METHODICAL PROBLEMS OF THE BIOPOLYMER ORGANIZATION OF PARTIALLY DEGRADED ECTEXINE

by

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Abstract

A new type of the Markham rotation was introduced for the study of the regular pentagonal biopolymer units of the partially degraded ectexine of *Pinus griffithii* McCLELL. In contrast to the previous methods the centrum of the rotation was not the middle point of an effective biopolymer unit (primary rotation) or a new point of symmetry, which appeared after a primary rotation (secondary rotation), but a new point of symmetry which was indicated as follows: The scheme of a basis PENROSE-unit (a central polygon surrounded with five other pentagonal polygons) was taken for a basis which appeared in consequence of a secondary rotation. The same scheme was re-joint to the first basis PENROSE equivalent modell, and from these new points of symmetry were chosen one for the centrum of the new type of rotation, named as tertiary rotation. Based on our first work, several types (at least three) of tertiary rotation may be distinguished according to the manner of the re-joint, or the orientation of the rotations axis. This new method was suitable to prove biopolymer organization from living plant cell wall built from the basic PENROSE-units.

Introduction.

During the transmission electron microscopical investigations of the partially degraded pollen wall it was established that the basic biopolymer unit is a regular pentagonal polygon. These units are organized into a quasi-crystalloid biopolymer skeleton (KEDVES, 1988a, KEDVES et al. 1988). The MARKHAM rotation method outside to justify the symmetry of the biopolymer unit guaranteed further opportunities. The basic paper for the rotation method applied to the basic biopolymer units and its organization of the plant cell wall was published in 1989 (KEDVES). Naturally the further development of this method seemed necessary "in statu nascendi".

Previously we succeeded in demonstrating a biopolymer system from living plant cell wall a regular pentagonal polygon unit, joint with further five pentagonal polygons with secondary rotation for the first time. This is the basis PENROSE-unti (1979, p. 32, *Fig. 1*). The further problem was evident. Is it a way to demonstrate the "second stage" of PENROSE-system (1979, p. 32, *Fig. 2*) or at least space-equivalent organization from the biopolymer system of the plant cell wall? This paper summarizes our first attempt and results in this subject.

Material

Although the recent experiment of the partial degradation of the plant cell wall mostly on sporomorphs, several regular pentagonal polygon biopolymer units were observed, it seemed to be the best to solve the methodical problems on our so-called standard biopolymer unit. The first documentation, including the first rotation picture from the biopolymer units of the sporopollenin is under publication (KEDVES, 1988b).

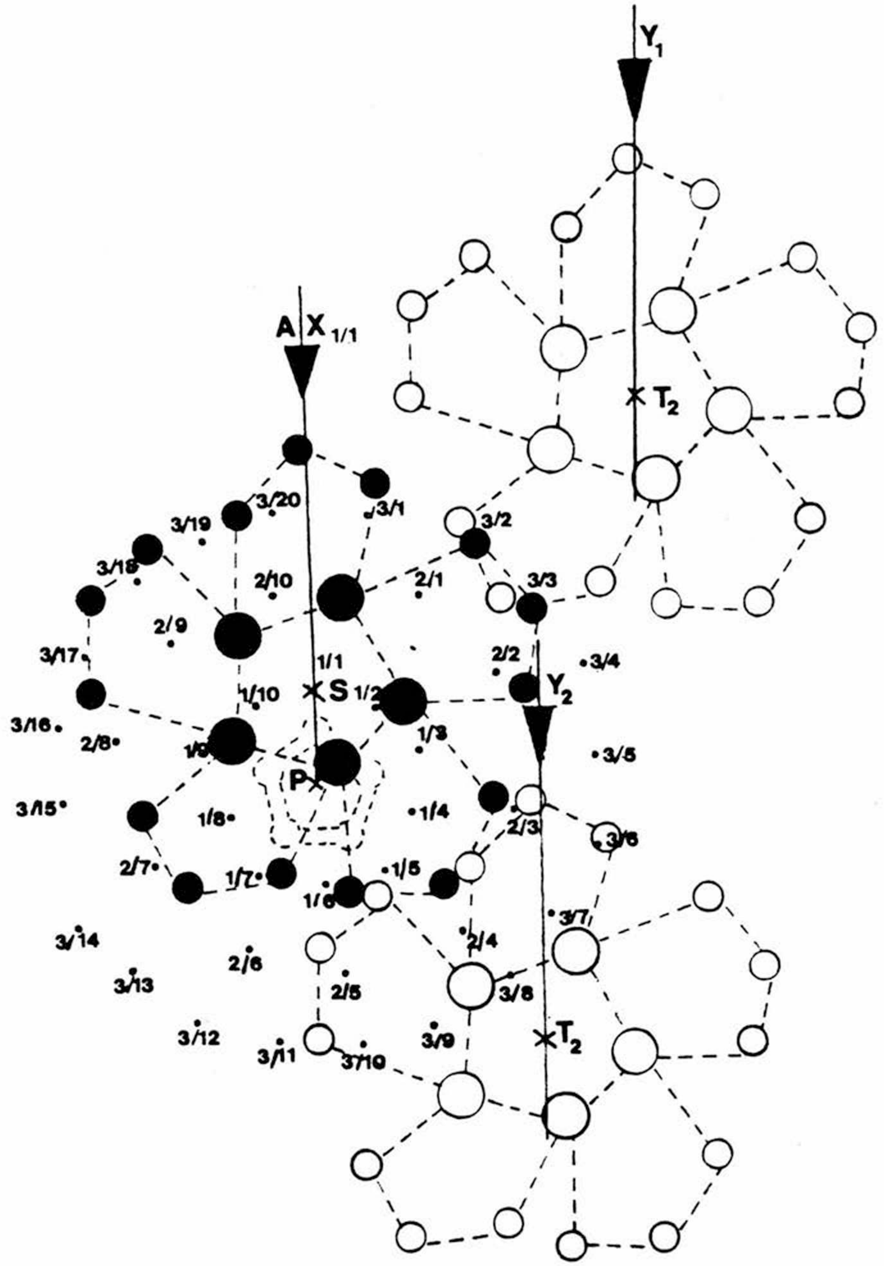

Fig. 1. Scheme of the basic PENROSE-unit, and joint on two point of symmetry after parallelization of the axis of rotation. The basic biopolymer unit is drawn with broken-line, and around the points of symmetry resulted by the rotation C.P.5.A.5.10.

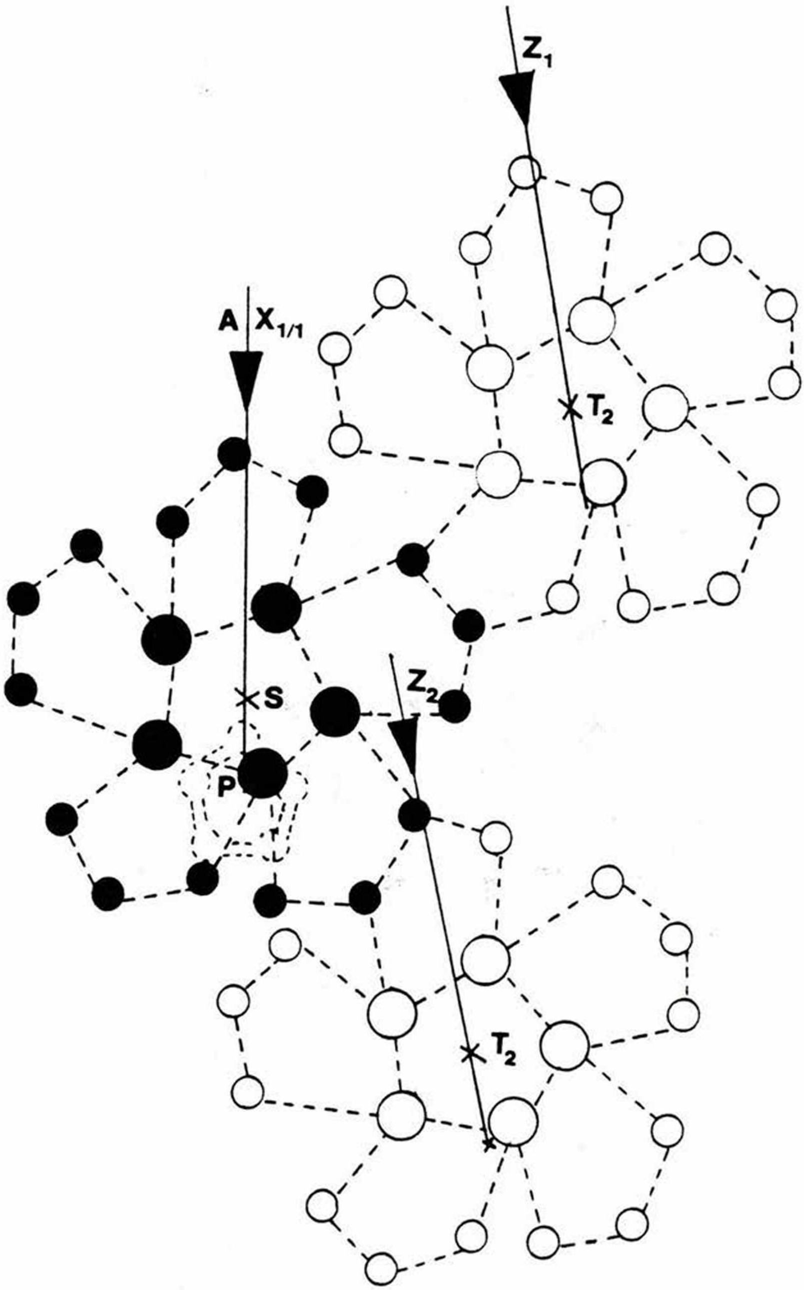

Fig. 2. Scheme for the joint of the basic PENROSE-units on two points of symmetry without the parallelization of the rotation axis.

Basis of the new method and its first results

Before the description of the new method, we shortly refer to the most important criteria of the previously elaborated methodical system.

C. - Complete rotation (the total of the angles of the rotation is 360°).
I. - Incomplete rotation (the total of the angles of the rotation is below 360°).
H. - Complex rotation (the character of the rotation is not uniform).
P. - Primary rotation (the centrum of the rotation is the middle of one bipolymer unit observed with the TEM method).
S. - Secondary rotation (the centrum of the rotation is one of the new points of symmetry which appeared after a primary rotation).

In this place may be place the new one:

T. - Tertiary rotation

The basis is the scheme of a basic PENROSE-unit which resulted after a secondary rotation. Namely a secondary regular pentagonal polygon each side of which is joint to further pentagonal biopolymer unit (Fig. 1-4; Plate I, fig. 1, II, fig. 1. III. fig. 1). To this standard scheme we have joined the same secondary one. The fashion of the joint and the orientation of the rotation axis may be different. On the basis of the fashion of the joint two types were distinguished:

T_2. - Two biopolymer points of symmetry namely one side were covered (Fig. 2, 4, cf. 1).
T_4. - Two sides namely four points of symmetry were covered *(Fig. 3).*

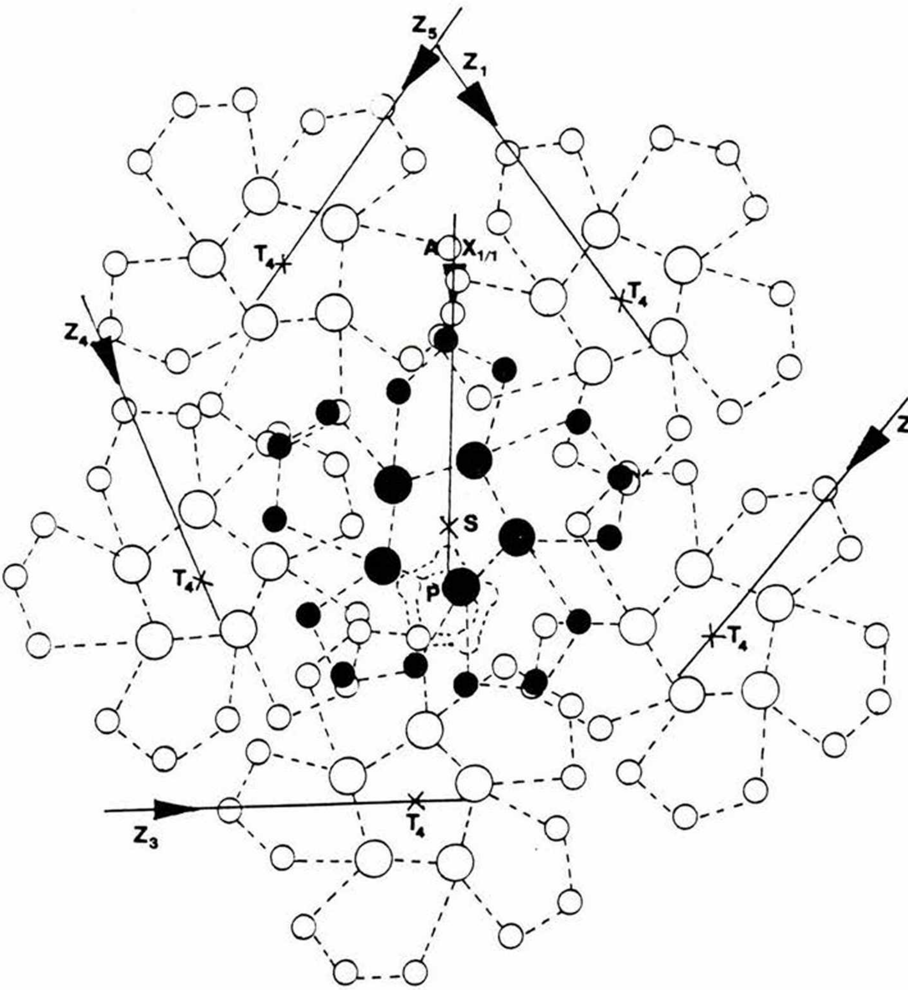

Fig. 3. Scheme of the quasi-crystalloid modell, after the joint of one side (four points of symmetry) of the basic PENROSE-unit.

The designation of the symmetry of the investigated biopolymer unit corresponds to the previous ones (5, 4, 3).

Taking into consideration the axis of the rotation the following were distinguished:

A. - The straight between the centrum of the effective biopolymer and one apex of the biopolymer polygon.
B. - The straight between the centrum of the veritable biopolymer and the bisecting point of two biopolymer polygons.
X. - The straight between the centrum of the veritable biopolymer and a non-primary point of symmetry.
Y. - Parallel with the P. A. axis, and crosses one non-primary point of symmetry.
Z. - The straight which crosses one non-primary point of symmetry, and its direction has a deviation angle.

The designation of the symmetry of the rotation (5, 4, 3 etc.) and the number of the expositions (5, 10, 4, 8, 3, 6 etc.) follows the previous ones.

For the tertiary rotation at the first attempt the scheme of the basic PENROSE-modell was taken for basis. This resulted in a secondary rotation. Centrum of the rotation: S $_{1/1}$, basic picture C.P.5.A.5.10., secondary rotation: C.S.5.X $_{1/1}$.5.5. At the tertiary rotations three manners were used with the two points of symmetry for each kind of rotation. The detail of the method, and the first results are summarized as follows:

1.1. C.T$_2$.5.Y$_1$.5.5. (Fig. 1, Plate I, fig. 2).

Namely the rotation is complete (C), tertiary (T), 2 index indicate that there are two joint biopolymer points of symmetry, 5. = the symmetry of the bipolymer unit. Y designate, that the axis of the tertiary rotation is parallel with the original P. A. axis. Index 1 refers that in relation to the P. A. axis right handed the rotation centrum is the centre of the first basic PENROSE-unit. This is the centrum of the so-called central pentagonal polygon. 5.5. = the symmetry of the rotation, respectively the number of the exposition.

Results. - At the corner of the picture appeared one part of the basis picture, which may be joint to the original (marked with an arrow). We belive, that this phenomenon has a particular importance. It is worth mentioning that when we have completely joined the corner of the fig. 2, with the corresponding part to the picture 1, the rotation axes were not parallel. The tertiary rotation resulted several well definable dark (positive) spherical units. The inner pentagonal polygon is approximatively the same in dimension as the basic biopolymer unit of the primary rotation. This polygon is surrounded by further two pentagonal polygons, bordered with spherical bipolymer units (Plate I, fig. 2). For this biological or molecular orderliness from the "non-biological" papers as analogies we refer to the following: MACKAY (1976), p. 407, "Figure 4 The hierarchic packing of pentagons". PENROSE (1979), p. 34, fig. 8. SACHDEV and NELSON (1985), p. 32, "Fig. 7. (a) Sites of the vertex icosahedral crystal and the Penrose rhombohedra projected along planes perpendicular to a fivefold symmetry axis". AUDIER and GUYOT (1986), fig. 2. "(d) high-resolution TEM micrographs along the five-fold axis (GUYOT and AUDIER 1985)". NELSON (1986), p. 46 "Icosahedral cluster of atoms..." fig. 1-4. SCHNEER (1988), p. 395, "Fig. 5. Inside of the pentagol pyramidal cap of an ISP $_3$ showing six spheres of the cap of the included IS $_2$"

1.2. C.T$_2$5.Y$_2$5.5. (Fig. 1, Plate I, fig. 3)

The centrum of the tertiary rotation was the centre of the second basic PENROSE-unit right handed to the P. A. axis. As this point on the original picture taken from the ultra-thin section is near the edge of the degraded ectexine. The result completely differs from the above discussed one (Plate IV). The appearance of one part at the edge of this tertiary rotations picture is more much express (marked with two arrows). Around the centrum of the rotation in all probability therefore the TEM negative doesn't contain really biopolymer structures, so the method of rotation in consequence of the not sufficient presence of the arrangeable matter resulted only one "fantastic picture" of the basic PENROSE-unit. This may be taken as a control.

2.1. C.T$_2$5.Z$_1$.5.5. (Fig. 2, Plate II, fig. 2)

It is interesting that this tertiary rotation resulted the negative picture of the original pentagonal polygon unit of the same size. The shade of the pin which fixed the centrum of the photographic paper is in the middle of two white globular biopolymer unit. The diameter of this negative pentagonal polygon is approximatively the same as that of the positive biopolymer unit, figured on the plate I, fig. 2. The second greater pentagonal polygon which is bordered with positive granular biopolymer units are identical with the previous ones (Plate I, fig. 2). But the contrast of the globular biopolymer units of the next polygon is not expressed. It is worth mentioning that the connection of the tertiary rotation picture with the basic photo (Plate II, fig. 1) is not so evident.

2.2. C.T2.5.Z2.5.5. (Fig. 2, Plate II, fig. 3)

In this case the centrum of the rotation is also on the dissolving part of the partially degraded ectexine. In this way there is a certain similarity to the previous one (Plate I, fig. 3). This method resulted positive and negative globular biopolymer units, which are arranged into regular pentagonal polygons.

Around a dark circle, which has approximatively the same diameter as the pentagonal polygon biopolymer unit figured on plate II, fig. 1, there are five units which resemble the basic PENROSE-unit. Between the last mentioned units (probably pentagonal polygons) there are frustrations. This tertiary rotation picture may be extremely well joined to the basic picture (marked with two arrows). Probably this is the best first evidence that from living systems – at this moment from the pollen wall – but we managed to demonstrate two connected pentagonal biopolymer organizations consisting of a central pentagonal polygon, which is surrounded by five further also pentagonal polygons. In this way not only the basic PENROSE-unit is present in the biopolymer skeleton of the ectexine. It is worth mentioning too that the demonstrated two basic PENROSE-units are not on the same organization level. This is self-understanding taking into consideration the space arrangement of the regular pentagonal polygon systems.

3.1. C.T4.5.Z1.5.5. (Fig. 3, Plate III, fig. 2)

This kind of tertiary rotation as it is well shown on the fig. 3. corresponds the best with the PENROSE-modell so this has a particular importance from another point of view. The fig. 2. on the plate III, on the one hand, may be well joined to the basic picture (Plate III, fig. 1), on the other hand, a new evidence for the not single PENROSE biopolymer organization in the ectexine. The white globular units forming a pentagonal polygon in the centrum are essentially identical with the fig. 1. on the plate III polygon, which is surrounded by five dark globular biopolymer units. The further so-called large polygon forming globular biopolymer units are not separated so well from the surrounding part. But the next white globular units of the pentagonal polygon is characteristic, and is roughly in the centrum of the five polygons which surround the central polygons. These units are also in the position of the positive biopolymer units.

3.2. C.T4.Z2.5.5. (Fig. 3, Plate III, fig. 3)

The white globular polygon units at the apices of the central pentagonal polygon correspond with the previously discussed (Plate III, fig. 2). But the further points of symmetry so these of the five polygons surrounding the central polygon are not so characteristic. This may be explained with the position of the centrum of the rotation, which is in this case also outside of the partially degraded ectexine. At this place on the ultra-thin sections there are only fragments of the biopolymer structures. But it must be emphasized that the joint of this tertiary rotation picture to the basic picture (Plate III, fig. 1), similarly to the previous also tertiary rotation picture (Plate III, fig. 2) is perfect. This latter connection is marked with three arrows.

Plate IV, represents a review of the real position of the rotation pictures. On a 1,250.000 magnified picture of the TEM structure of the partially degraded ectexine the centrum and the axes of the rotation are indicated. The results of the rotation are oriented in the direction of the corresponding axes. Magnification of these pictrues is 500.000. Well shown are the axes out of the T_2 centrum with different angles (T_2Z_1. 9°; T_2Z_2 11°), and the axes T_4Z_1 respectively T_4Z_2, which represent in principle two sides on one large pentagonal polygon *(Fig. 3.)* The distortion originates from the not so perfect symmetry and position of the biopolymers.

Finally, in connection with the *Fig. 4.* which represents the scheme of the PENROSE-units joint on two points of symmetry. On the basis of our up-to-date knowledge the five basic PENROSE-units surrounding the central unit may form only one more or less regular pentagonal polygon in the way that the manner of the joints are not consistent and are of different value. But the T_2Z_1., and the T_2Z_2 rotation resulted interesting results, and it seems to conclude that later we need to return to this problem thereupon, because at this moment we cannot give a sufficient explication.

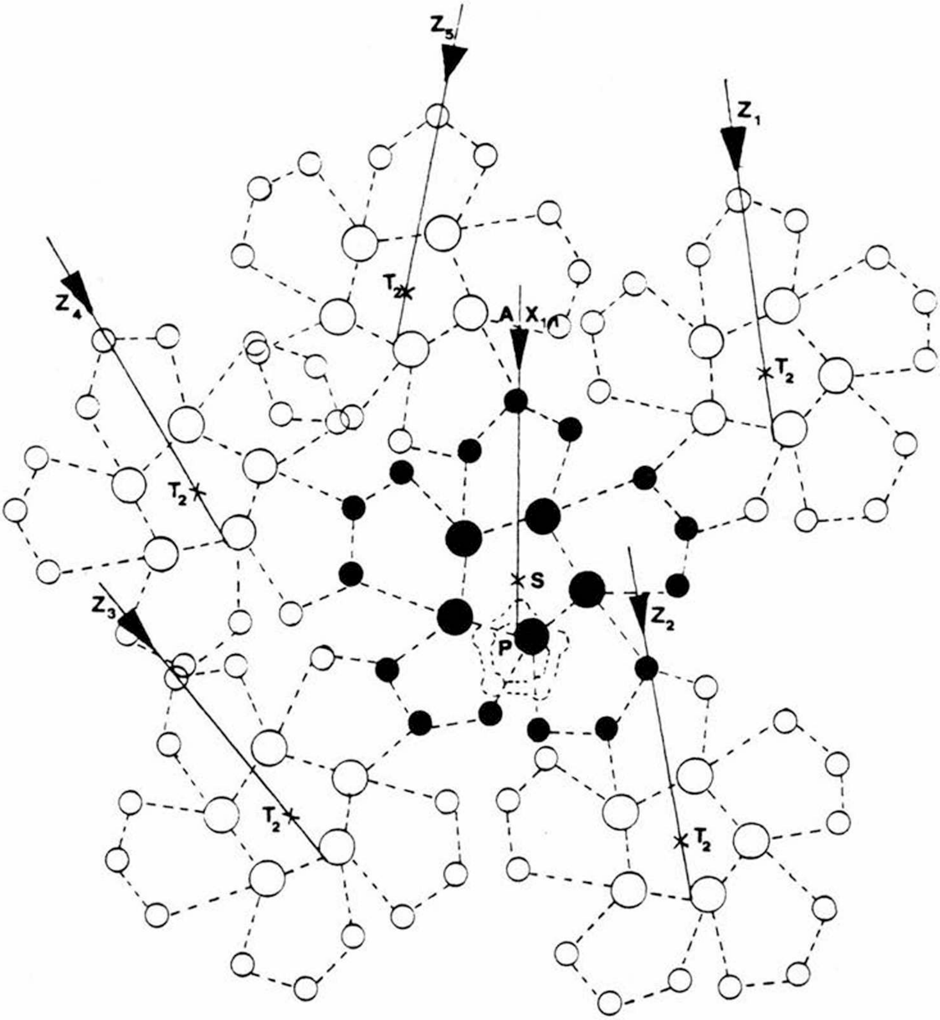

Fig. 4. Scheme of the joint of two points of symmetry. Well shown are that it was not possible to join in every case all the PENROSE-units, and the frustrations between the different units are not the same, and there are overlaps also between the pentagonal polygons. This scheme is published here with the intention of elevating this problem.

Final conclusions

In this paper the bases of the tertiary rotation method elaborated for the study of the organization of the biopolymer structures of the partially degraded exines. Naturally we have not dealt with all the theoretical opportunities because their number seems to be extremely large. Other methodical investigations are in progress, and after the results of these will be decided whether it is necessary to return to this question later.

Acknowledgements

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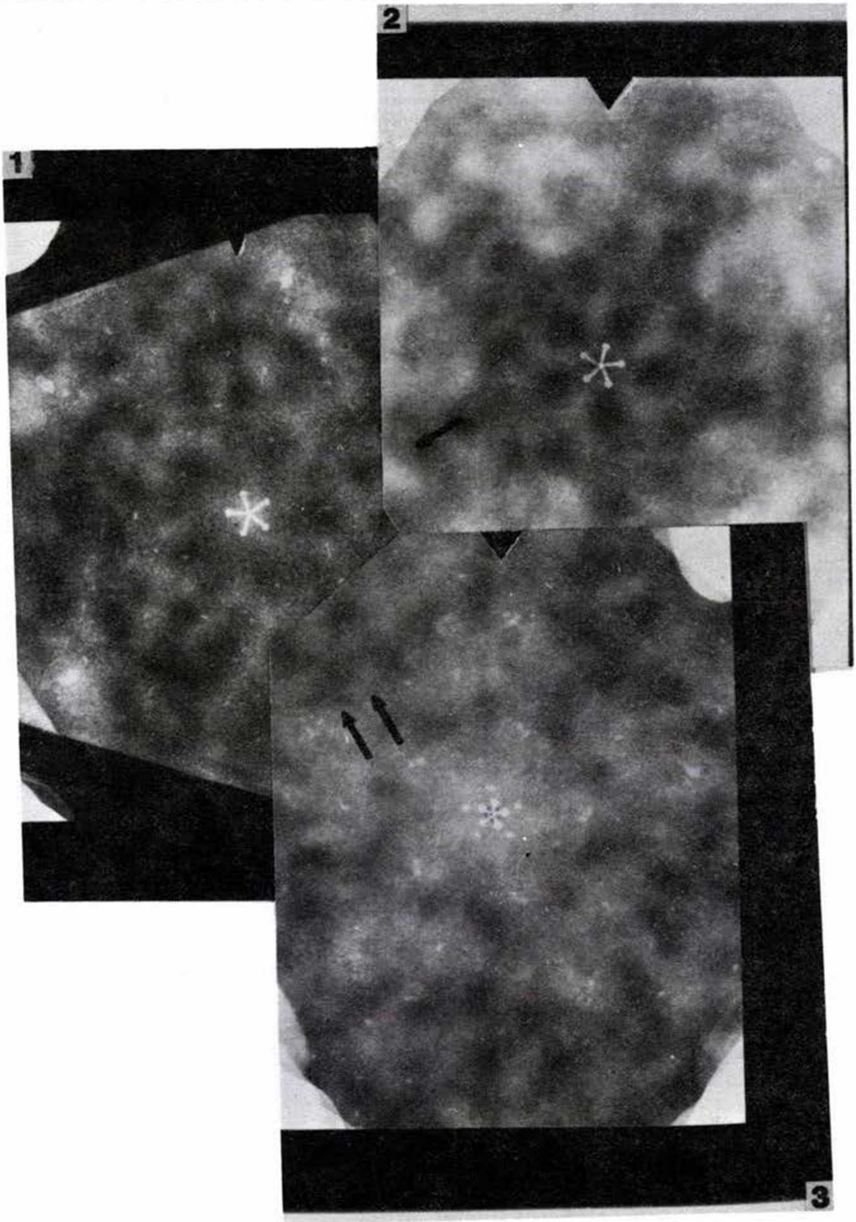

Plate I.

Figs. 1-3. Biopolymer organization of the partially degraded exine of *Pinus griffithii* McCLELL. Fig. 1. The basic secondary rotation picture; C.P. 5. A.5.10., $C.S.5.X_{1}/_{1}.5.5.$, Figs. 2,3. Tertiary rotation pictures. Fig. 2. $C.T_{2}Y_{1}.5.5.$ the joint of the tertiary and secondary rotation pictures is marked with an arrow. Fig. 3. $C.T_{2}.5.Y_{2}.5.5.$ the joint of the tertiary and secondary rotation picture is marked with two arrows. N : 1 million.

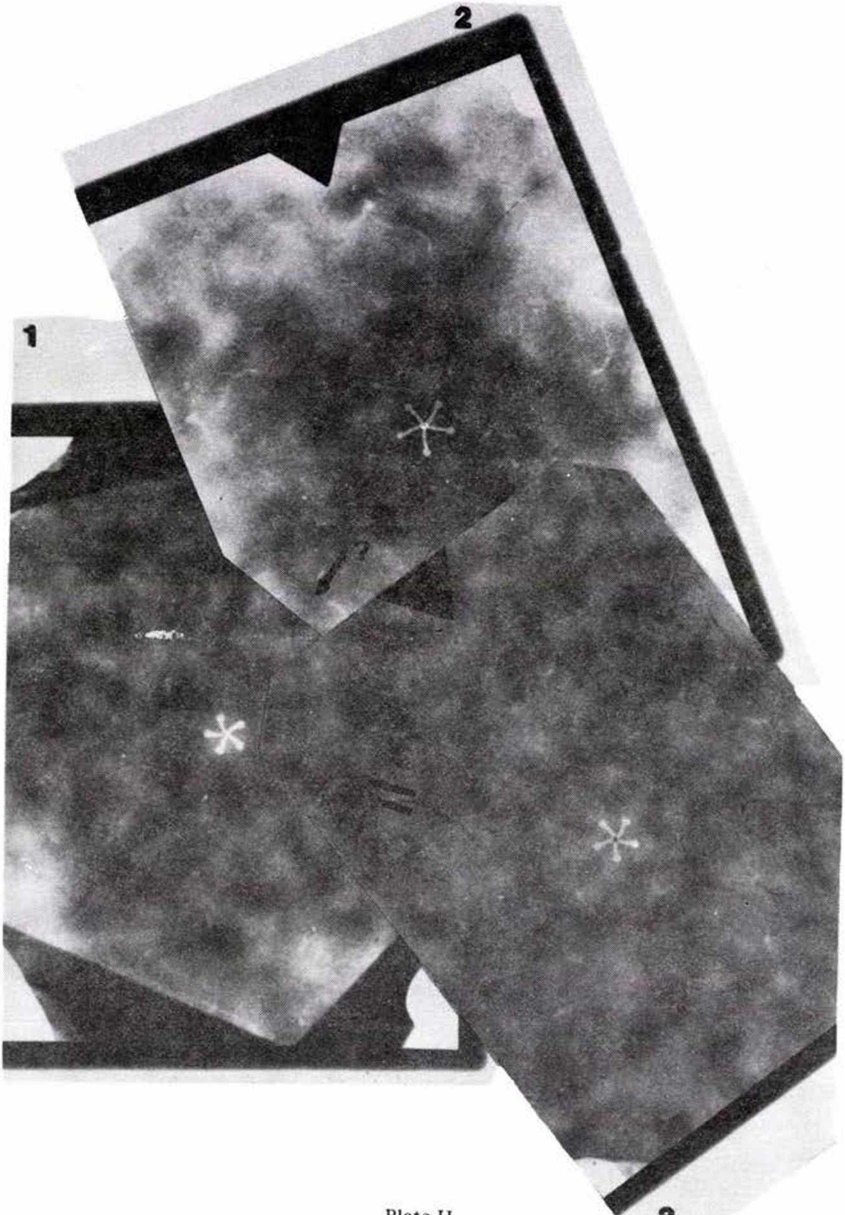

Plate II.

Figs. 1-3. Biopolymer organization of the partially degraded exine of *Pinus griffithii* McCLELL. Fig. 1. The basic secondary rotation picutre; C.P.5.A.5.10., C.S.5.$X_{1/1}$.5.5. Figs. 2,3. Tertiary rotation pictures. Fig. 2. C.$T_2$5.Z_1.5.5. the connection of the tertiary and secondary rotation picture is not so clear, because it is a note of interrogation after the arrow. Fig. 3. C.T_2.5.$Z_2$5.5. the joint of the tertiary and secondary rotation picture is characteristic, marked with two arrows. N : 1 million.

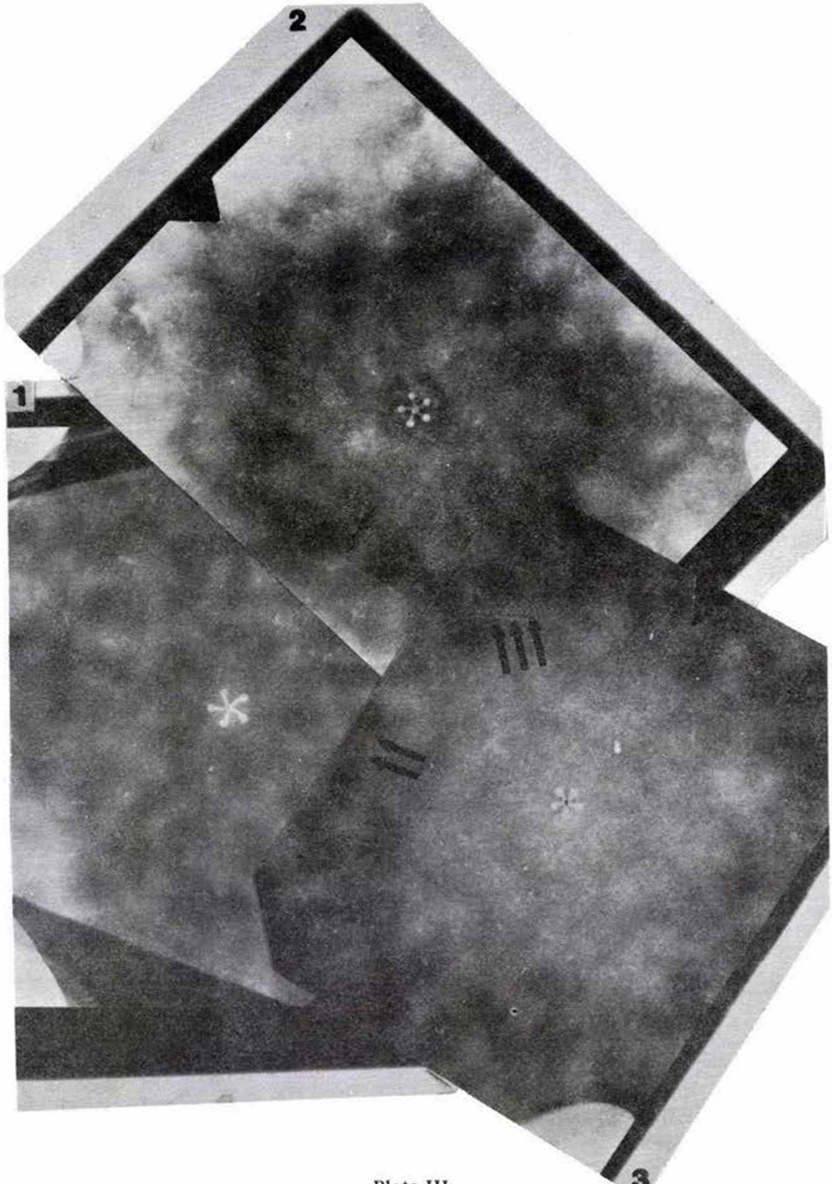

Plate III.

Figs. 1-3. Biopolymer organization of the partially degraded exine of *Pinus griffithii* McCLELL. Fig. 1. The basic secondary rotation picture; C.P.5.A.5.10., C.S.5.$X_{1/1}$.5.5. Figs. 2,3. Tertiary rotation pictures. Fig. 2. C.T_4.5.Z_1.5.5. the joint of the tertiary and secondary rotation pictures is characteristic, marked with an arrow. Fig. 3. C.T_4Z_2.5.5. the secondary and the tertiary rotation pictures joint well, marked with two arrows, moreover the connection of the two tertiary rotation pictures is characteristic, marked with three arrows. N : 1 million.

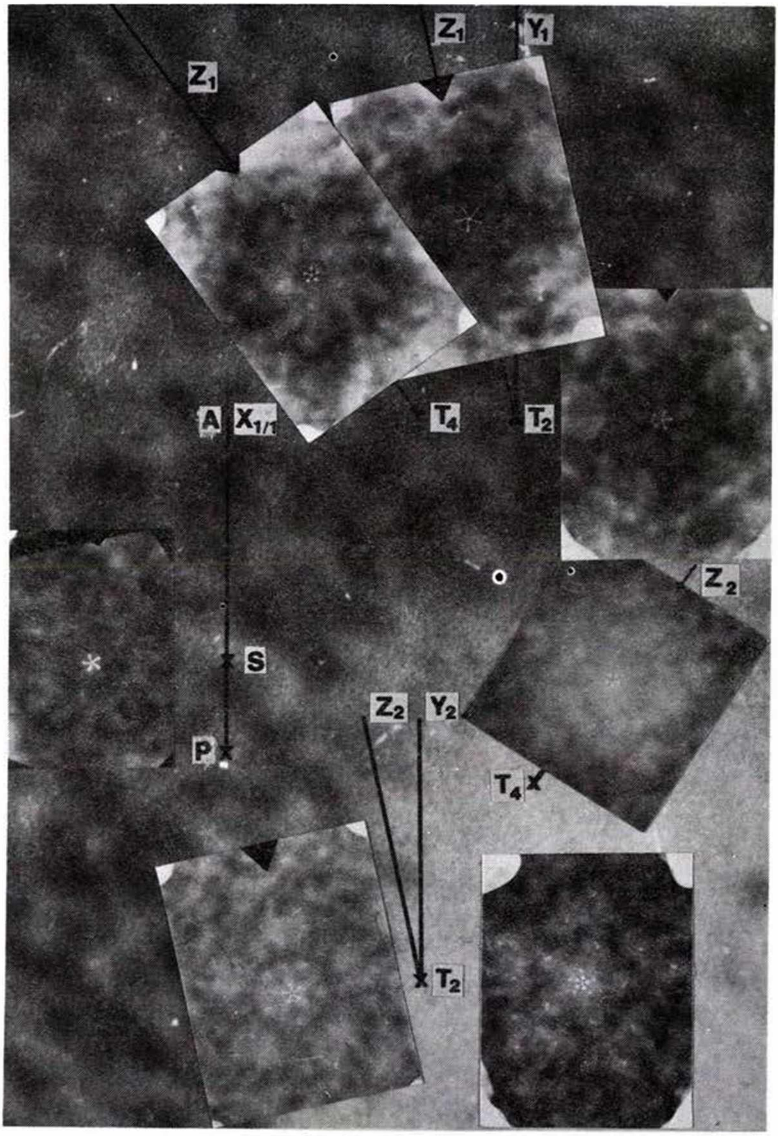

Plate IV.

Comprehensive photo plate about the up-to-date tertiary rotation results. The basis is a TEM picture from the partially degraded ectexine of *Pinus griffithii* McCLELL magnified 1,250.000 P = the centrum of the standard biopolymer unit, P. A. = the basic primary rotation axis, S = the centrum of the basic secondary rotation. $S.X_{1/1}$. = the axis of the secondary rotation, which in this case corresponds to the P. A. axis. T_2, T_4 = tertiary rotation centrum, Y and Z with indexes marks the second points of the tertiary rotation axis. The basic secondary rotation picture and the tertiary rotation pictures are fixed on the basic picture. The magnification of these pictures for the easy to survey is 500.000.

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