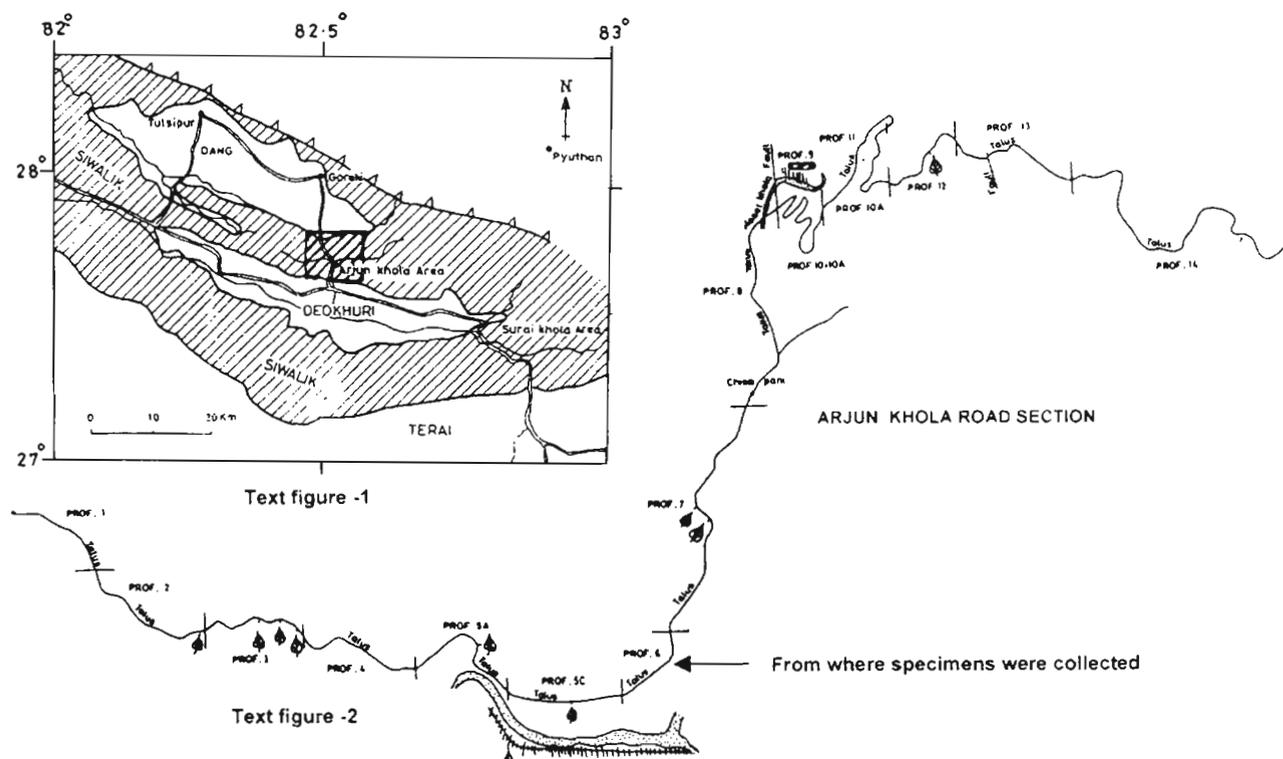


Fig. 1—Map showing Siwalik Formation in Nepal and fossil locality, Fig. 2—Showing Arjun Khola Road section indicating different 14 profiles with their fossiliferous beds.

of the Churia Group have been studied by Auden (1935), Lehner (1943), Hagen (1959), Bordet (1961), Gleinnie & Ziegler (1964), Sharma (1980), Kumar & Gupta (1981), Chaudhuri (1983), West (1984), Tokuoka *et al.* (1986), Corvinus (1990), Appel *et al.* (1991). The Churia Group has been classified into two formations (i) Lower Churia Formation (Sandstone facies) and (ii) Upper Churia Formation (Conglomerate facies) by Hagen (1959), Bordet (1961) and Gleinnie & Ziegler (1964). The Lower Churia Formation with an average thickness of about 1800 ft is composed of fine grained calcareous well bedded sandstones and siltstones while Upper Churia Formation consists of mainly of boulder pebbles and loose micaceous sandstones exposed south of the Lower formation in the Dang area.

The present fossil locality of Arjun Khola (27°52' : 82°50') falls in the Dang section of western Nepal and is situated about 3 km north-west of a well known small town, Lamhi in Deokhuri District of Nepal. Almost a complete and uninterrupted sequence of the Churia Group is well exposed all along the road from Arjun Khola bridge to Ghorai of about 15 km stretch (Figs 1, 2). This sequence consists of molasse sediments of the Lower and Middle Siwalik. The whole sequence is divided into 14 profiles (Personal communication with Dr G. Corvinus, University of Erlangen, Germany). There are more than 30 fossiliferous beds of mainly shales, siltstones

and some fine sandstones. Most of them have yielded, a variety of well preserved leaves, fruit and seed impressions and some fossil woods.

Although a rich collection of plant megafossils comprising fossil wood, leaves, fruit and seed impressions have been made mainly from the Lower and Middle Siwalik sediments of Arjun Khola Sequence but none of them has been described so far. In present communication the morphological and cuticular study of two leaf impressions collected from profile 6 of Middle Siwalik have been carried out.

MATERIAL AND METHODS

The present specimen of leaf impressions were collected from the Middle Siwalik sediments (Profile 6) of Arjun Khola Sequence, western Nepal. The leaf impressions are with cuticles and preserved on grey shale. The specimens were studied morphologically with a hand lens and a low power microscope under reflected light. For description of leaf impressions, the terminology given by Hickey (1973) and Dilcher (1974) has been followed. The cuticles were removed from leaf impressions with the help of organic chemicals and

treated with acid followed by KOH and washed with water before the preparation of slides.

SYSTEMATICS

ANGIOSPERMS

DICOTYLEDONS

Family—STERCULIACEAE

Genus—STERCULIA Linn.

STERCULIA KATHGODAMENSIS Prasad 1994a

(Pl. 1.1-3, 6)

Number of specimens examined—1.

Description—Leaflet almost symmetrical; lanceolate; lamina length 13 cm, maximum width 4.5 cm; apex broken; base acute, normal margin entire; texture coriaceous; venation pinnate, eucamptodromous, petiole not preserved; primary vein (1°) single, prominent, massive, almost straight; secondary veins (2°) only 5 pairs visible, 0.6-2.7 cm apart, angle of divergence acute (about 60°), moderate, curved up and run parallel to margin for a short distance, alternate to opposite unbranched; intersecondary vein present, simple, rare; tertiary veins (3°) fine, with angle of origin RR, percurrent, straight to sinuous, branched, oblique in relation to midvein, predominantly alternate and close.

Upper epidermal cells are usually isodiametric, hexagonal, hypostomatic, differentiated into costal and intercostal area. Cells are usually thick and with straight walls. Cells square to rectangular in shape, 8-10 µm, in length and 6-8 µm in width. Intercostal cells are rectangular in shape, 18-20 µm in length, 10-12 µm in width.

Stomata are observed in the lower foliar surface, they are distributed randomly, anomocytic, subsidiary cells are irregular in shape, 38-40 µm in length, 30-32 µm in width, frequency 12-15 per mm. fungal spore present.

Specimen—BSIP Museum No. 38918.

Locality—Arjun Khola, western Nepal.

Horizon and Age—Middle Siwalik Formation, U. Miocene.

Affinities—The diagnostic features of the present fossil leaf such as symmetrical, oblanceolate shape, acute base, entire margin, coriaceous texture, eucamptodromous venation, characteristic curvature of secondary veins which arise at moderate acute angle, presence of inter secondary veins, RR and close tertiaries and type and nature of stomata and epidermal cells indicate that the present fossil leaf shows close affinity with the extant leaves of *Sterculia coccinea* Jack. of the family Sterculiaceae (Pl. 1. 4, 5.).

So far, only one fossil leaf resembling the genus *Sterculia* Linn. has been described as *Sterculia kathgodamensis* from the Lower Siwalik sediments of Kathgodam area in Nainital District, Uttaranchal (Prasad, 1994a). This fossil leaf shows close affinity with the extant taxa *Sterculia coccinea*. As the present fossil leaf has also been compared with *S. coccinea* Jack. and also possesses more or less similar morphological features as described from species *Sterculia kathgodamensis* Prasad, the present fossil leaf has been kept under the same species. Moreover, a fossil wood, *Sterculinium kalagarhensis* resembling the same extant taxa *Sterculia coccinea* Jack. has also been reported from Siwalik sediments of Kalagarh, Pauri Garwal District, Uttaranchal (Prasad, 1993). The occurrence of this fossil wood further confirm the presence of *Sterculia coccinea* in the Himalayan foot hills during Siwalik period. *Sterculia coccinea* Jack. with which the fossil leaf resembles closely, is a tree found in the eastern Himalayas ascending up to 900 m in Sikkim, Bhutan and Burma (Chowdhury & Ghosh, 1958; Brandis, 1971).

FAMILY—EBENACEAE

GENUS—DIOSPYROS Linn.

DIOSPYROS PRETOPOSIA Prasad, 1990

(Pl. 2.1, 2, 5)

Number of specimens examined-1.

Description—Leaflet almost symmetrical; narrow oblong to ovate; lamina length 18 cm, maximum width 5.3 cm; apex broken; base wide acute, normal; margin entire; texture coriaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single prominent, straight, thicker toward base; secondary veins (2°) about 12 pairs visible, angle of divergence acute (about 60°), moderate, 0.8-2 cm apart, alternate, uniformly curved up, branched; inter secondary veins present, simple, frequent and branched; tertiary veins (3°) fine, with angle of origin AR-RO, percurrent, straight, usually oblique in relation to midvein, alternate to opposite and close.

Upper epidermal cells are isodiametric usually (hexagonal), elongated into costal and intercostal area, cells are usually thick with straight walls.

Cells are variable in shape, costal cells are irregular, square to rectangular, 6-8 cm in length, 4-6 µm in width, intercostal cells are rectangular in shape, 15-20 µm in length, 10-12 µm in width.

Stomata are observed in the lower surface, and are distributed uniformly. These are arranged in regular pattern, anomocytic, subsidiary cells 4-7, irregular in shape, 30-50 µm in length, 20-25 µm in width, guard cells are almost oval to elongated, 16-18 µm in length, 6-8 µm in the width, frequency of stomata 25-30 per mm.

Specimen—BSIP Museum No. 38919.

Locality—Arjun Khola, western Nepal.

Horizon and Age—Middle Siwalik Formation, U. Miocene.

Affinities—The characteristic features of the present fossil leaf are the large size, narrow oblong shape, wide acute base, entire margin eucamptodromous venation, alternate, uniformly curved secondary veins, presence of intersecondary veins, percurrent, AR-RO, straight and close tertiaries. These features are found common among the species of the genus *Diospyros* Linn. of the family Ebenaceae. After a critical examination of a variety of herbarium sheet of different species and their cuticular features it has been concluded that the extant taxon *Diospyros toposia* Ham. shows closest affinity with the present fossil in all morphological features (Pl. 2, 3, 4).

The fossil leaves showing close resemblance with those of *Diospyros* have been described under two generic names i.e., *Diospyros* Linn. and *Diospyrophyllum* Velenovsky. The latter consists of only one species *Diospyrophyllum provectum* Velenovsky 1889 from the Upper Cretaceous of Bohemia. However, *Diospyros* Linn. contains about 72 species reported from different parts of the world viz., Africa, Bohemia, Canada, Europe, England, Greece, Greenland, Japan, Panama, Switzerland and USA (Schimper, 1874; Heer, 1874; Lesquereux, 1878, 1891-92; Probst, 1884; Berry, 1916, 1918, 1919, 1930; Principi, 1921; Gothan, 1933; Saloman Calvi, 1934; Hollick, 1936; MacGinite, 1937, 1941; LaMotte, 1952; Jahnichen, 1958; Chaney & Axlerod, 1959; Kilpper, 1969; Huzioka & Uemura, 1973; Tanai, 1976). Thus it is obvious that this genus was cosmopolitan in distribution in the geological past. From the geological distribution of fossil *Diospyros* it is evident that its earliest record goes back to the Upper Cretaceous (Velenovsky, 1884).

So far, seven species have been reported from the Siwalik sediments of India and abroad. These are *Diospyros embryopterisites* Verma 1968 from the Middle Siwalik of Hardwar, Uttaranchal, India; *D. miocenica* Prasad & Awasthi 1996, *D. miokaki* Awasthi & Prasad 1990 from Lower Siwalik sediments of Surai Khola, western Nepal; *D. kathgodamensis* Prasad 1994a & *D. palaeobenum* Prasad 1994b from the Lower Siwalik of Kathgodam, Uttaranchal, India; *Diospyros pretoposia* Prasad 1990 and *D. koilabasensis* Prasad 1990 from the Lower Siwalik sediments of Koilabas, western Nepal. The later species has also been reported from the Lower-Middle Siwalik of Darjeeling District, West Bengal, India, *D.*

tulsipurensis Prasad *et al.*, 1997 from the Lower Siwalik of Seria Naka at Indo-Nepal Border, in Gonda District of Uttar Pradesh, India, *D. darwajensis* Prasad *et al.*, 1999 from the Siwalik sediments of Koilabas, western Nepal and *D. miocenicum* Prasad & Awasthi and *D. pretoposia* Prasad from Miocene Neyveli lignite deposit of Tamil Nadu (Agarwal, 2002). The present fossil leaf has been compared with all the above available species and found that it shows close similarity with the fossil leaf described as *Diospyros pretoposia* Prasad from the Siwalik sediments of Koilabas, western Nepal. Therefore, it has been described under the same species *Diospyros pretoposia*.

The genus *Diospyros* Linn. consists of about 500 species of trees or rarely shrub distributed in tropical and mild temperate regions of the world, a few in South Africa and North America (Hooker, 1882; Purkayastha, 1982). About 55 species are found in the Indian region. The modern comparable species *Diospyros toposia* Ham. is an evergreen, middle-sized tree growing in Khasi Hills, Cachar, Chittagong, Tinneveli hills and in the moist regions of Sri Lanka (Brandis, 1971).

CONCLUSION

The present fossil leaves show affinity with the extant taxa, *Sterculia coccinea* Jack. and *Diospyros toposia* Ham. of the family Sterculiaceae and Ebenaceae respectively. Both the extant taxa are distributed presently in the evergreen forest of northeast India and Myanmar. The present day distribution of the modern equivalent taxa of the fossils and the presence of fungal spore in their cuticles collectively indicate the prevalence of warm humid climate in the area during sedimentation. The micro-morphological feature of cuticles of these fossils would help in confirmation of the identification of its leaf impressions to the specific level and their nonconsistent features would also help in interpreting palaeoecology of the area.

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PLATE 1



Sterculia kathgodamensis Prasad

1. Fossil leaf with cuticles in natural size showing shape, size and venation pattern.
2. A part of fossil leaf cuticle showing cellular structure and distribution of stomata. x 180.
3. A part of lower epidermis showing fungal spore.
4. A part of cuticle of extant *Sterculia coccinea* showing similar

5. cellular structure and distribution of stomata. x 180.
5. Magnified view of modern leaf cuticle of *Sterculia coccinea* showing similar details of stomata as Fig. 6. x 350.
6. Magnified view of fossil leaf cuticle showing details of Stomata. x 350.

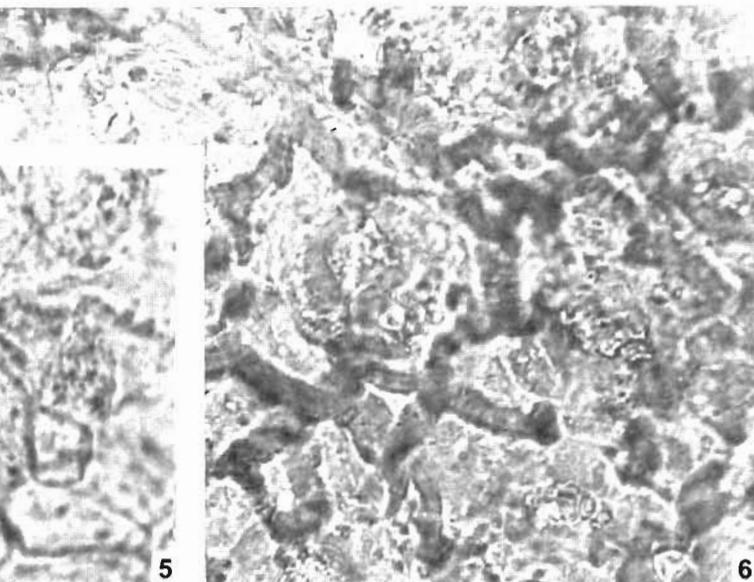
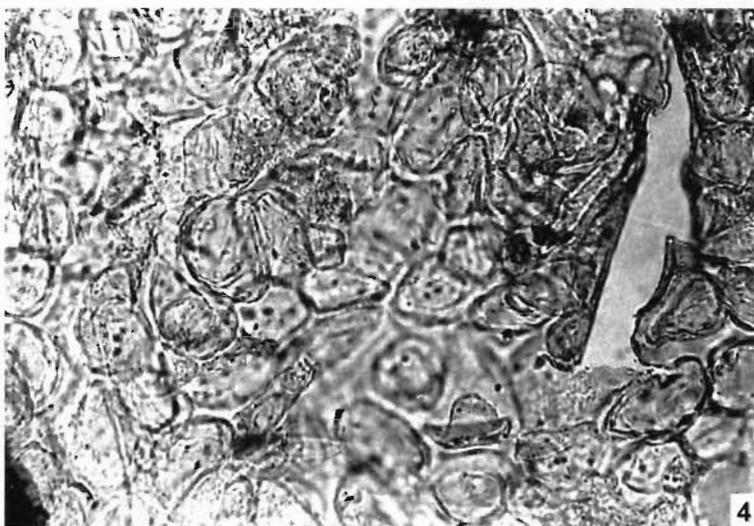
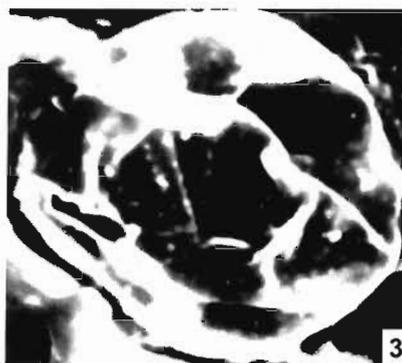


PLATE 1

and providing necessary facilities for field work. We are also thankful to authorities of the Central National Herbarium, Howrah for permission to consult the Herbarium. Thanks are also due to Dr N Awasthi, Ex. Dy. Director, BSIP, Lucknow for his generous help during the collection of material.

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PLATE 2



- Diospyros pretoposia* Prasad
1. Fossil leaf with cuticle in natural size showing shape, size and venation pattern.
 2. A part of fossil leaf cuticle showing cellular structure and distribution of stomata. x 180.
 3. A part of cuticle of *Diospyros pretoposia* showing similar cellular structure and distribution of stomata. x 180.
 4. Magnified view of a part of cuticle of *Diospyros pretoposia* showing similar details of stomata and guard cells as Fig. 5. x 350.
 5. Magnified view of a part of fossil leaf cuticle showing details of stomata and guard cells. x 350.

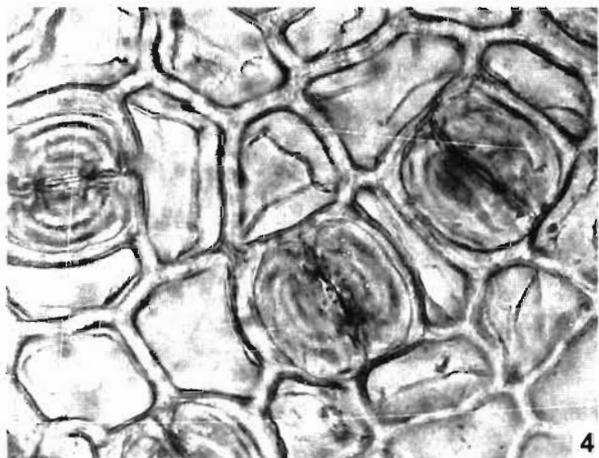
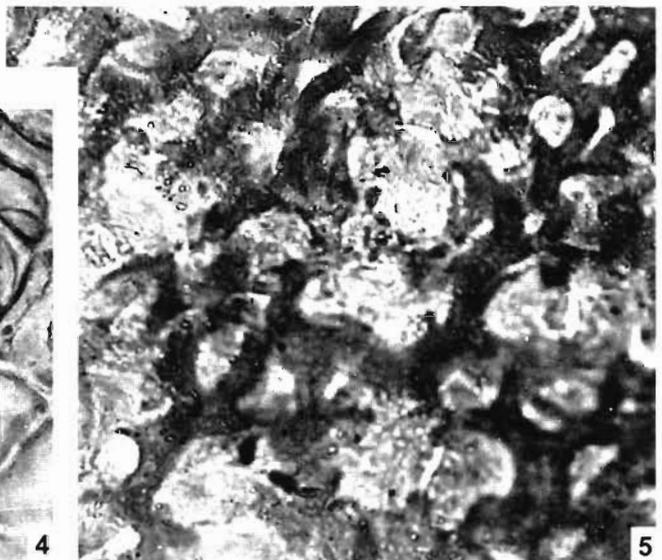
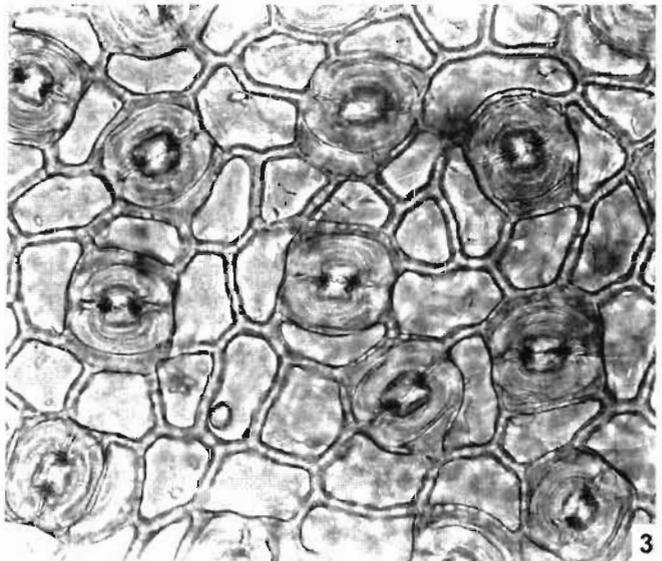
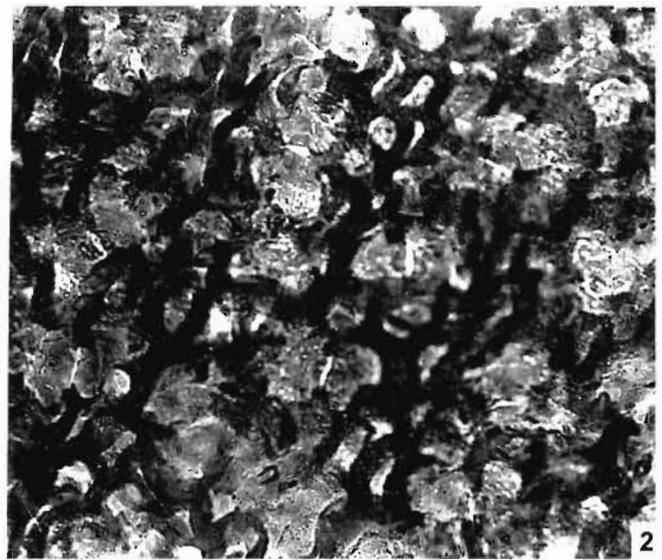


PLATE 2

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