7. INCOMPLETE AND NON-FIVEFOLD ROTATION OF THE BASIC BIOPOLYMER UNIT OF THE EXINE OF PINUS GRIFFITHII MCCLELL

M. KEDVES, A. TÓTH and E. GOTTL

1. Cell Biological and Evolutionary Micropaleontological Laboratory of the Department of Botany of the J. A. University, H–6701, P. O. Box 657, Szeged, Hungary

Abstract

In this paper the results of the incomplete and non-fivefold rotation method applied to the basic pentagonal biopolymer unit of *Pinus griffithii* MCCLELL are presented. This is a new contribution to the method of the basic pentagon biopolymer unit of the sporoderm.

Key words: Palynology, exine, biopolymer structure, rotation method.

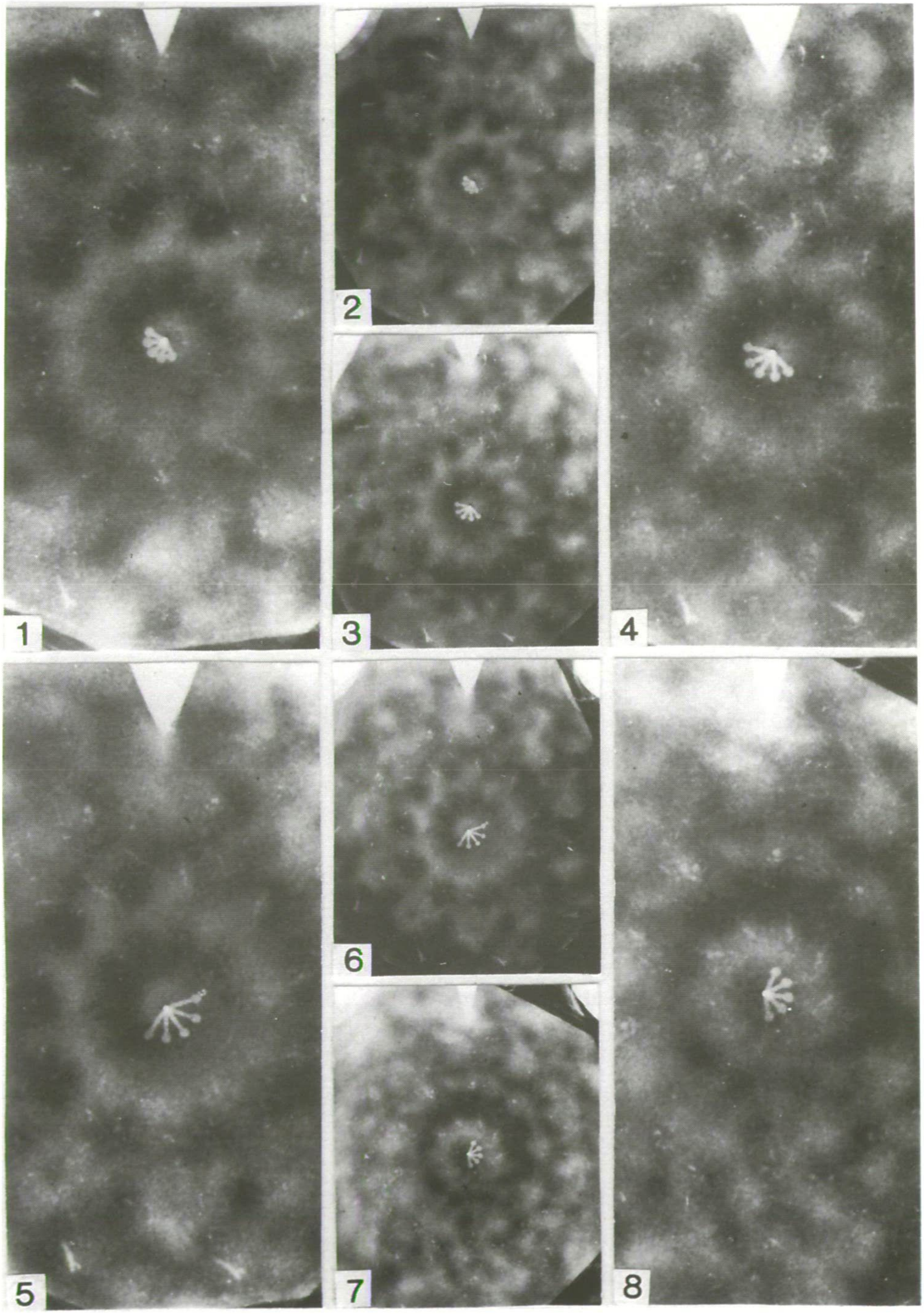
Introduction

It was not long after the discovery of SHECHTMAN, BLECH, GRATIAS and CAHN (1984) that in 1988 the presence of the quasi-crystalloid biopolymer structure in living system was first reported from the partially degraded exine of *Pinus griffithii* MCCLELL (KEDVES, 1988). The research program of this subject has split into several directions. One of them is the basic, two-dimensional field which uses the modified MARKHAM rotation method (e. g., KEDVES, 1989, 1990, KEDVES and FARKAS, 1991, etc.).

In the first methodical paper (KEDVES, 1989) the incomplete and non-fivefold rotation of the regular pentagonal polygon biopolymer system in angstroem dimension was also pointed out as a theoretical possibility. Until now, the non-fivefold rotation method has been used in peculiar cases such as the symmetry operations of the TICOS polyhedra modelling to the biopolymer system (KEDVES, 1991) and to the peculiar biopolymer network of the partially degraded and fragmented wall of *Botryococcus braunii* KÜTZ. isolated from the Upper Tertiary oil shale of Hungary (KEDVES, TÓTH and FARKAS, 1993, in print).

Material and Methods

As it has been emphasized several times in a number of publications (cf. SOUTHWORTH, 1986), the basis of partial degradation is the heterogeneity of the different components of the sporoderm, in general, of the ultrastructural elements of the living systems. In this way the solubility and the resistance of the different components is not the same. Using partial degradation before the TEM method, we obtained several


1
2
3
4
5
6
7
8

data concerning the biopolymer organization of the plant cell wall on different levels. Since this paper is essentially a new methodical contribution to the actual investigations, we have used the basic regular pentagonal unit, discovered first, which was published in several papers before (cf. KEDVES, 1989).

Results

INCOMPLETE ROTATION METHOD
(Plate 7.1., figs. 1–8, plate 7.2., figs. 1–4)

Designations:
I = Incomplete rotation; the total of the angles of rotation is below 360 °.
P = Primary rotation; the centre of rotation is the middle of one biopolymer unit observed with direct TEM method.
I.P.5.A.5.10/2,1–5. (Plate 7.1., figs. 1,2)

In the case a regular fivefold biopolymer unit rotated with the starting AP axis around the first half of the tenfold rotation (C.P.5.A.5.10). 10/2,1–5 indicate, that the expositions were made at the first five rotation axes as follows:
1st exposition – at the 1st globular biopolymer unit of the regular basic pentagon,
2nd exposition – at the central point of the 1st and 2nd globular biopolymer units of the regular basic pentagon,
3rd exposition – at the 2nd globular biopolymer unit of the regular basic pentagon,
4th exposition – at the central point of the 2nd and 3rd globular biopolymer units of the regular basic pentagon,
5th exposition – at the 3rd globular biopolymer unit of the regular basic pentagon.
Short: this rotation may be designated: A – B – A – B – A. Three globular units and two central points.
I.P.5.A.5.10/2,2–6. (Plate 7.1., figs. 3,4)
1st exposition – at the central point of the 1st and 2nd globular biopolymer units of the regular basic pentagon,
2nd exposition – at the 2nd globular biopolymer unit of the regular basic pentagon,
3rd exposition – at the central point of the 3rd and 4th globular biopolymer units of the regular basic pentagon,

◂ Plate 7.1.

1–8. *Pinus griffithii* MCCLELL. Recent. Experiment No: 79, negative no: 7451. Incomplete rotation pictures.
1. I.P.5.A.5.10/2,1–5. 1 Million.
2. I.P.5.A.5.10/2,1–5. 500.000x.
3. I.P.5.A.5.10/2,2–6. 500.000x.
4. I.P.5.A.5.10/2,2–6. 1 Million.
5. I.P.5.A.5.10/2,3–7. 1 Million.
6. I.P.5.A.5.10/2,3–7. 500.000x.
7. I.P.5.A.5.10/2,4–8. 500.000x.
8. I.P.5.A.5.10/2,4–8. 1 Million.

4th exposition – at the 3rd globular biopolymer unit of the regular basic pentagon,
5th exposition – at the central point of the 3rd and 4th globular biopolymer units of the regular basic pentagon.

Short: this rotation may be designated: B – A – B – A – B. Three central points and two globular biopolymer units.

I.P.5.A.5.10/2,3–7. (Plate 7.1., figs. 5,6)

1st exposition – at 2nd globular biopolymer unit of the regular basic pentagon,
2nd exposition – at the central point of the 2nd and 3rd globular biopolymer units of the regular basic pentagon,
3rd exposition – at the 3rd globular biopolymer unit of the regular basic pentagon,
4th exposition – at the central point of the 3rd and 4th globular biopolymer units of the regular basic pentagon,

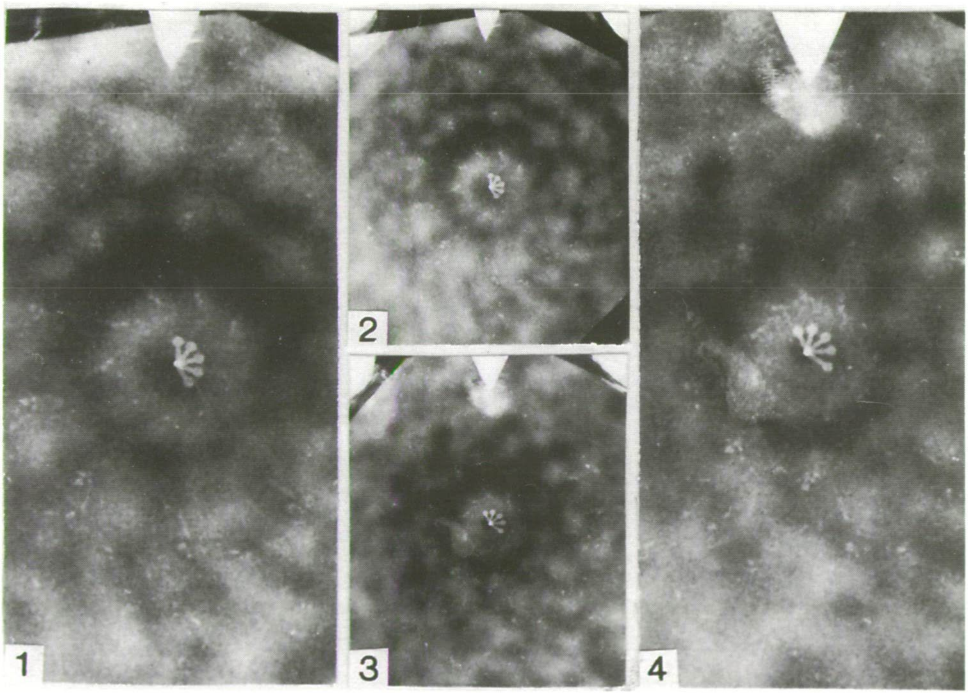


Plate 7.2.

1–4. *Pinus griffithii* McClell. Recent. Experiment No: 79, negative no: 7451. Incomplete rotation pictures.
1. I.P.5.A.5.10/2,5–9. 1 Million.
2. I.P.5.A.5.10/2,5–9. 500.000x.
3. I.P.5.A.5.10/2,6–10. 500.000x.
4. I.P.5.A.5.10/2,6–10. 1 Million.

5th exposition – at the 4th globular biopolymer unit of the regular basic pentagon.
Short: this rotation may be designated: A – B – A – B – A. Three globular units and two central points again.

I.P.5.A.5.10/2,4–8. (Plate 7.1., figs. 7,8)

1st exposition – at the central point of the 2nd and 3rd globular biopolymer units of the regular basic pentagon,
2nd exposition – at the 3rd globular biopolymer unit of the basic regular pentagon,
3rd exposition – at the central point of the 3rd and 4th globular biopolymer units of the regular basic pentagon,
4th exposition – at the 4th globular biopolymer unit of the regular basic pentagon,
5th exposition – at the central point of the 4th and 5th globular biopolymer units of the regular basic pentagon.
Short: this rotation may be designated: B – A – B – A – B. Three central points and two globular units.

I.P.5.A.5.10/2,5–9. (Plate 7.2., figs. 1,2)

1st exposition – at 3rd globular biopolymer unit of the regular basic pentagon,
2nd exposition – at the central point of the 3rd and 4th globular biopolymer units of the basic regular pentagon,
3rd exposition – at the 4th globular biopolymer unit of the regular basic pentagon,
4th exposition – at the central point of the 4th and 5th globular biopolymer units of the basic regular pentagon,
5th exposition – at the 5th globular biopolymer unit of the regular basic pentagon.
Short: this rotation may be designated: A – B – A – B – A. Three globular units and two central points.

I.P.5.A.5.10/2,6–10. (Plate 7.2., figs. 3,4)

1st exposition – at the central point of the 3rd and 4th globular biopolymer units of the basic regular pentagon,
2nd exposition – at the 4th globular biopolymer unit of the regular basic pentagon,
3rd exposition – at the central point of the 4th and 5th globular biopolymer units of the basic regular pentagon,
4th exposition – at the 5th globular biopolymer unit of the regular basic pentagon,
5th exposition – at the central point of the 5th and 1st globular biopolymer units of the basic regular pentagon.
Short: this rotation may be designated: B – A – B – A – B. Three central points and two globular units.

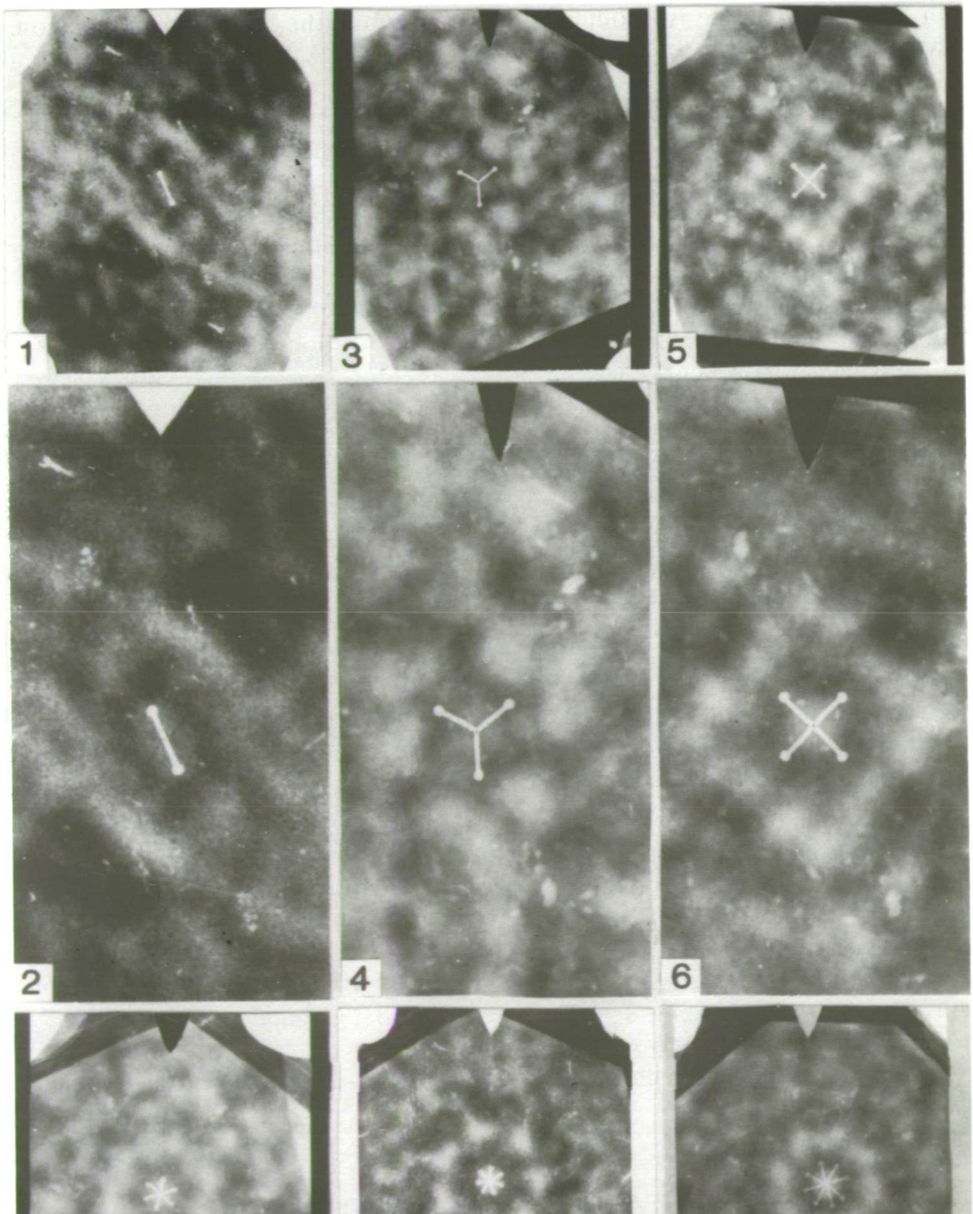
NON-FIVEFOLD ROTATION METHOD OF THE REGULAR BASIC PENTAGONAL BIOPOLYMER UNIT

C.P.5.A.2.2. (Plate 7.3., figs. 1,2)

Interesting secondary points appeared in a peculiar arrangement. This more or less linear biopolymer system is oblique to the PA axis.

C.P.5.A.3.3. (Plate 7.3., figs. 3,4)

In the two circles two times three points of symmetries are reinforced.


1
3
5
2
4
6
7
8
9

C.P.5.A.4.4. (Plate 7.3., figs. 5,6)

Quadrangular points of symmetry appeared with well characterized rotation areas. The discussion of the rotation areas is under preparation in another paper.

C.P.5.A.3.6. (Plate 7.3., fig. 7, plate 7.4., fig. 1)

Interesting circular points of symmetry appeared. These are sexangular in several circles, but the elements of symmetry that appeared in the same circle are not equivalent.

C.P.5.A.7.7. (Plate 7.3., fig. 8, plate 7.4., fig. 2)

This kind of rotation also resulted seven positive and negative points of symmetry together with characteristic rotation areas. But similarly to the previous one, an interesting kind of asymmetry can be observed at the secondary points of symmetry.

C.P.5.A.4.8. (Plate 7.3., fig. 9, plate 7.4., fig. 3)

Negative and positive points of symmetry appeared. The rotation area is almost symmetrical.

C.P.5.A.9.9. (Plate 7.4., figs. 4,5)

This kind of ninefold rotation is essentially the same as the previous one, except for the fact that there are nine positive and nine negative points of symmetry. The rotation area is characteristic.

Secondary rotation picture: C.P.5.A.2.2. – C.S.X$_{1/2}$.2.2. (Plate 7.4., figs. 6,7)

Several twofold biopolymer units appeared following this kind of secondary rotation. The whole picture and the orientation is similar to those of the primary twofold rotation of the pentagonal biopolymer unit.

Secondary rotation picture: C.P.5.A.2.2. – C.S.X$_{1/2}$.5.5. (Plate 7.5., figs. 1,4)

Very characteristic fivefold positive and negative points of symmetry appeared after this kind of rotation, together with characteristic rotation areas.

Secondary rotation picture: C.P.5.A.2.2. – C.S.X$_{1/2}$.4.4. (Plate 7.5., figs. 2,5)

The secondary points that appeared are of tetragonal symmetry with the characteristic rotation areas. The points are more or less duplicate.

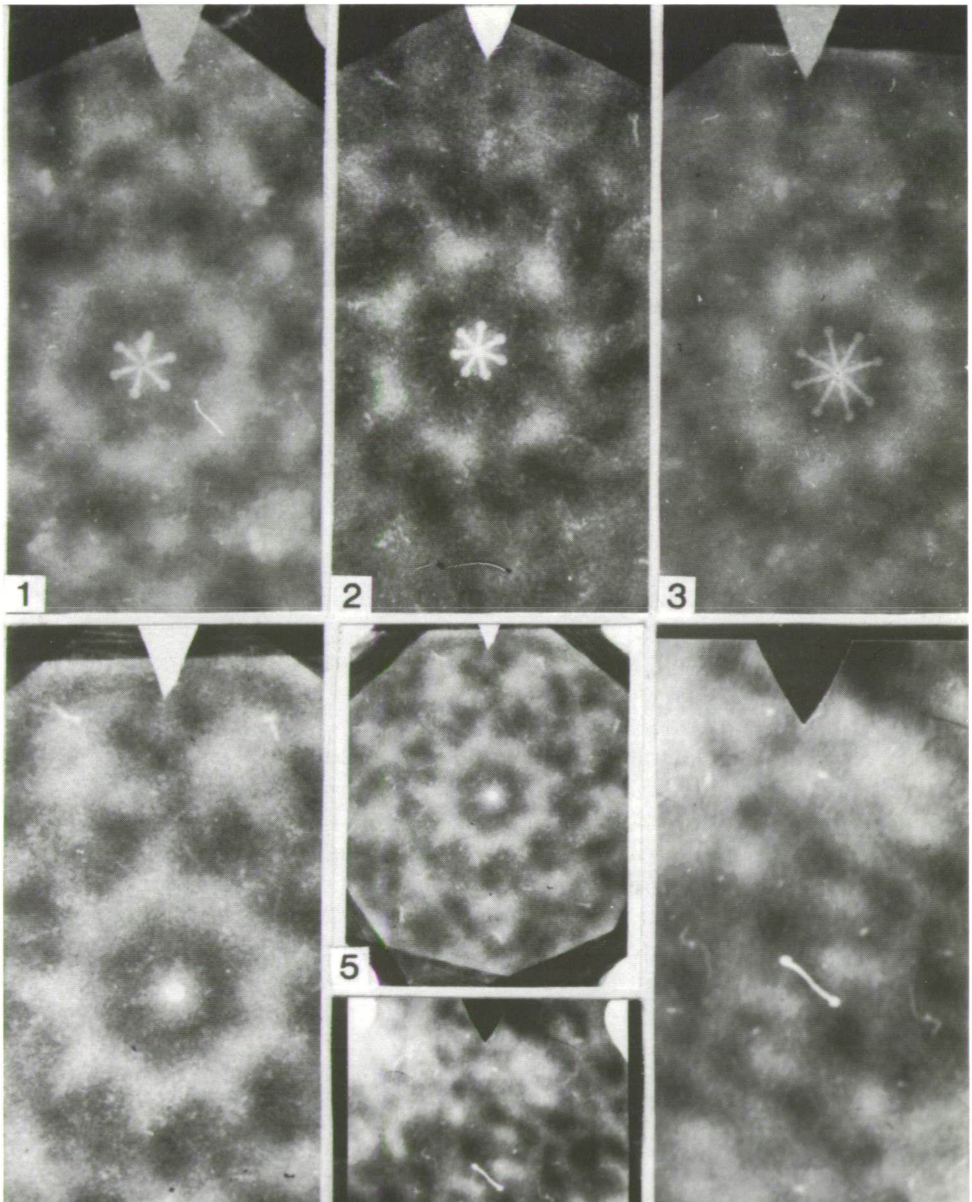
Secondary rotation picture: C.P.5.A.4.4. – C.S.X$_{2/1}$.5.5. (Plate 7.5., figs. 3,6)

Several positive and negative points of symmetry appeared in an unusual, interesting pentagonal arrangement. The delineation of the rotation area is definite.

◂ Plate 7.3

1–9. *Pinus griffithii* McClell. Recent. Experiment No: 79, negative no: 7451. Non-fivefold rotation pictures.

1. C.P.5.A.2.2. 500.000x.
2. C.P.5.A.2.2. 1 Million.
3. C.P.5.A.3.3. 500.000x.
4. C.P.5.A.3.3. 1 Million.
5. C.P.5.A.4.4. 500.000x.
6. C.P.5.A.4.4. 1 Million.
7. C.P.5.A.3.6. 500.000x.
8. C.P.5.A.7.7. 500.000x.
9. C.P.5.A.4.8. 500.000x.


1
2
3
4
5
6
7

Secondary rotation picture: C.P.5.A.3.6. – C.S.$X_{2/1}$.3.6. (Plate 7.6., figs. 1,2)

The rotation area is characteristic and sexangular. The positive and negative secondary points of symmetry are generally duplicate.

Secondary rotation picture: C.P.5.A.3.6. – C.S.$X_{2/1}$.5.5. (Plate 7.6., figs. 3,4)

The secondary points of symmetry are in a pentagonal arrangement. The delineation of the rotation area is not characteristically straight.

Discussion and Conclusions

Regarding the incomplete rotation, our methodical results can be summarized as follows:

			A	B
10/2, 1–5,	7.1.,1,2	A – B – A – B – A	3	2
10/2, 2–6,	7.1.,3,4	B – A – B – A – B	2	3
10/2, 3–7,	7.1.,5,6	A – B – A – B – A	3	2
10/2, 4–8,	7.1.,7,8	B – A – B – A – B	2	3
10/2, 5–9,	7.2.,1,2	A – B – A – B – A	3	2
10/2, 6–10,	7.2.,3,4	B – A – B – A – B	2	3

It is a normal periodicity at this kind of rotation. But when we compare the results of 10/2,1–5, 3–7, 5–9, and 10/2, 2–6, 4–8, 6–10, it is not so easy to distinguish between the similarities of these two groups. It is interesting that at all of the "half tenfold" rotations the results are almost identical with the secondary points of symmetry of a tenfold rotation. The differences can also be established in contrast to the rotation pictures.

The results of the non-fivefold rotation of the basic regular pentagonal biopolymer unit verified again the complexity of the biopolymer system of the sporoderm. To this, the three-dimensional modelling of the quasi-crystalloid biopolymer unit (KEDVES 1991b, 1992, and KEDVES, TÓTH and FARKAS, 1993, in print) contribute useful pieces of information. The arrangement of the units of biopolymer systems seems to have a lot of variations.

◂ Plate 7.4.

1–7. *Pinus griffithii* MCCLELL. Recent. Experiment No: 79, negative no: 7451.
1–5. Non-fivefold rotation pictures.
1. C.P.5.A.3.6. 1 Million.
2. C.P.5.A.7.7. 1 Million.
3. C.P.5.A.4.8. 1 Million.
4. C.P.5.A.9.9. 1 Million.
5. C.P.5.A.9.9. 1 Million.
6. Secondary rotation picture: C.P.5.A.2.2. – C.S.$X_{1/2}$.2.2. 500.000x.
7. Secondary rotation picture: C.P.5.A.2.2. – C.S.$X_{1/2}$.2.2. 1 Million.

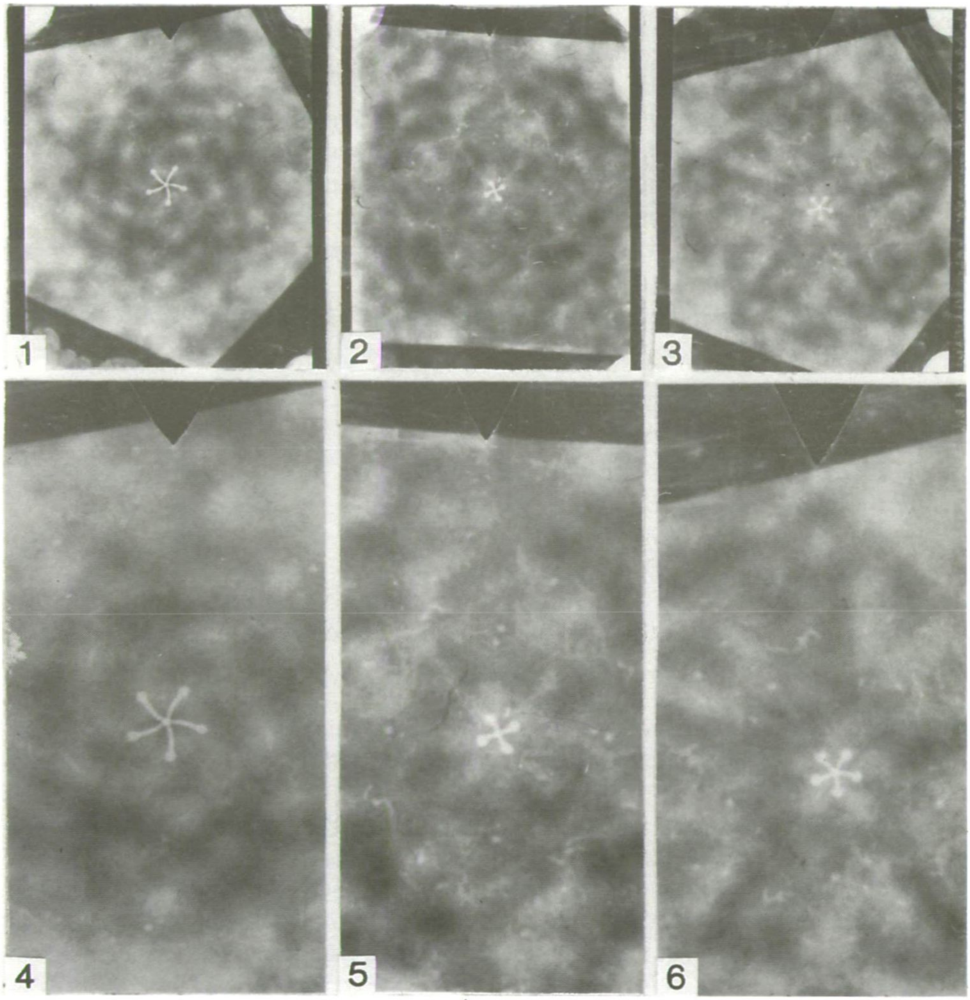


Plate 7.5.

1–6. *Pinus griffithii* McClell. Recent. Experiment No: 79, negative no: 7451.
1. Secondary rotation picture: C.P.5.A.2.2. – C.S.$X_{1/2}$.5.5. 500.000x.
2. Secondary rotation picture: C.P.5.A.4.4. – C.S.$X_{2/1}$.4.4. 500.000x.
3. Secondary rotation picture: C.P.5.A.4.4. – C.S.$X_{2/1}$.5.5. 500.000x.
4. Secondary rotation picture: C.P.5.A.2.2. – C.S.$X_{1/2}$.5.5. 1 Million.
5. Secondary rotation picture: C.P.5.A.4.4. – C.S.$X_{2/1}$.4.4. 1 Million.
6. Secondary rotation picture: C.P.5.A.4.4. – C.S.$X_{2/1}$.5.5. 1 Million.

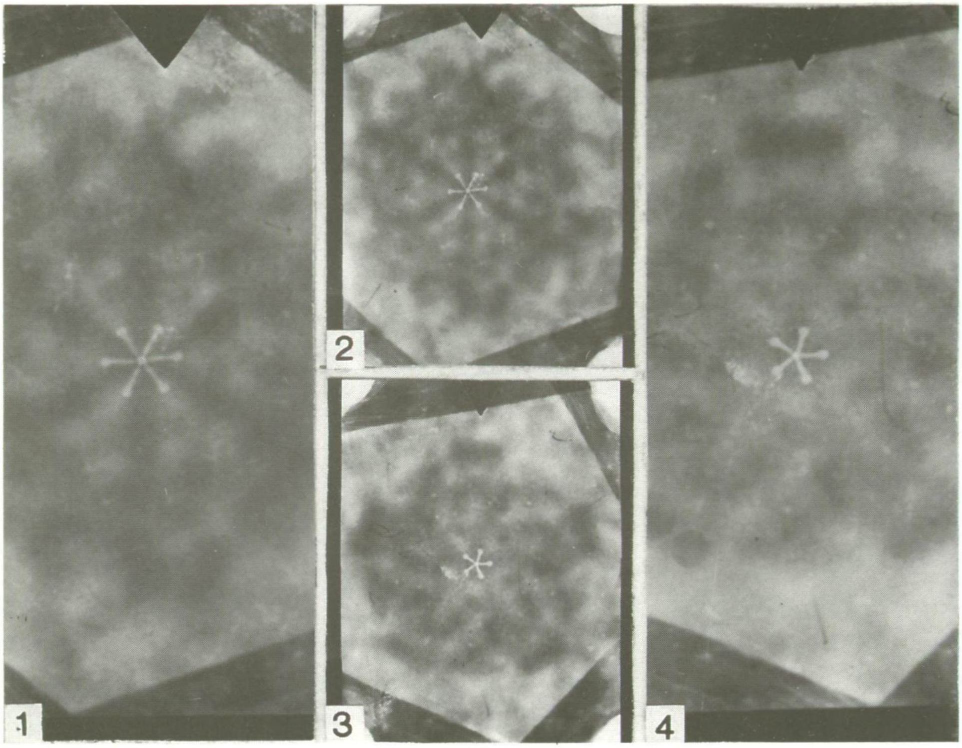


Plate 7.6.

1–4. *Pinus griffithii* McClell. Recent. Experiment No: 79, negative no: 7451.
1. Secondary rotation picture: C.P.5.A.3.6. – C.S.$X_{2/1}$.3.6. 1 Million.
2. Secondary rotation picture: C.P.5.A.3.6. – C.S.$X_{2/1}$.3.6. 500.000x.
3. Secondary rotation picture: C.P.5.A.3.6. – C.S.$X_{2/1}$.5.5. 500.000x.
4. Secondary rotation picture: C.P.5.A.3.6. – C.S.$X_{2/1}$.5.5. 1 Million.

Acknowledgements

This work was supported by the Grant OTKA 1/3, 104.

References

Kedves, M. (1988): Quasi-crystalloid basic molecular structure of the sporoderm. – 7 Internat. Palynol. Congr. Brisbane, Abstracts, 82.

Kedves, M. (1989): Méthod d'étude des biopolymères de la paroi pollinique à structure quasi-cristalloïde. – Rev. de Micropaléontologie *32,* 226–234.

Kedves, M. (1990): Quasi-crystalloid basic molecular structure of the sporoderm. – Rev. Palaeobot. Palynol. *64,* 181–186.

KEDVES, M. (1991a): TICOS polyhedra as a model in the pentasporan organization. In: Plant Cell Biology and Development *2*, ed.: M. KEDVES, 43–48, Szeged.
KEDVES, M. (1991b): Three dimensional modelling of the biopolymer structure of the plant cell wall I. In: Plant Cell Biology and Development *2*, ed.: M. KEDVES, 63–74, Szeged.
KEDVES, M. (1992): Three dimensional modelling of the biopolymer structure of the plant cell wall II. In: Plant Cell Biology and Development *3*, ed.: M. KEDVES, 67–87, Szeged.
KEDVES, M. and FARKAS, E. (1991): Basis of the tertiary rotation and TICOS modelling of the quasi-crystalloid biopolymer skeleton of the plant cell. In: Plant Cell Biology and Development *2*, ed.: M. KEDVES, 36–42, Szeged.
KEDVES, M., TÓTH, A. and FARKAS, E. (1993, in print): Experimental investigation of the biopolymer organization of both recent abd fossil sporoderms. – Grana,
SHECHTMAN, D., BLECH, I., GRATIAS, D. and CAHN, J. W. (1984): Metallic phase with long-range order and no translational symmetry. – Phys. Rev. Lett. *53*, 1951–1953.
SOUTHWORTH, D. (1986): Substructural organization of pollen exines. In: Pollen and Spores: Form and Function, eds.: S. BLACKMORE and I. K. FERGUSON, 61–69, Linnean Soc. London.