Ultrastructure of the hen eggshell
and its physiological interpretation

Figures

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Introduction

This volume of figures and captions forms an integral part of the book 'Ultrastructure of the hen eggshell and its physiological interpretation'.

Most of the plates are from photographs taken by the Technical and Physical Engineering Research Service at Wageningen.

A few are from photographs made under a Leitz Ortholux light microscope (l.m.).

Some transmission electron micrographs (t.e.m.) were made with a Philips EM 100; others with a Siemens Elmiskop I or Philips EM 300 transmission electron microscope.

Scanning electron micrographs (s.e.m.) were made with a Stereoscan or JSM 2 scanning electron microscope.

The section of plate enclosed by a rectangle is enlarged on another plate.

An arrow on the left hand side at the top of the photographs, points towards the outside of the eggshell.

List of abbreviations

be	=	belt
ca	=	cavity
ch	=	central hole
cv	=	cuticular vesicle
de	=	deposit
fb	=	fibre bundle
fc	=	fibre core
fcl	=	fibre cleft
fh	=	fibre hole
fi	=	fibril
fm	=	fibre mantle
fp	=	fibre protuberances
fs	=	fibre of shell membrane
fv	=	fibre vacuole
il	=	inner layer of inner membrane
IM	=	Inner Membrane
is	=	intermammillary space
la	=	lamella
LC	=	Layer of Cones and basal caps
lh	=	large hole
mcl	=	cleft between mammillae
OM	=	Outer Membrane
ph	=	pitlike hole
PL	=	Palisade Layer
pl	=	plug
po	=	pore
pp	=	pore plaque
ro	=	row of small openings
SC	=	Surface Crystal layer
TC	=	True Cuticle
th	=	triangular hole
vh	=	vesicular hole

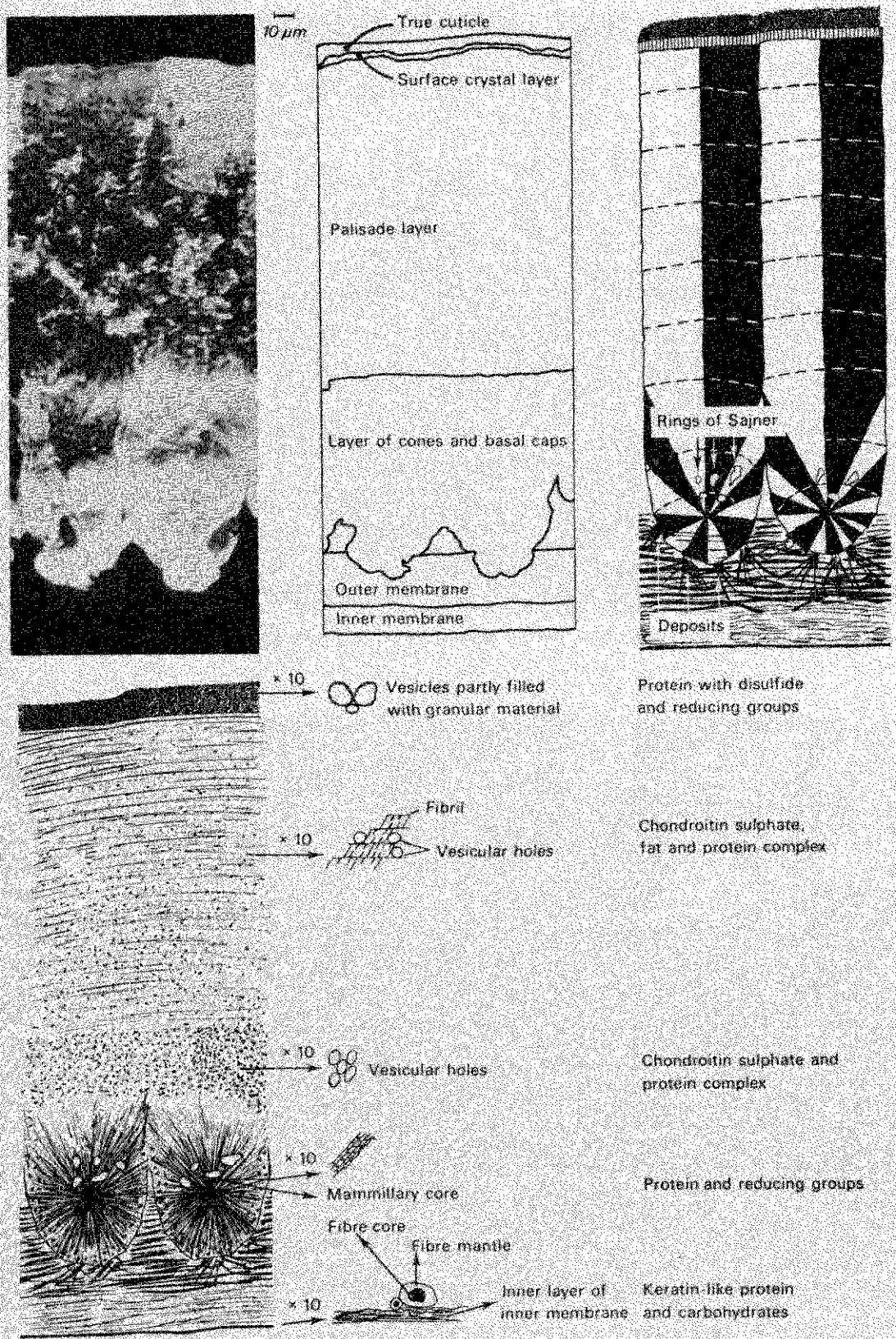

Fig. 1. Diagrammatic representation of a radial section of the shell and membranes of the hen egg showing the crystalline structure above and the organic material below (Organic composition according to Simkiss, 1958).

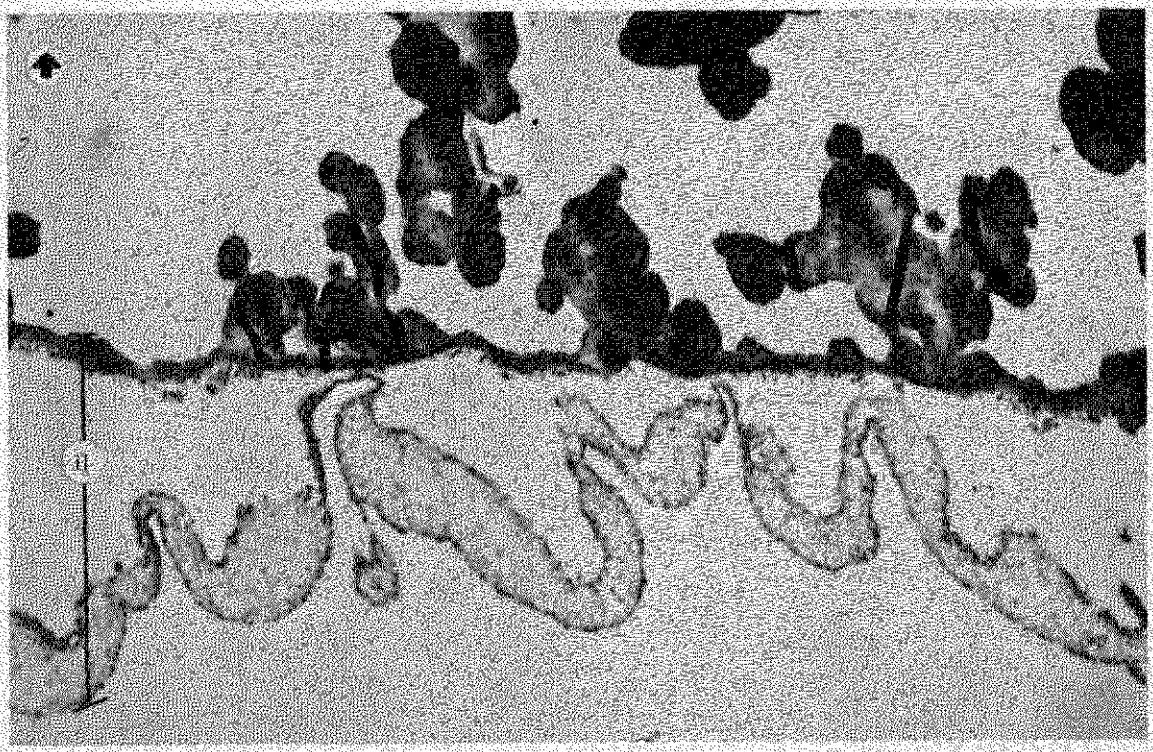

Fig. 2. Egg 568. Radial section inner layer of inner membrane. $KMnO_4$-stain. (12,000×, t.e.m.)

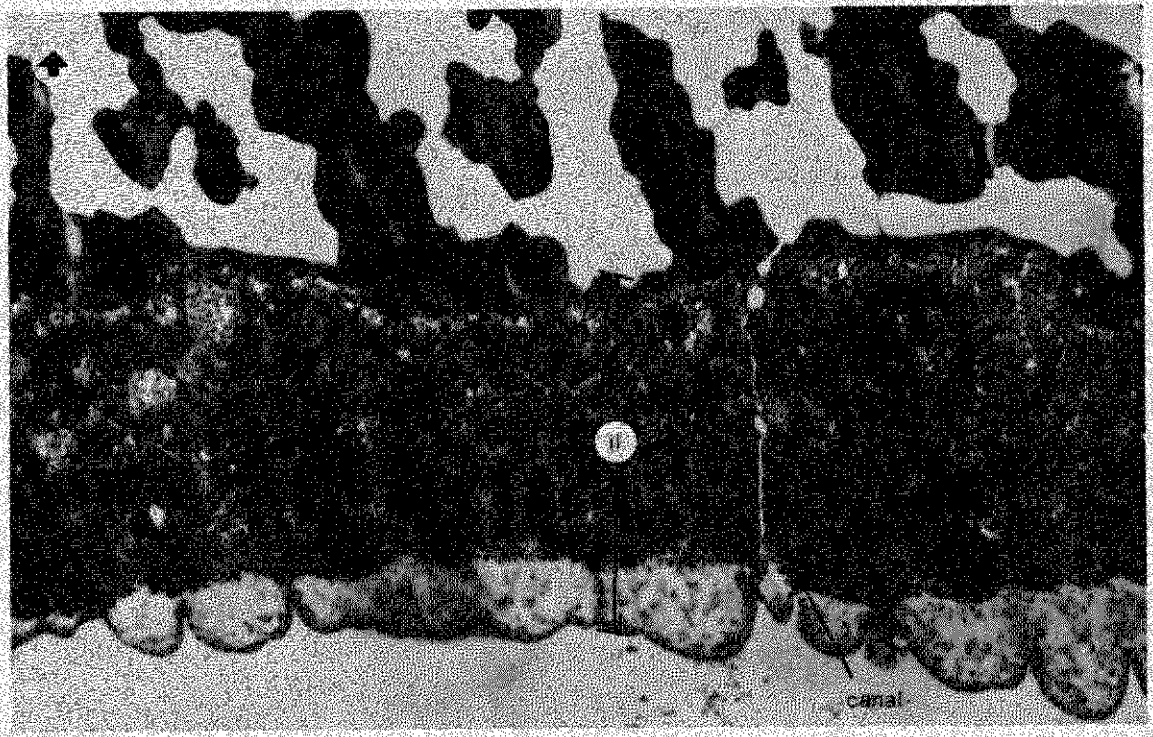

Fig. 3. Egg 502. Radial section inner layer of inner membrane. $KMnO_4$-stain. (9,000× t.e.m.)

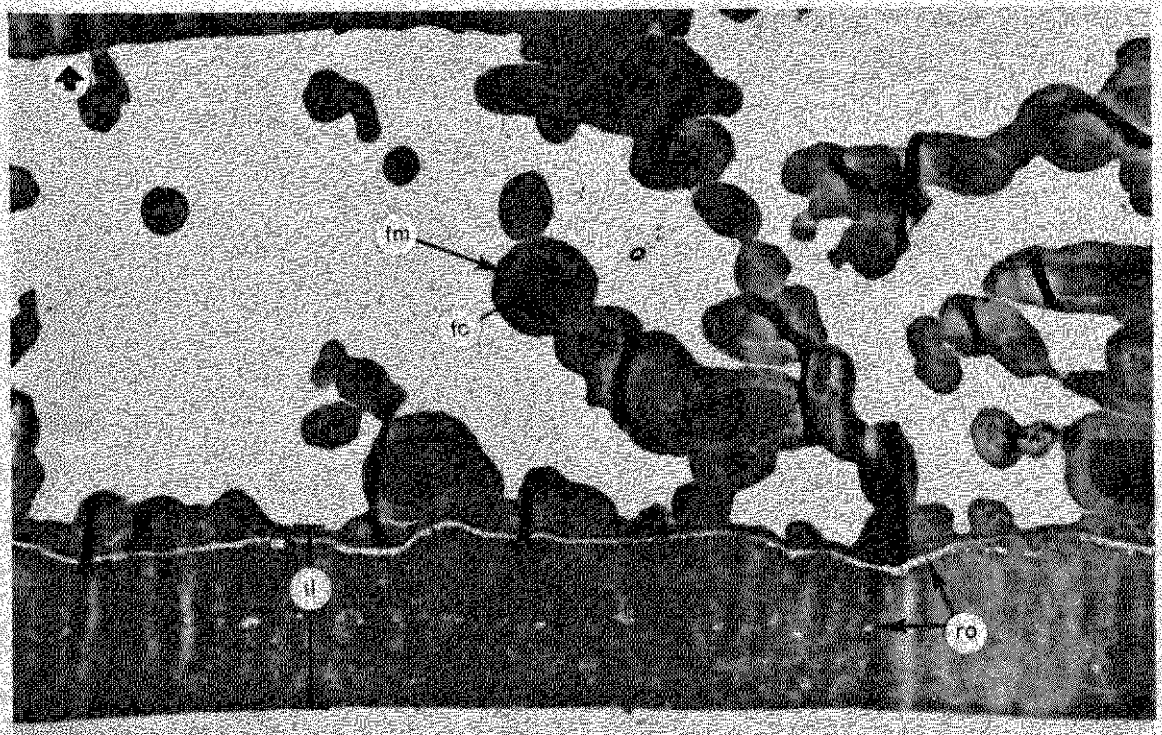

Fig. 4. Egg 597. Radial section inner layer of inner membrane. $KMnO_4$-stain. (9,000×, t.e.m.)

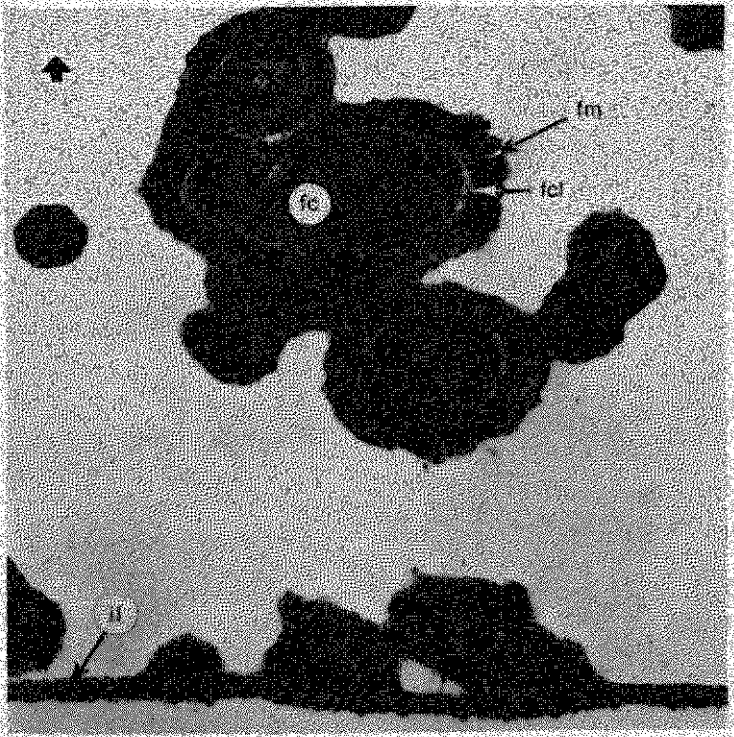

Fig. 5. Radial section inner part of inner membrane of a 4 h premature egg. (17,000 ×, t.e.m.)

Fig. 6. Inner layer of inner membrane seen from inside. (490 ×, s.e.m.)

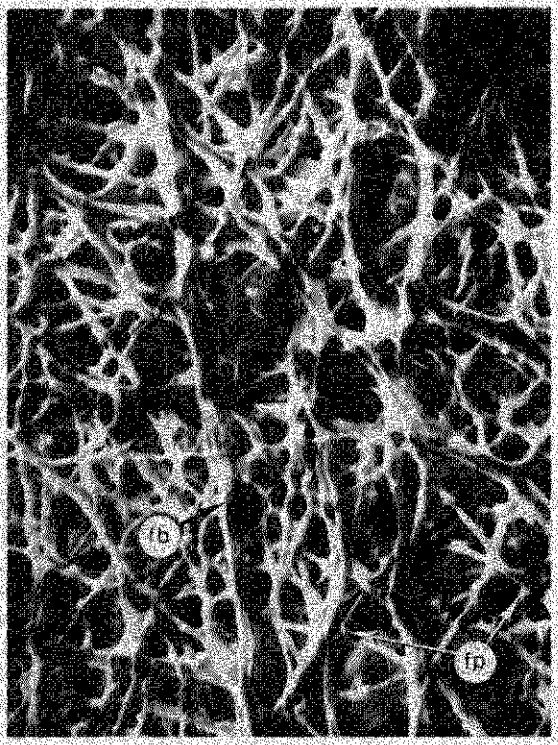

Fig. 7. Outer membrane seen from inside. (1,600 ×, s.e.m.)

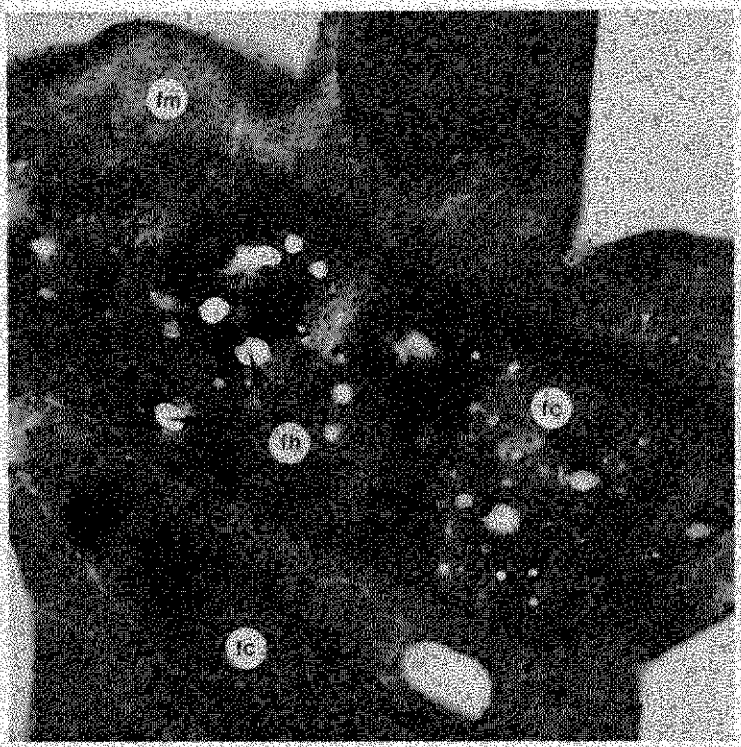

Fig. 8. Radial section fibres outer membrane. (17,000 ×, t.e.m.)

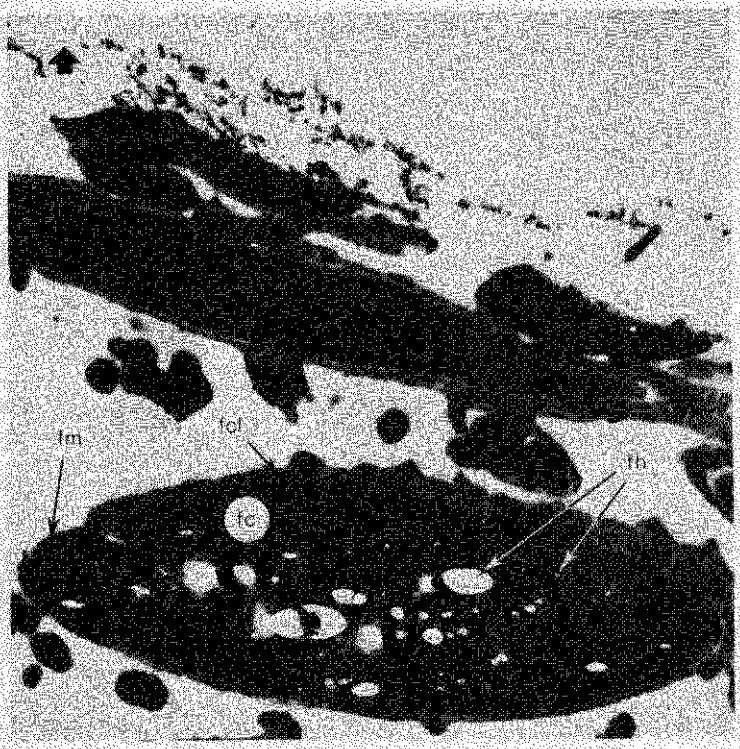

Fig. 9. Radial section outer part outer membrane of premature isthmus egg. (6,200 ×, t.e.m.)

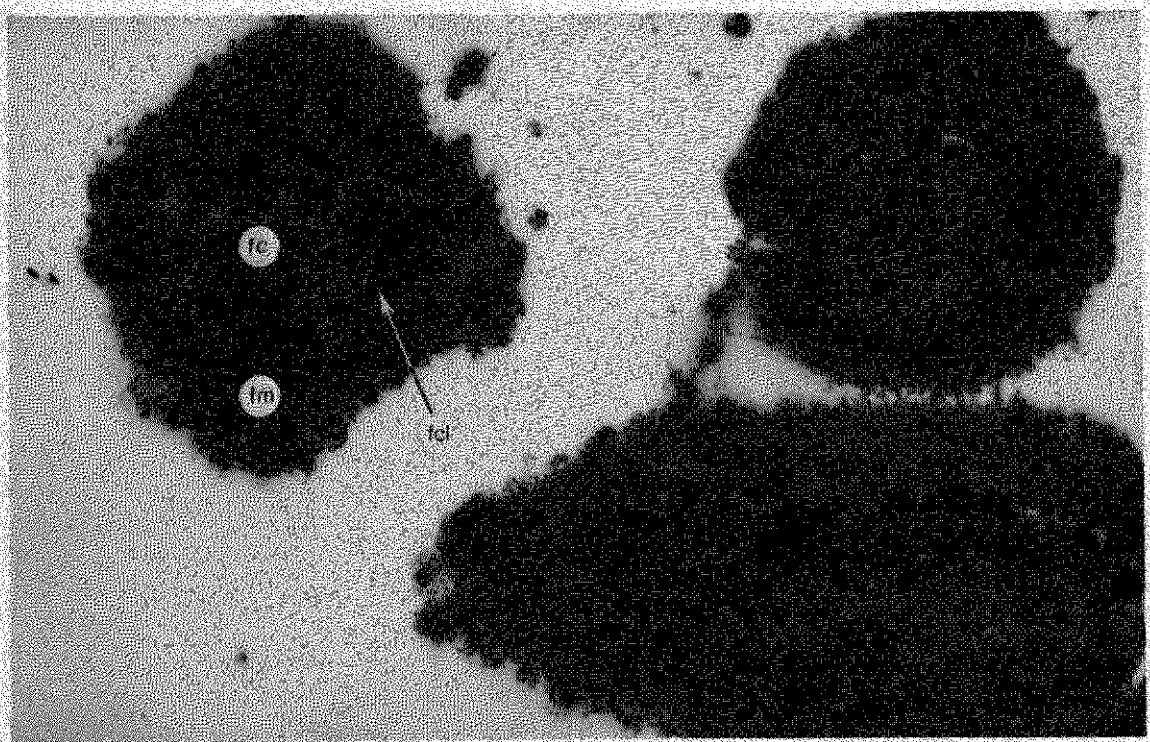

Fig. 10. Radial section fibres in inner part of outer membrane after stay in copper or iron solution. Lead citrate stain. (33,300×, t.e.m.)

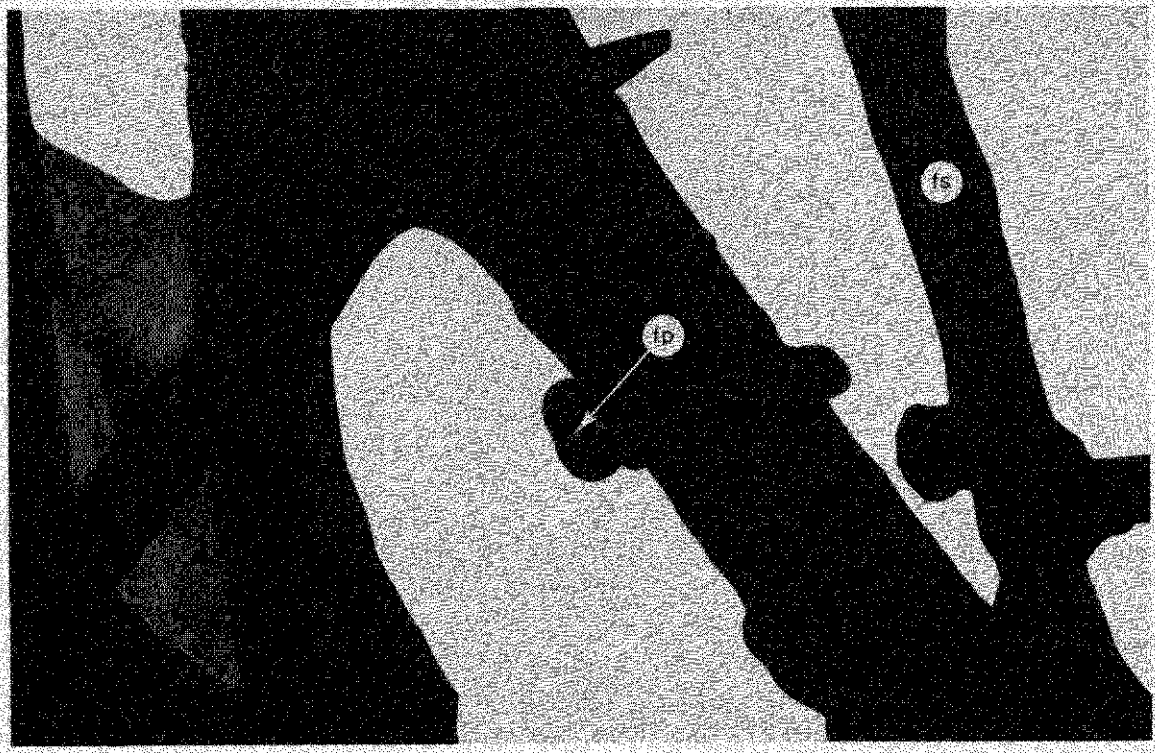

Fig. 11. Fibres outer membrane. (10,300 ×, t.e.m.)

Fig. 12. Fibres outer membrane. (5,900 ×, t.e.m.)

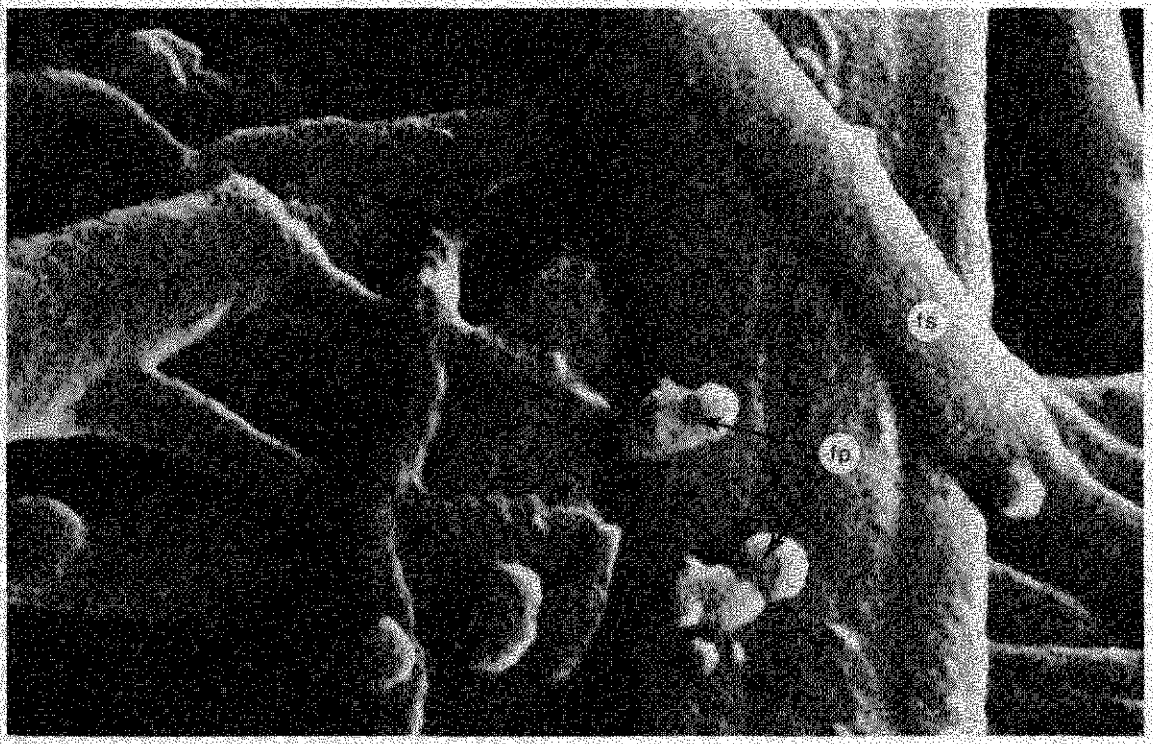

Fig. 13. Outer membrane seen from inside. (16,500 ×, s.e.m.)

Fig. 14. Radially fractured surface shell with membranes. (230 ×, s.e.m.)

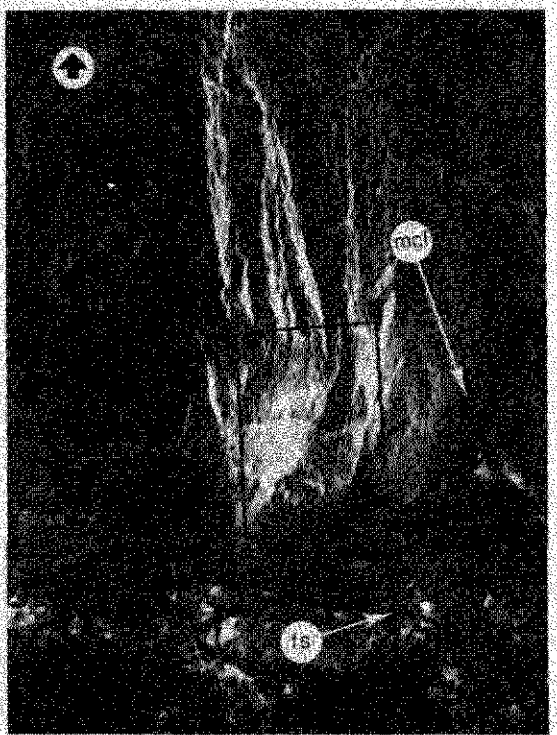

Fig. 15. Radially fractured surface mammillae and membranes. (550 ×, s.e.m.)

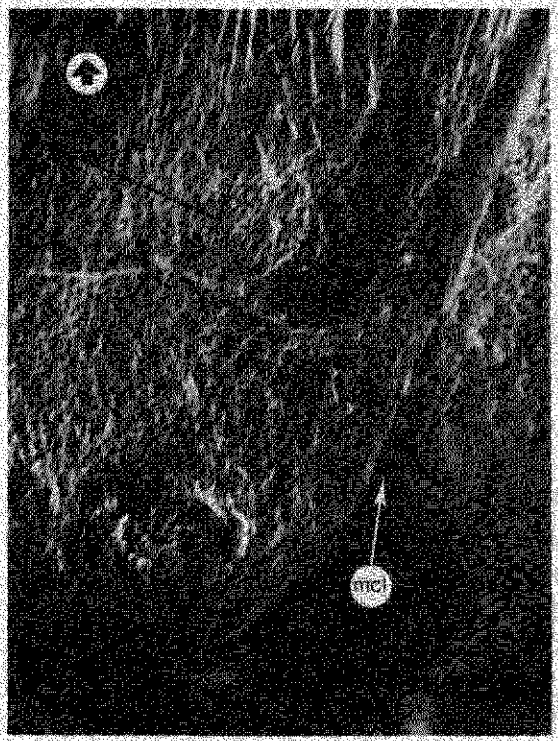

Fig. 16. Radially fractured surface of mammilla. Detail of Fig. 15. (1,800 ×, s.e.m.)

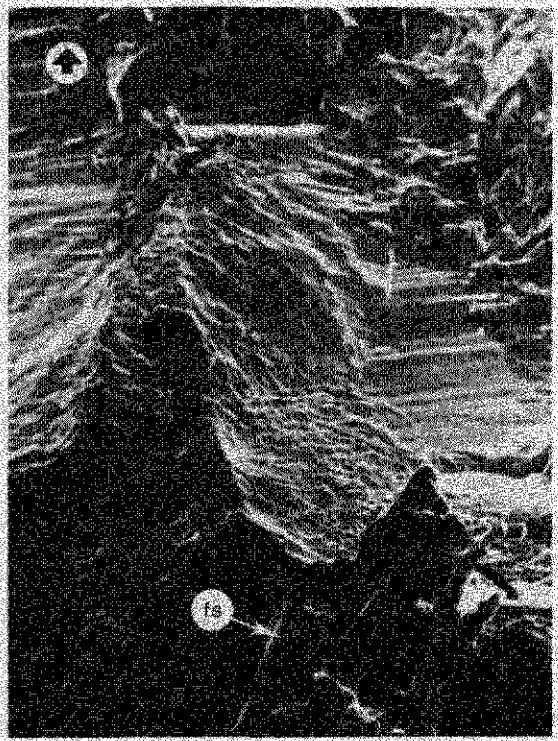

Fig. 17. Radially fractured surface of mammilla. Detail of Fig. 14. (2,300 ×, s.e.m.)

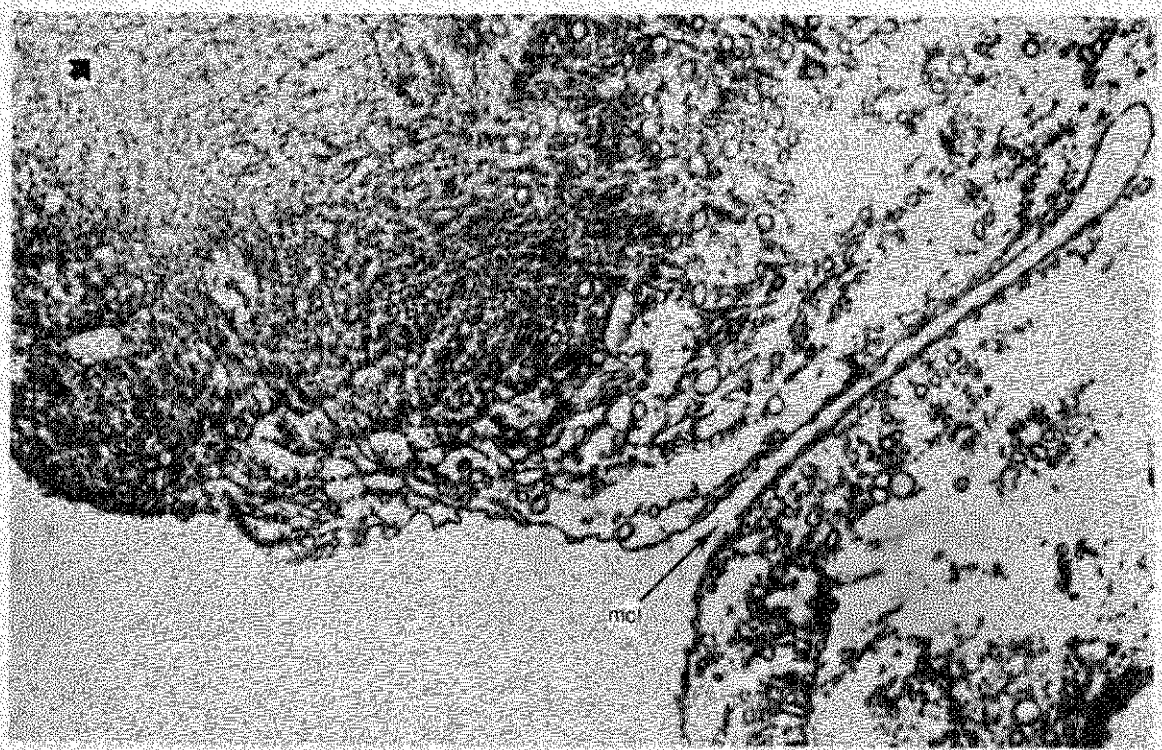

Fig. 18. Decalcified eggshell. Radial section of neighbouring mammillae with cleft between them. $KMnO_4$-stain. (9,000 ×, t.e.m.)

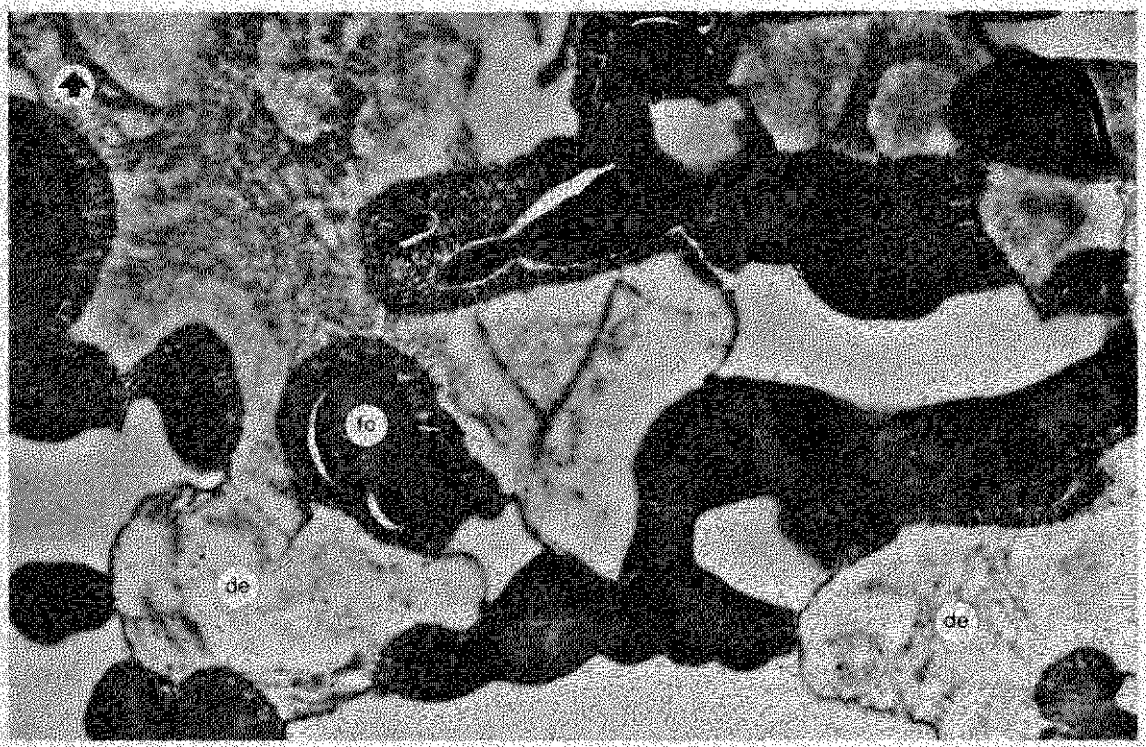

Fig. 19. Decalcified eggshell. Radial section of mammillary deposits in contact with membrane fibres. (9,000×, t.e.m.)

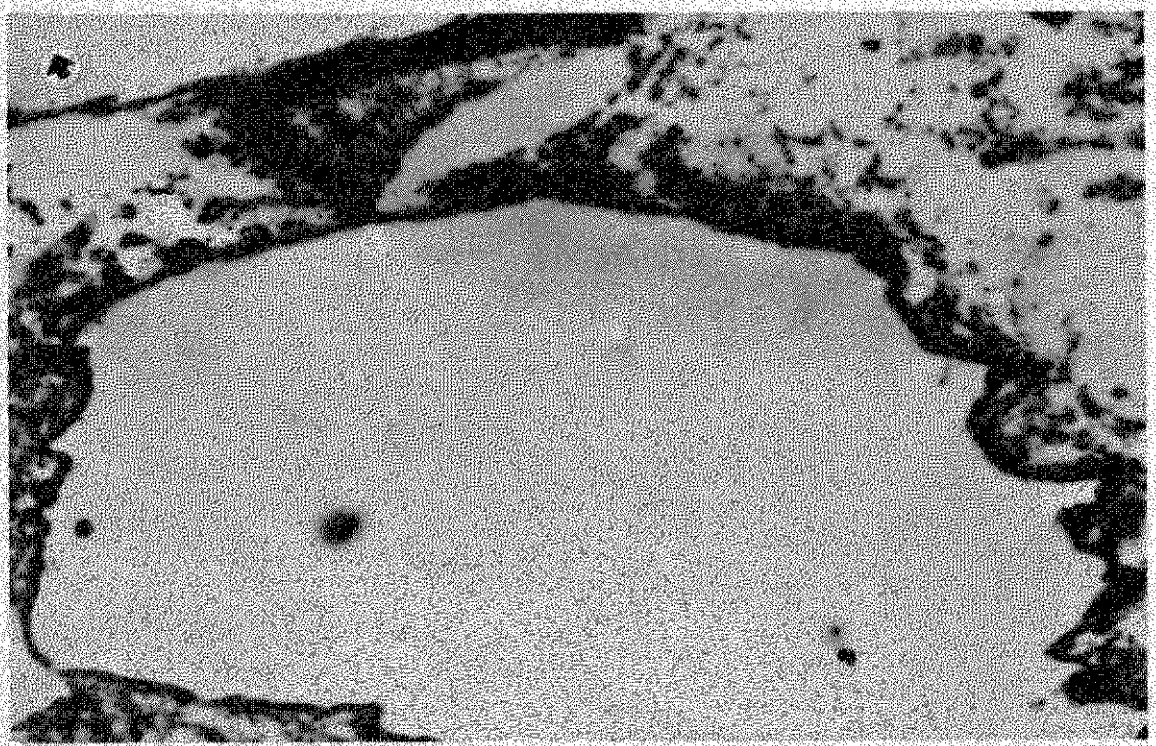

Fig. 20. Decalcified eggshell. Radial section of bridge between neighbouring mammillae. OsO_4-fixation. Ruthenium red stain. (11,300 ×, t.e.m.)

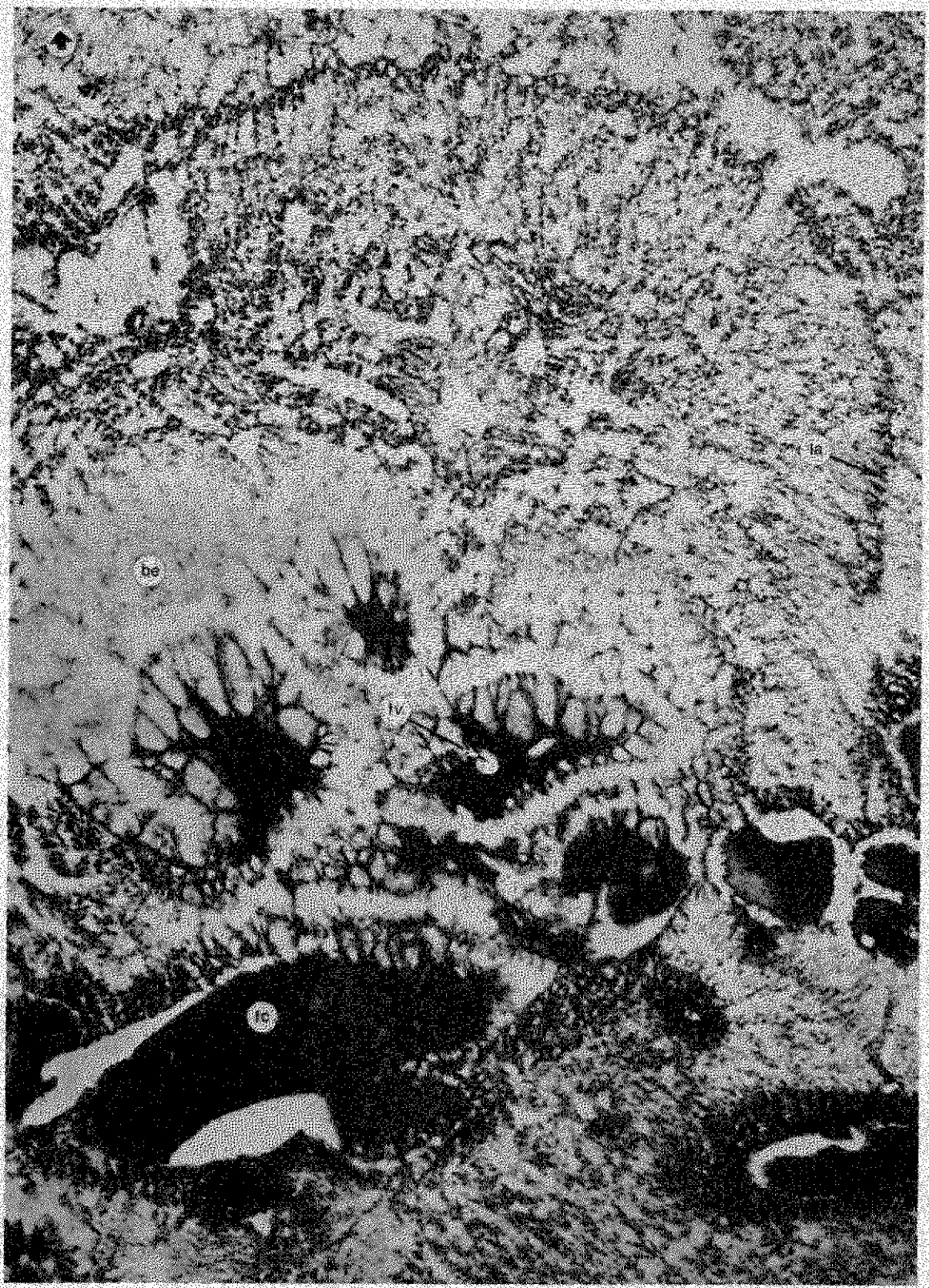

Fig. 21. Decalcified eggshell. Radial section through centre of mammilla with membrane fibres anchoring in it. (18,000 ×, t.e.m.)

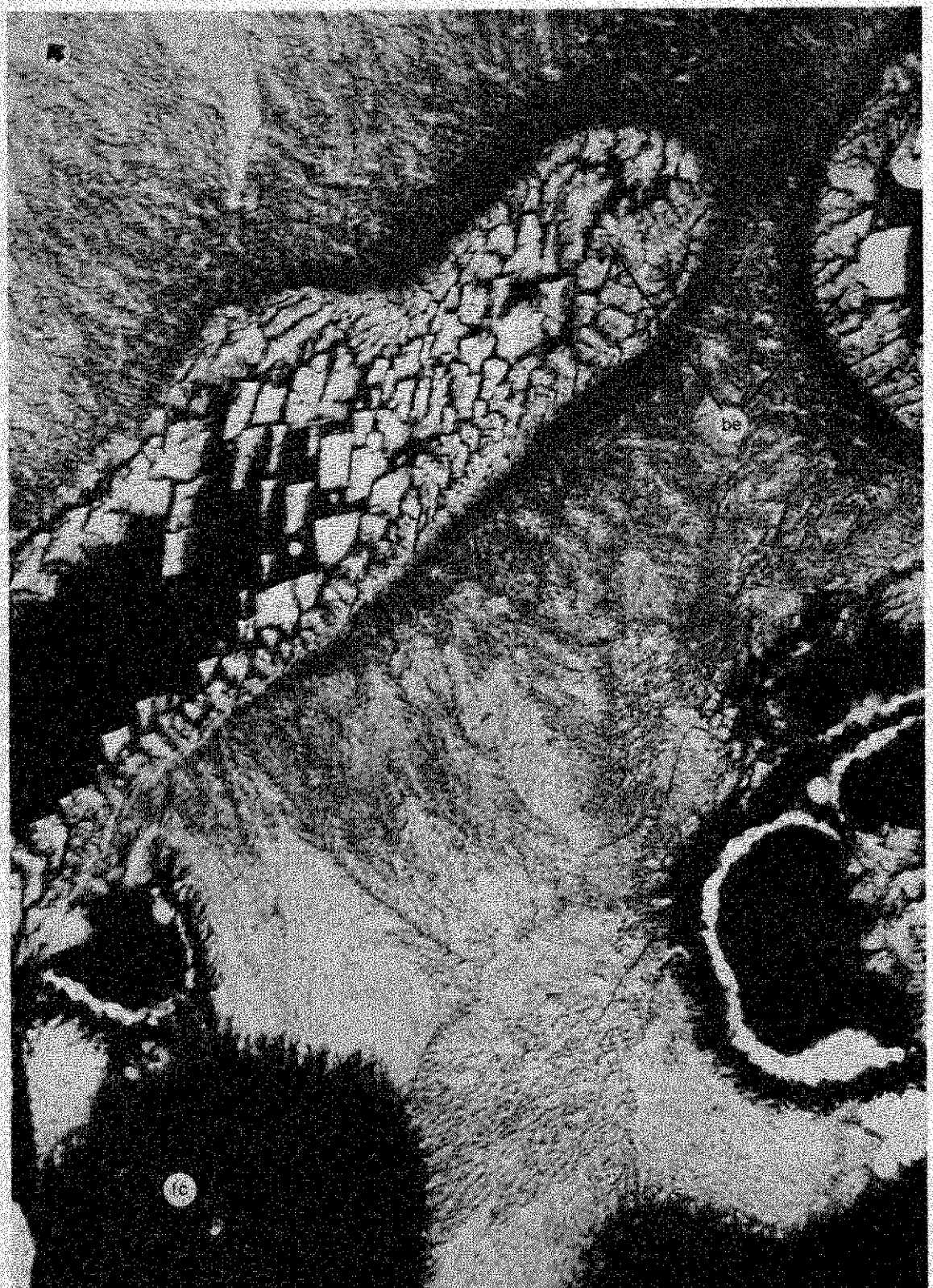

Fig. 22. Decalcified eggshell of a 4 h premature egg. Radial section mammillary matrix with membrane fibres anchoring in it. Lead citrate and uranyl acetate stain. (30.000 ×, t.e.m.)

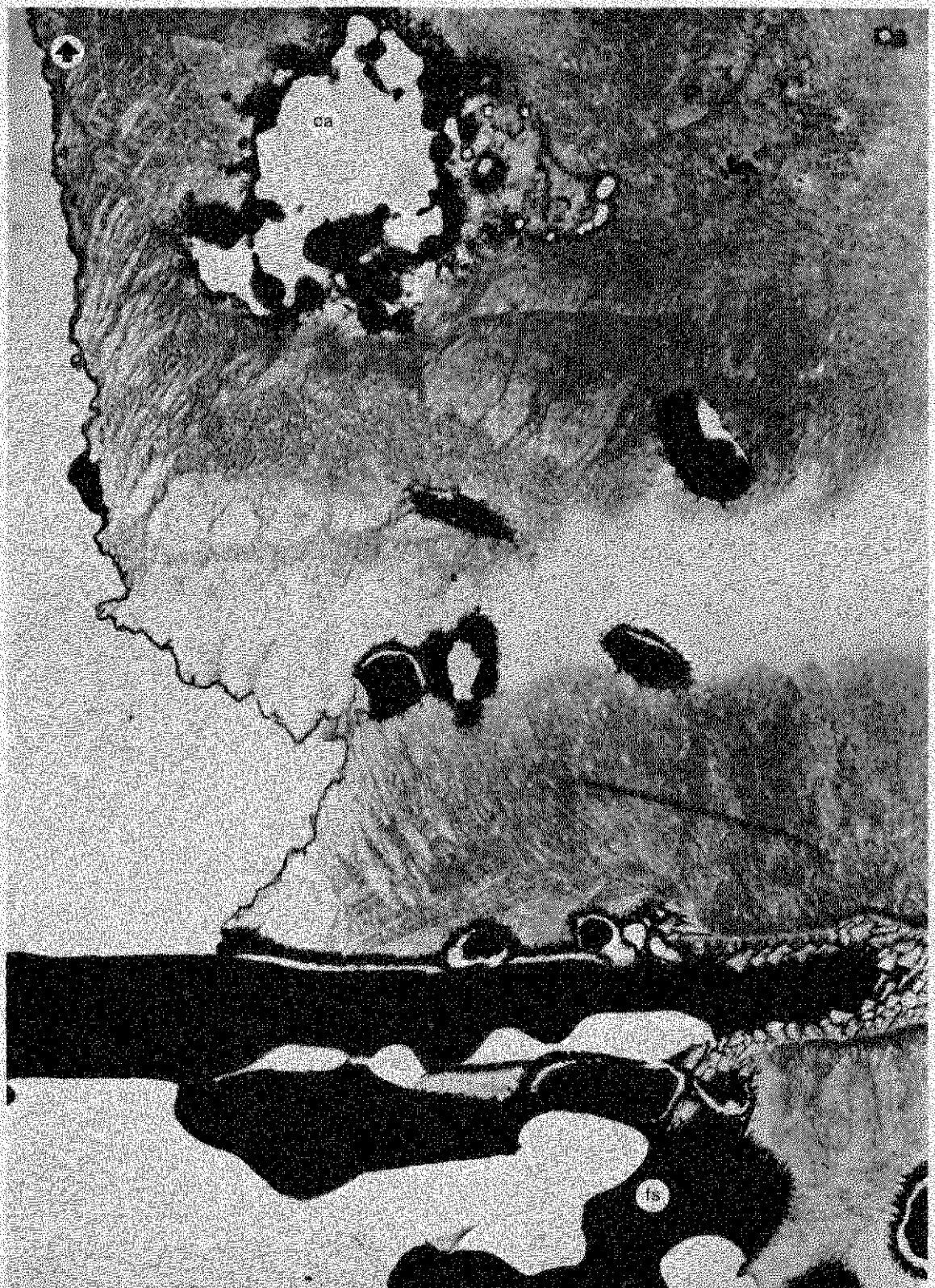

Fig. 23. Decalcified eggshell of a 4 h premature egg. Radial section of base of mammilla with some membrane fibres in it. Lead citrate and uranyl acetate stain. (9,000 ×, t.e.m.)

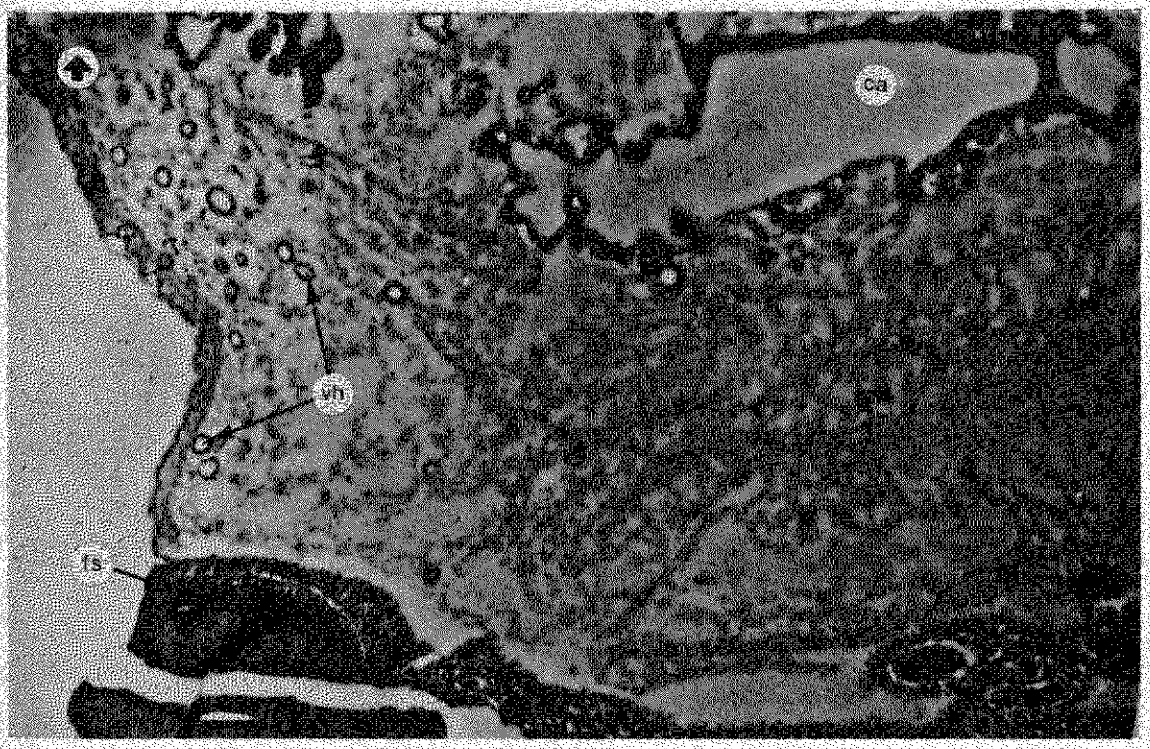

Fig. 24. Decalcified eggshell. Radial section in base of mammilla and membrane fibres. OsO_4-fixation. (9,000 ×, t.e.m.)

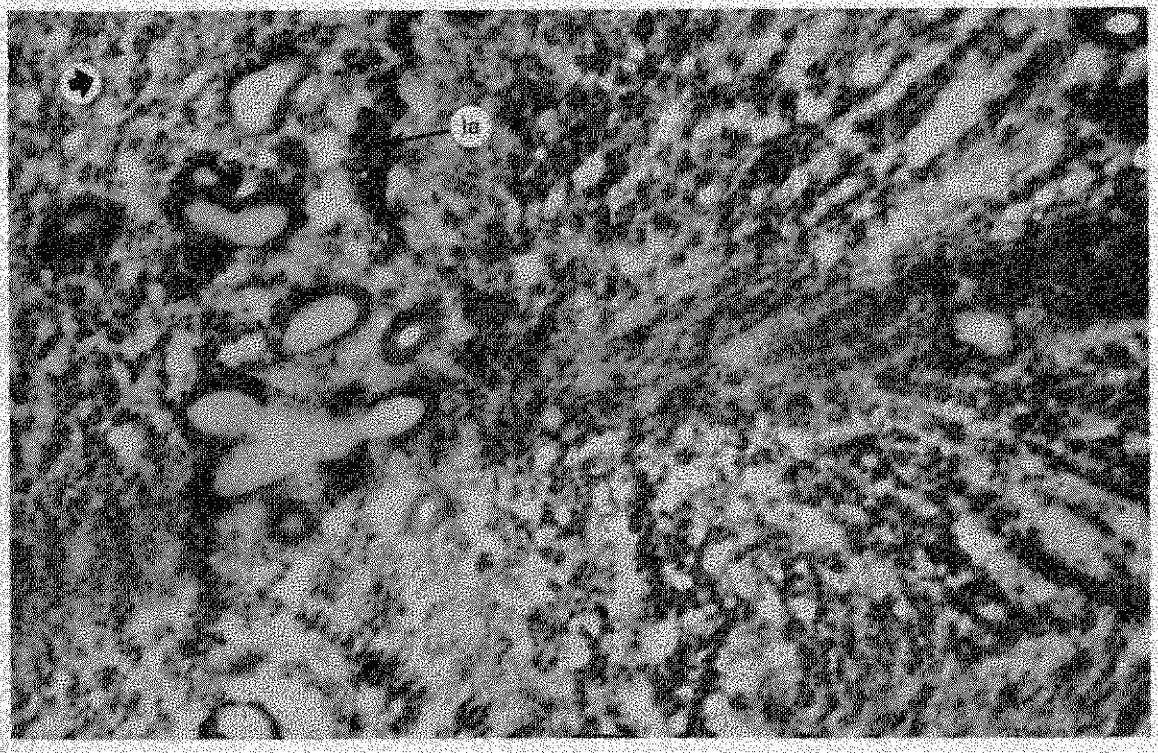

Fig. 25. Decalcified eggshell. Radial section in centre of mammilla with a fan-like orientation. $KMnO_4$-stain. (30,000 ×, t.e.m.)

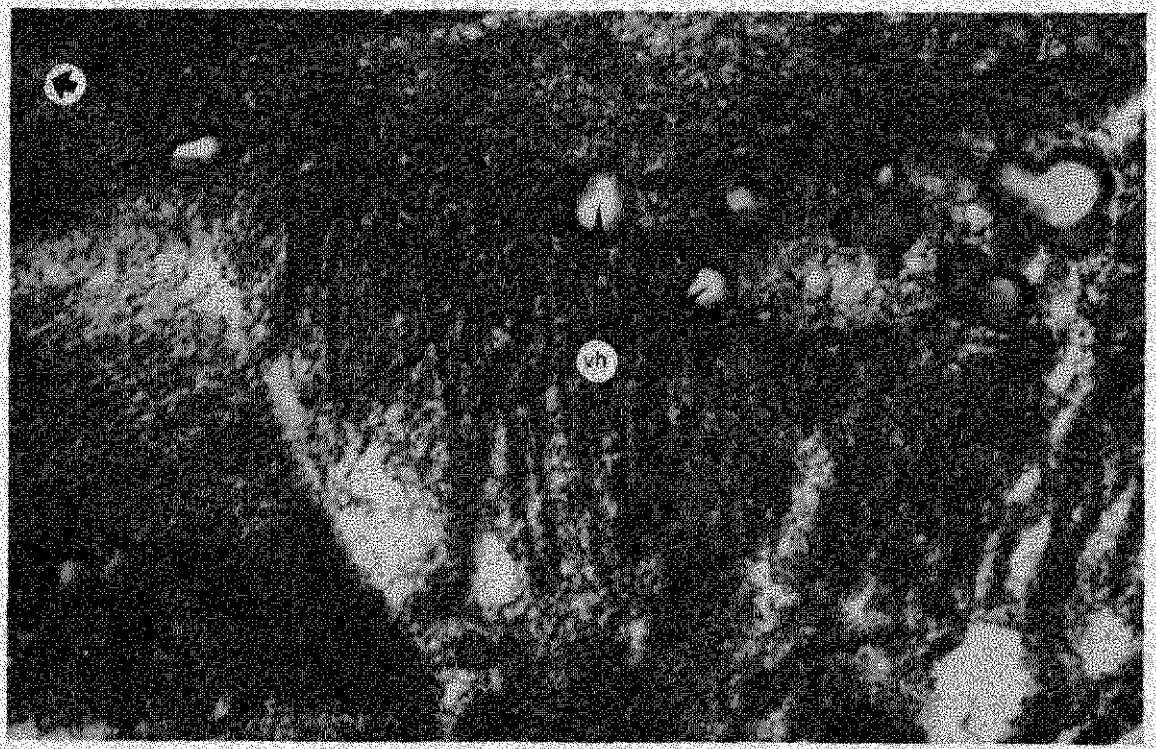

Fig. 26. Decalcified eggshell of a 8 h premature egg. Radial section of mammillary matrix. (24,000 ×, t.e.m.)

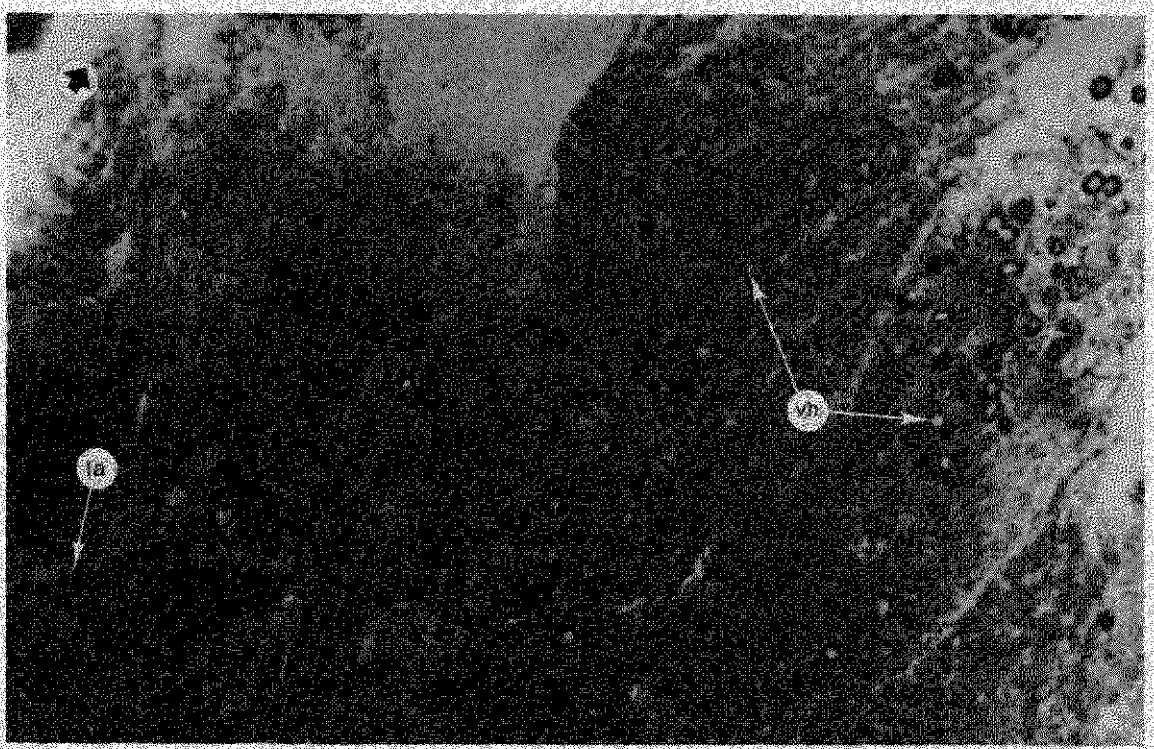

Fig. 27. Decalcified eggshell. Radial section in part of cone layer. OsO_4-fixation. (10,300×, t.e.m.)

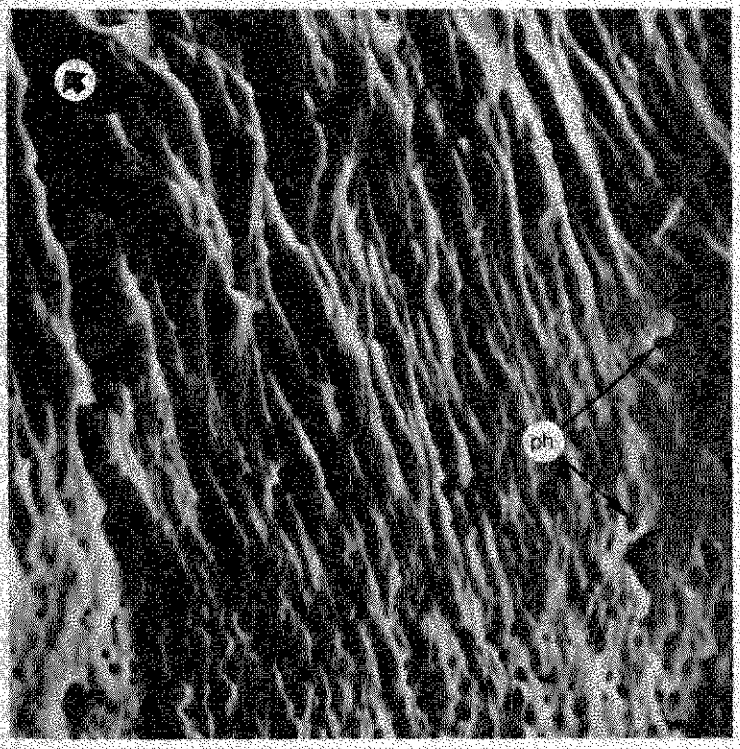

Fig. 28. Radially fractured surface of mammilla. Detail of Fig. 16. (5,400 ×, s.e.m.)

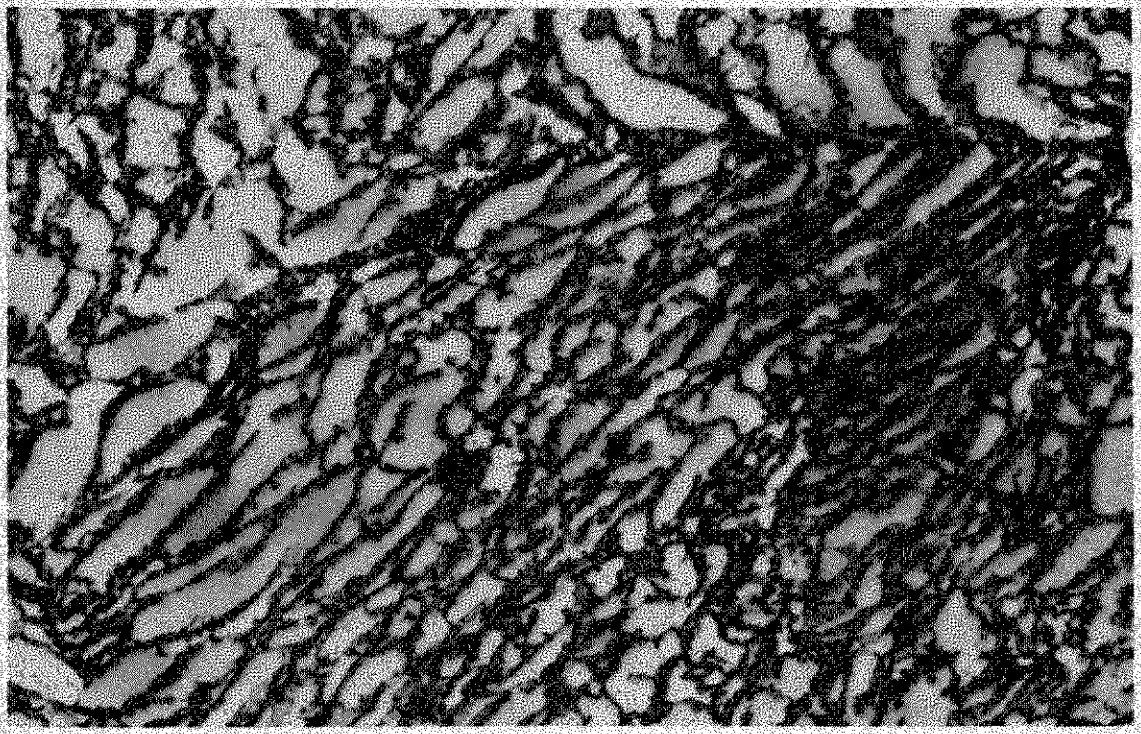

Fig. 29. Decalcified guinea-fowl eggshell. Radial section in cone layer. (24,300 ×, t.e.m.)

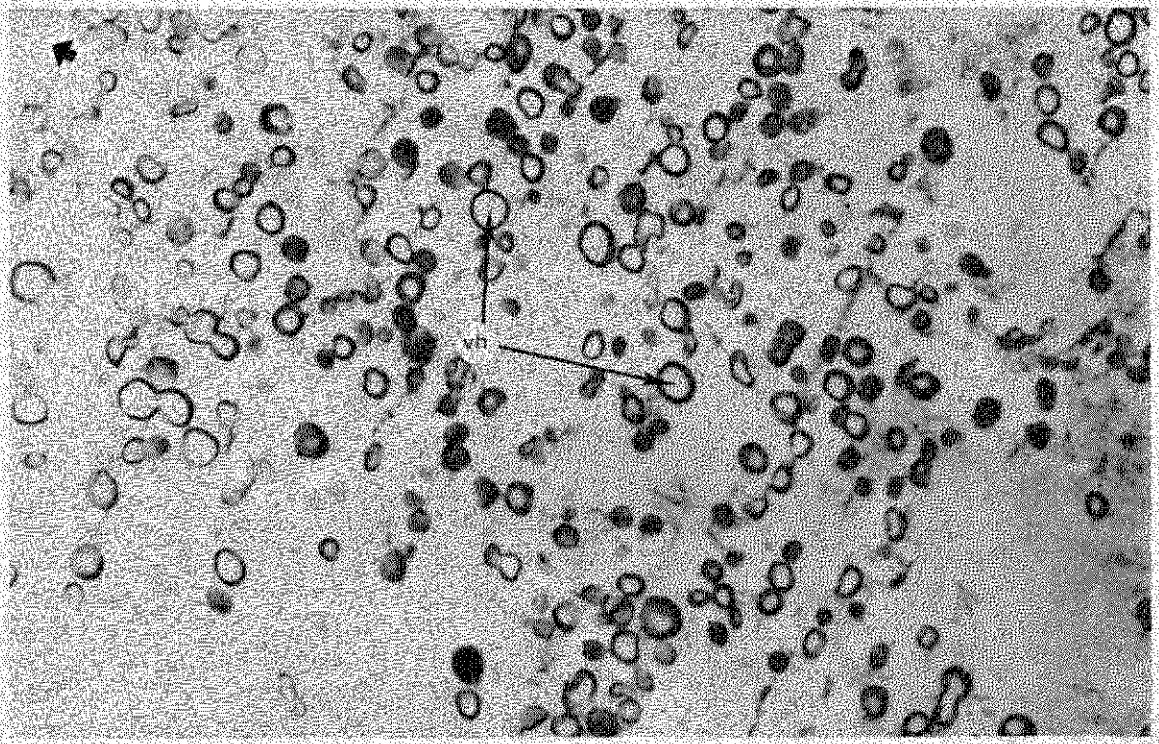

Fig. 30. Decalcified eggshell of a 4 h premature egg. Radial section in outer part of cone layer and inner part of palisade layer. Lead citrate stain. (12,000 ×, t.e.m.)

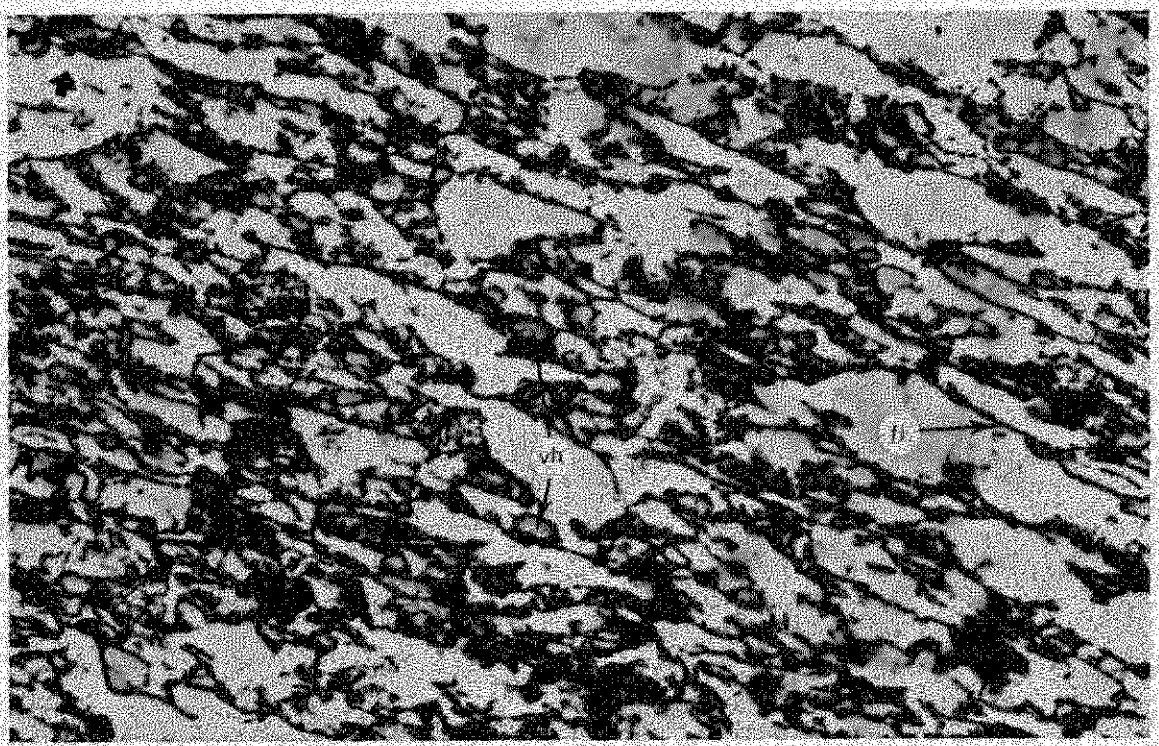

Fig. 31. Decalcified guinea-fowl eggshell. Radial section through outer part of cone layer. (10,400 ×, t.e.m.)

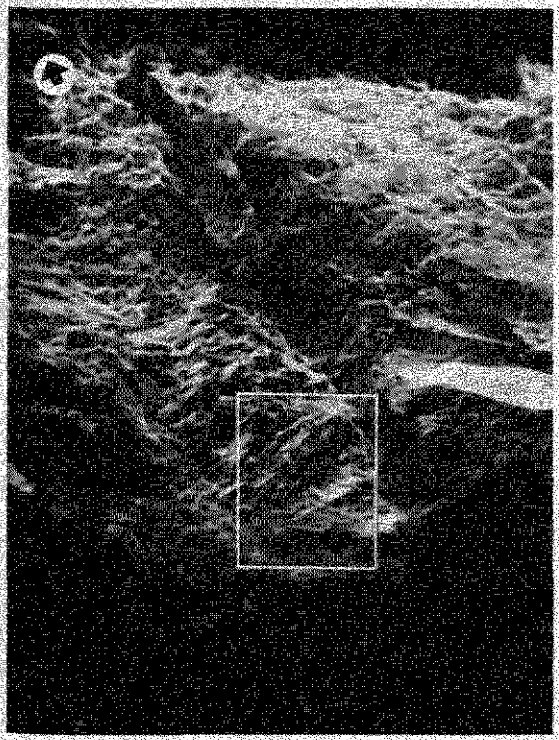

Fig. 32. Radially fractured surface through centre of mammilla. (500 ×, s.e.m.)

Fig. 33. Radially fractured surface through centre of mammilla. Detail of Fig. 32. (1,700 ×, s.e.m.)

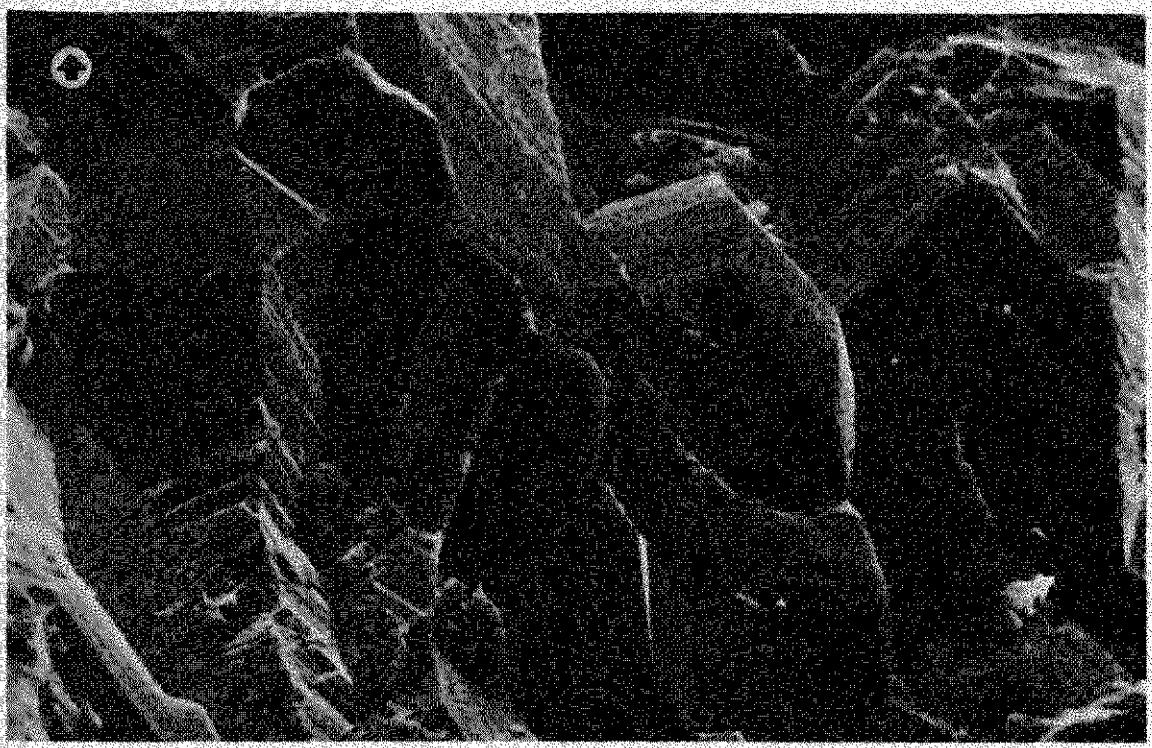

Fig. 34. Radially fractured surface in cone layer of emu eggshell. Detail of Fig. 48. (1,000 ×, s.e.m.)

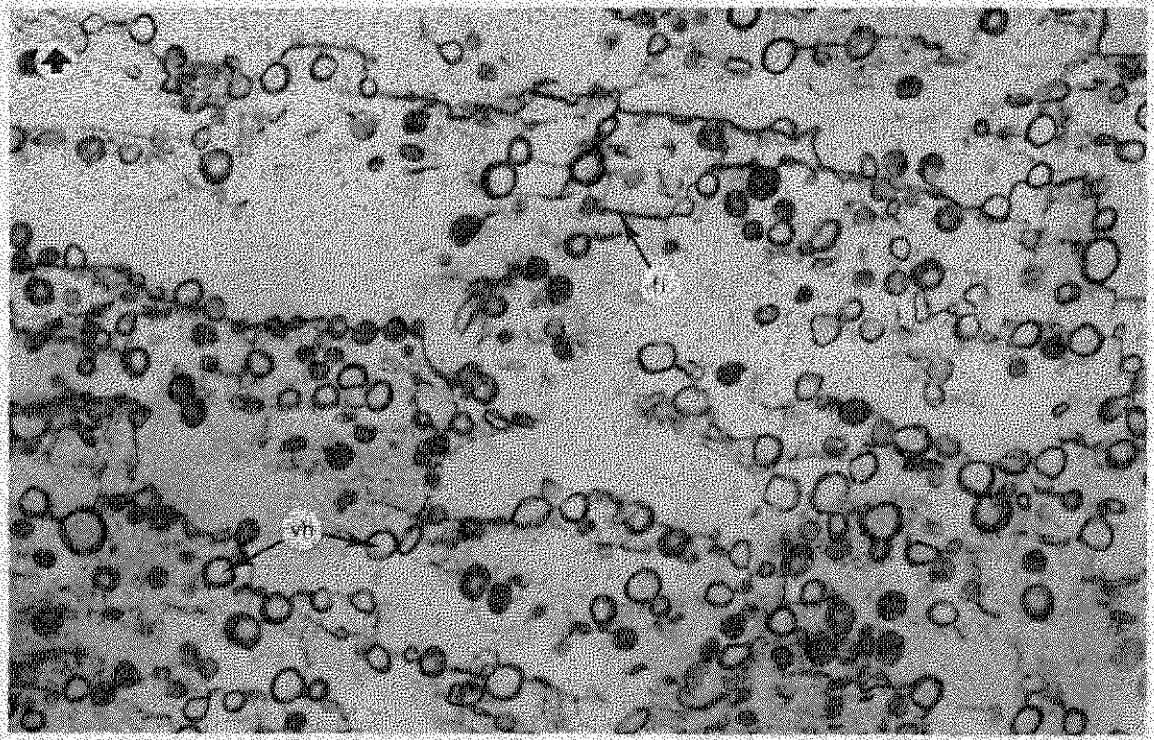

Fig. 35. Decalcified eggshell in a 4 h premature egg. Radial section in palisade layer. Lead citrate stain. (12,000 ×, t.e.m.)

Fig. 36. Decalcified eggshell. Radial section in outer part of palisade layer, surface crystal layer and part of true cuticle. OsO_4-fixation. $KMnO_4$-stain. (4,000 ×, t.e.m.)

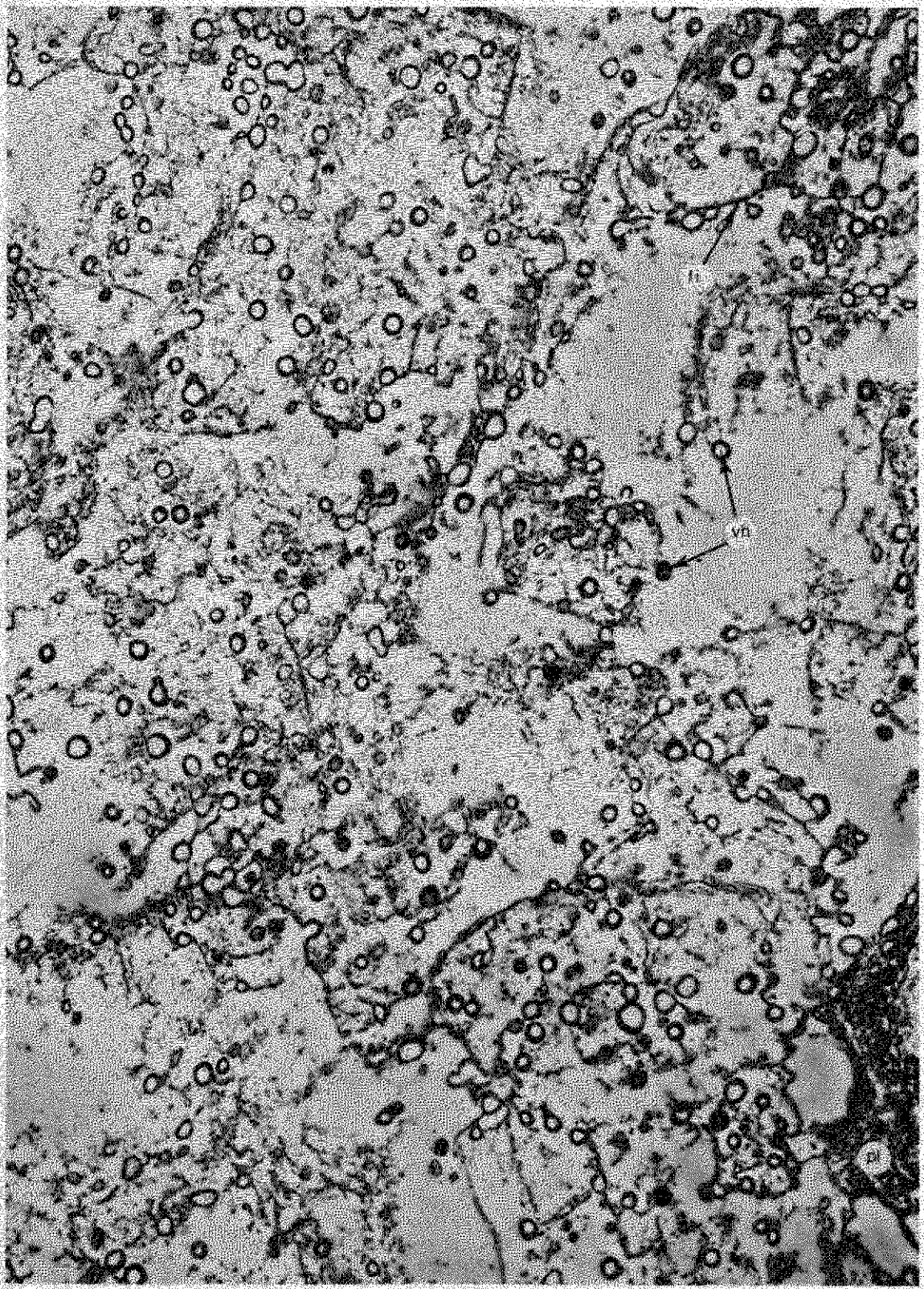

Fig. 37. Decalcified eggshell. Tangential section in palisade layer. (9,000 ×, t.e.m.)

Fig. 38. Decalcified guinea-fowl eggshell. Radial section in palisade layer. (32,400 ×, t.e.m.)

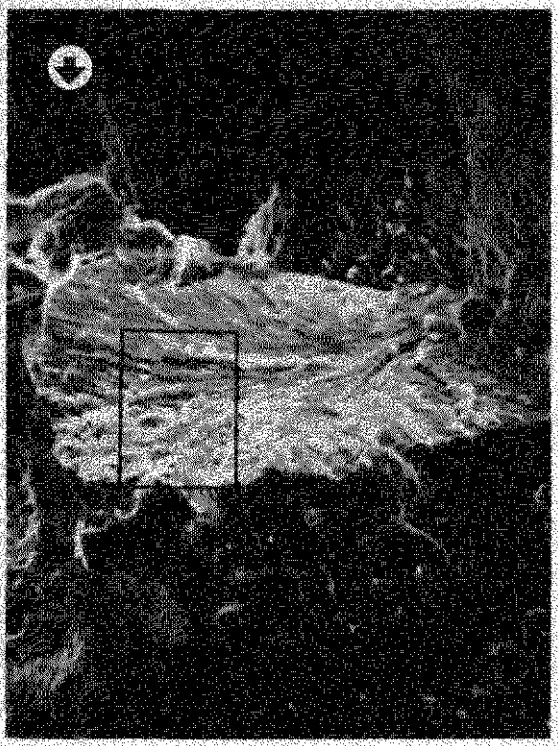

Fig. 39. Radially fractured surface through palisade layer. Fracture through column. Detail of Fig. 63. (1,500 ×, s.e.m.)

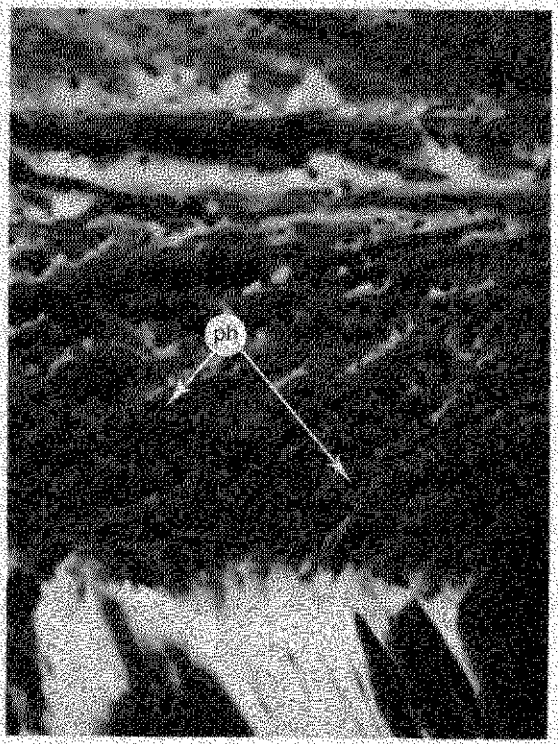

Fig. 40. Tangentially fractured surface through column. Detail of Fig. 39. (5,600 ×, s.e.m.)

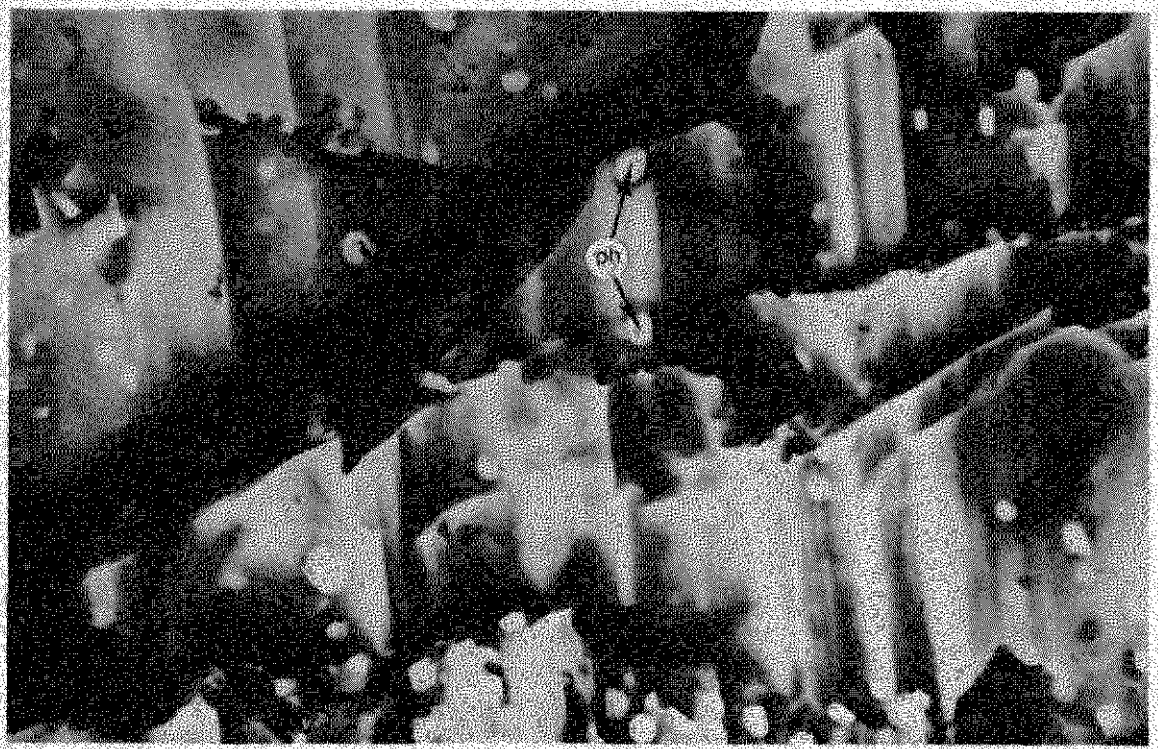

Fig. 41. Radially fractured surface palisade layer obtained by replica technique. (20,000 ×, t.e.m.)

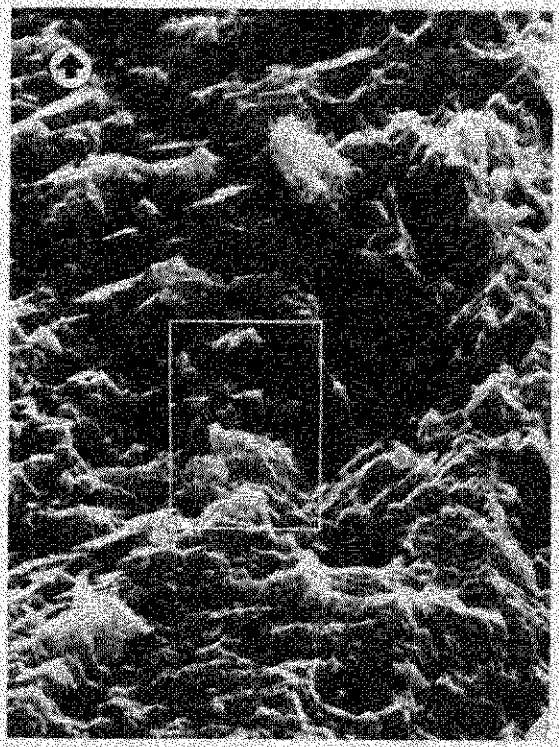

Fig. 42. Radially fractured surface palisade layer. Detail of Fig. 14. (2,700 ×, s.e.m.)

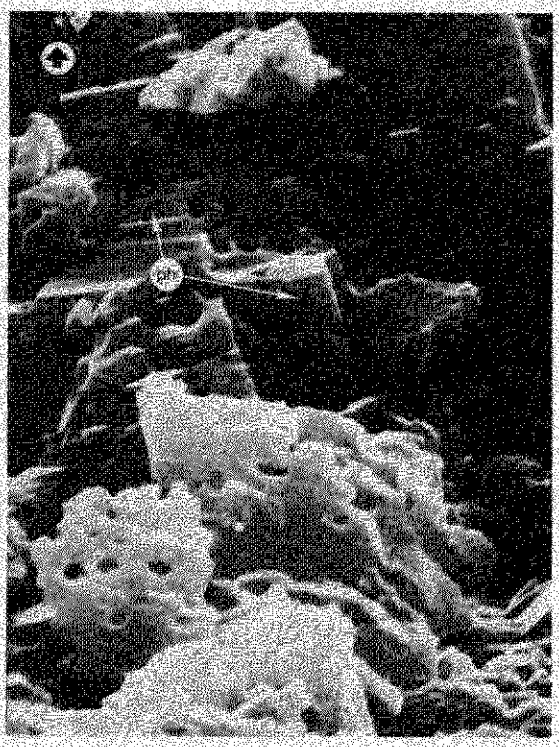

Fig. 43. Radially fractured surface palisade layer. Detail of Fig. 42. (15,000 ×, s.e.m.)

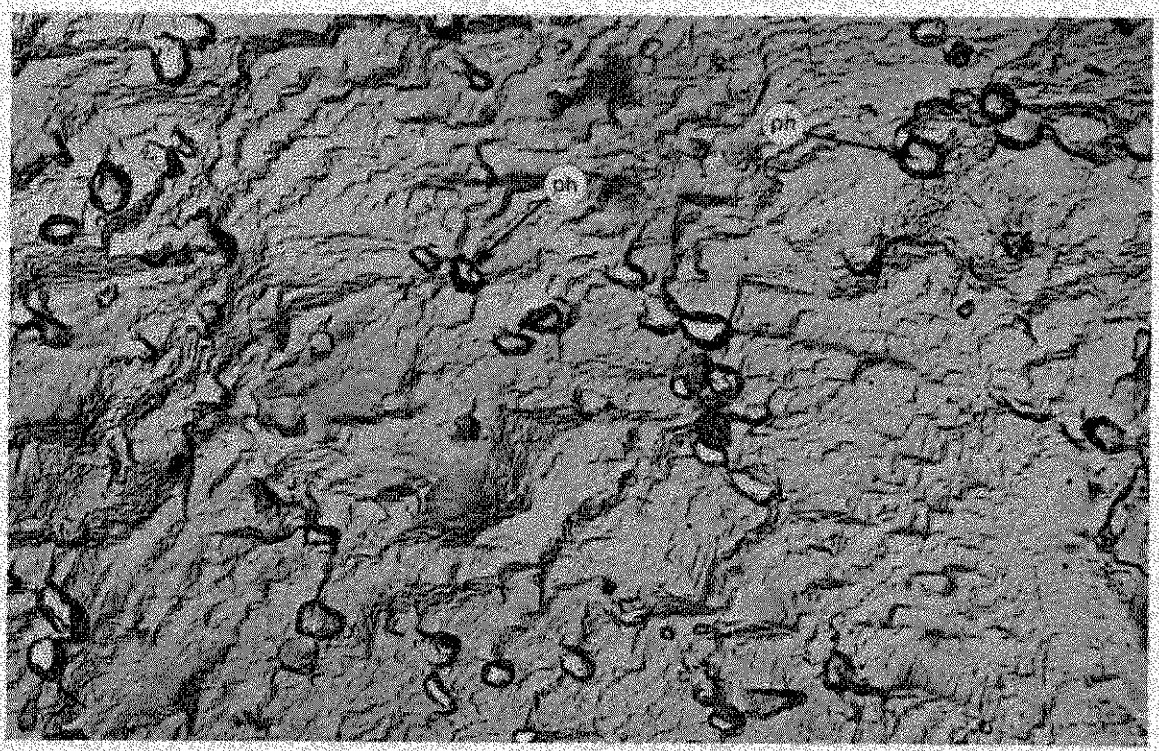

Fig. 44. Radially fractured surface palisade layer obtained by replica technique. (± 20,000 ×, t.e.m.)

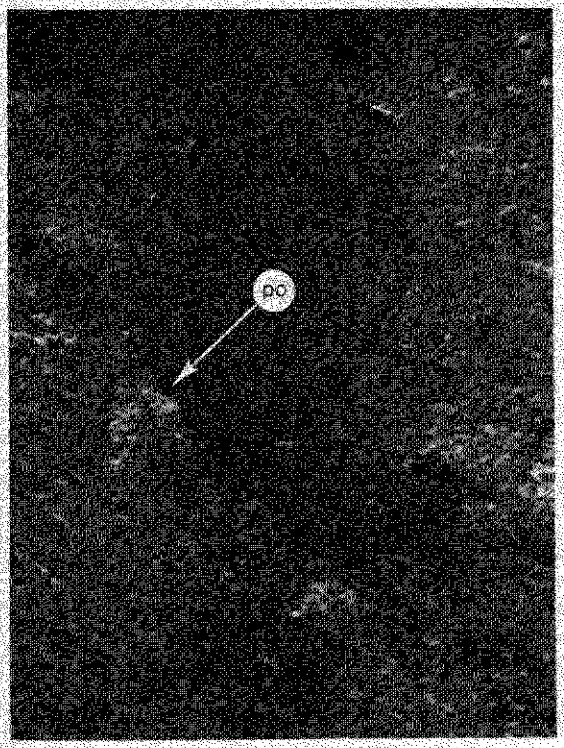

Fig. 45. Shell surface. True cuticle removed with EDTA. (160 ×, s.e.m.)

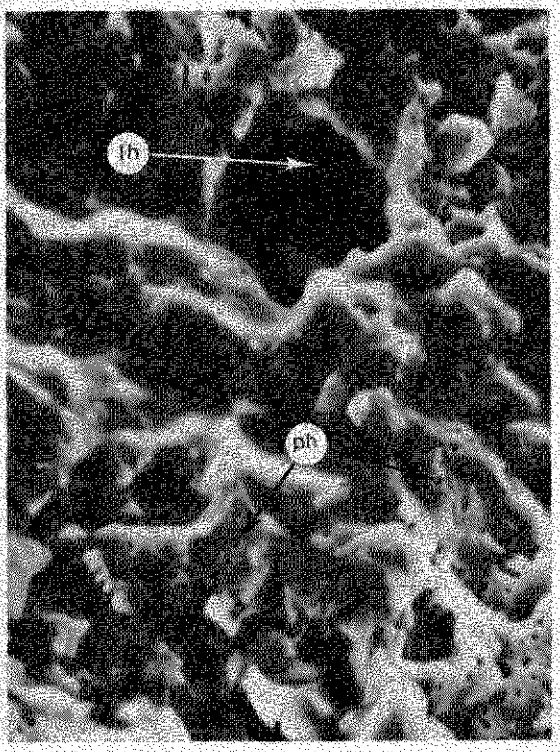

Fig. 46. Radially fractured surface. Palisade layer. (5,400 ×, s.e.m.)

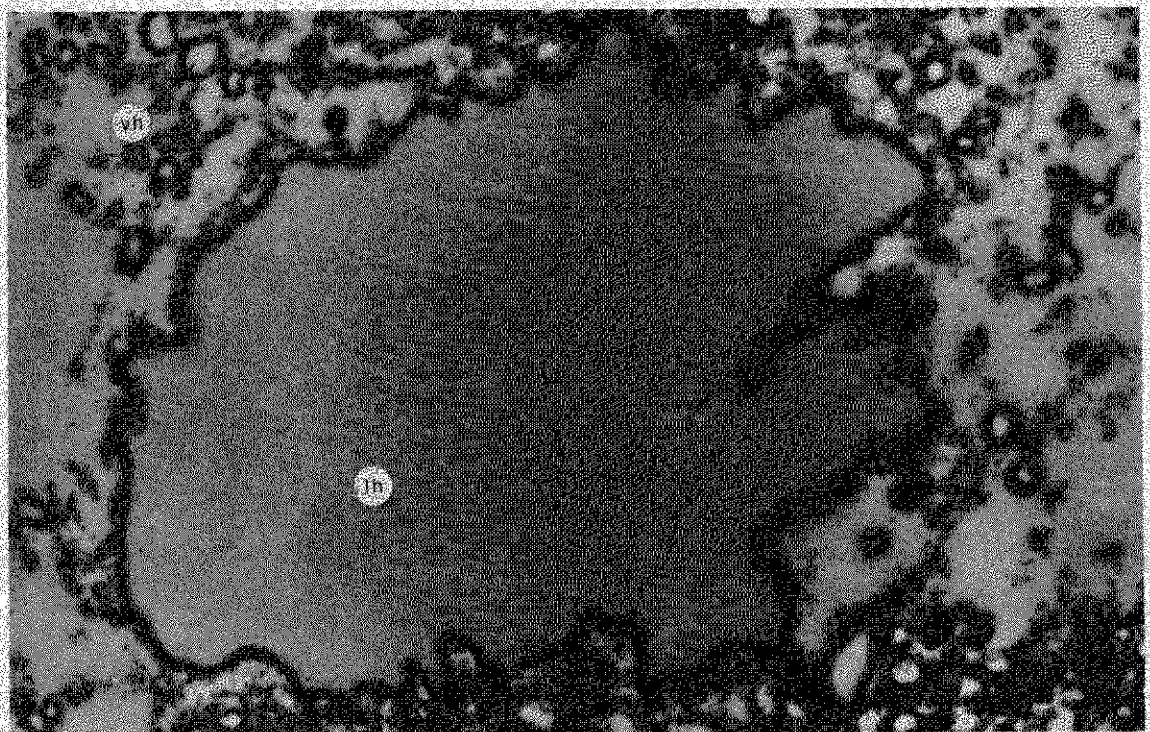

Fig. 47. Decalcified eggshell of egg laid under climatic stress. Tangential section in palisade layer. (15,000 ×, t.e.m.)

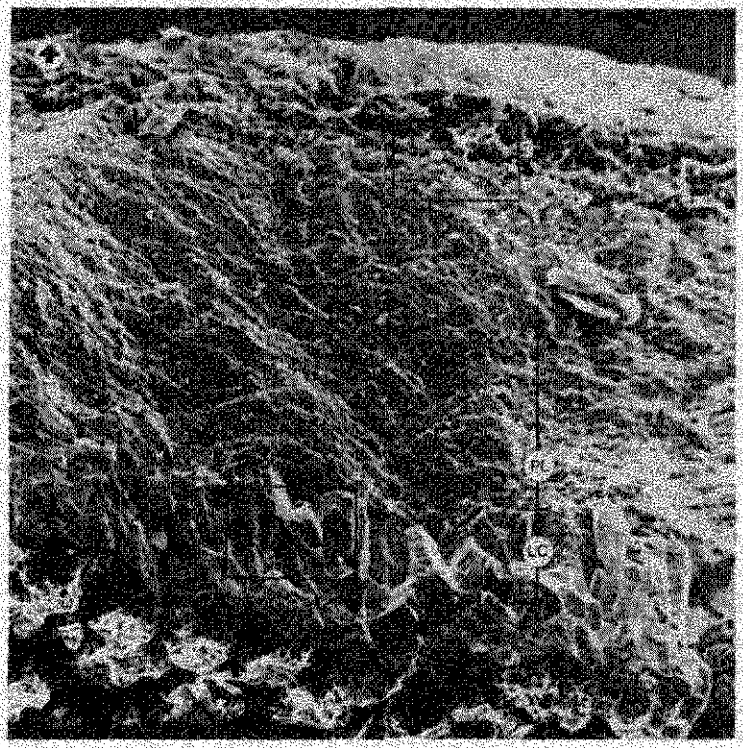

Fig. 48. Inside and radially fractured surface of emu eggshell. (140×, s.e.m.)

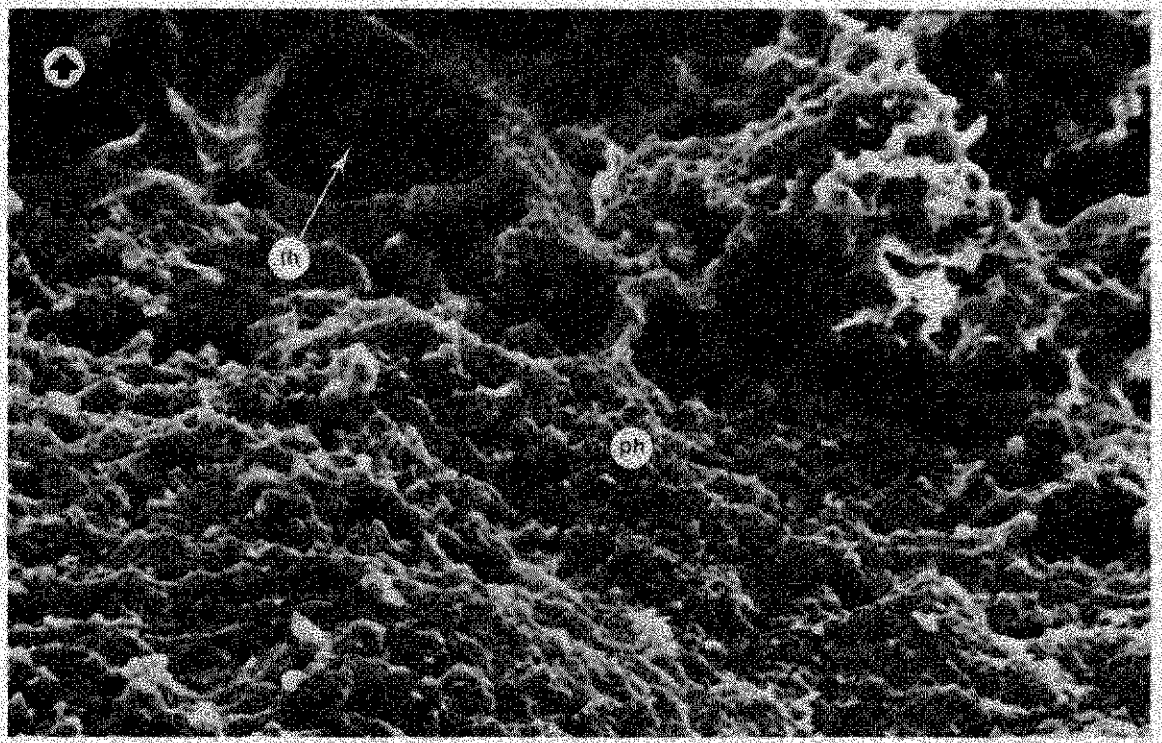

Fig. 49. Radially fractured surface in the outer part of palisade layer of emu eggshell. Detail of Fig. 48. (1,300 ×, s.e.m.)

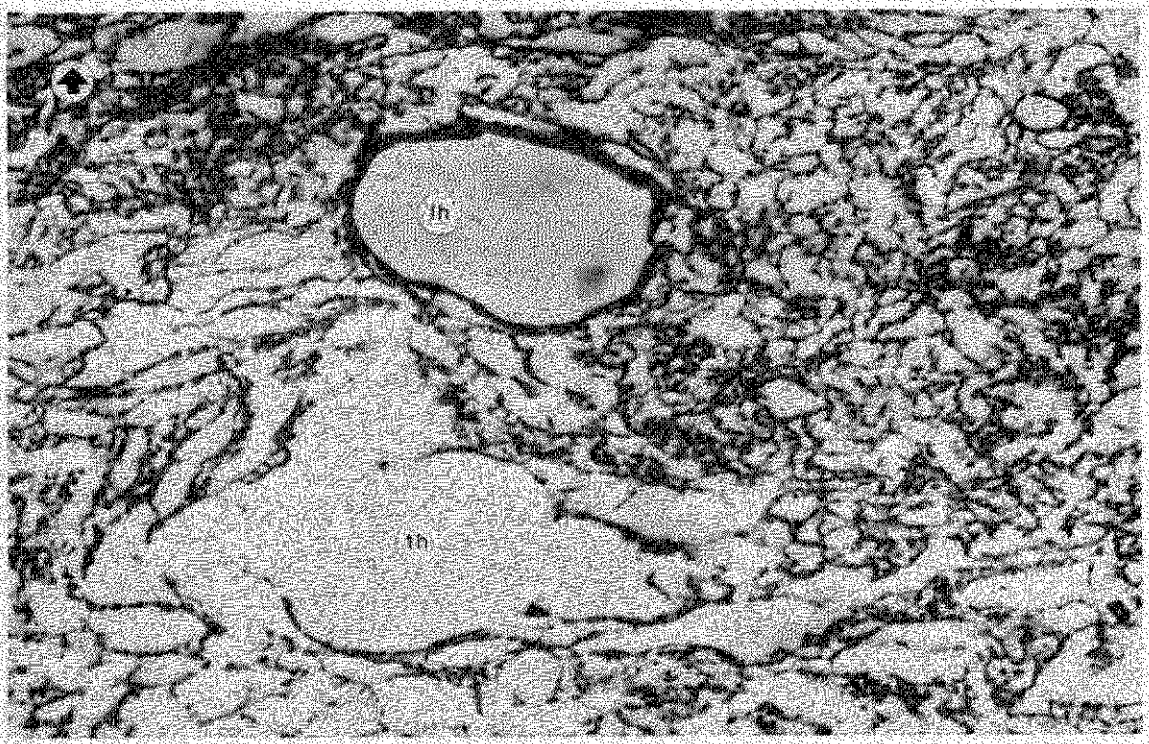

Fig. 50. Decalcified guinea-fowl eggshell. Radial section in palisade layer. (24,300 ×, t.e.m.)

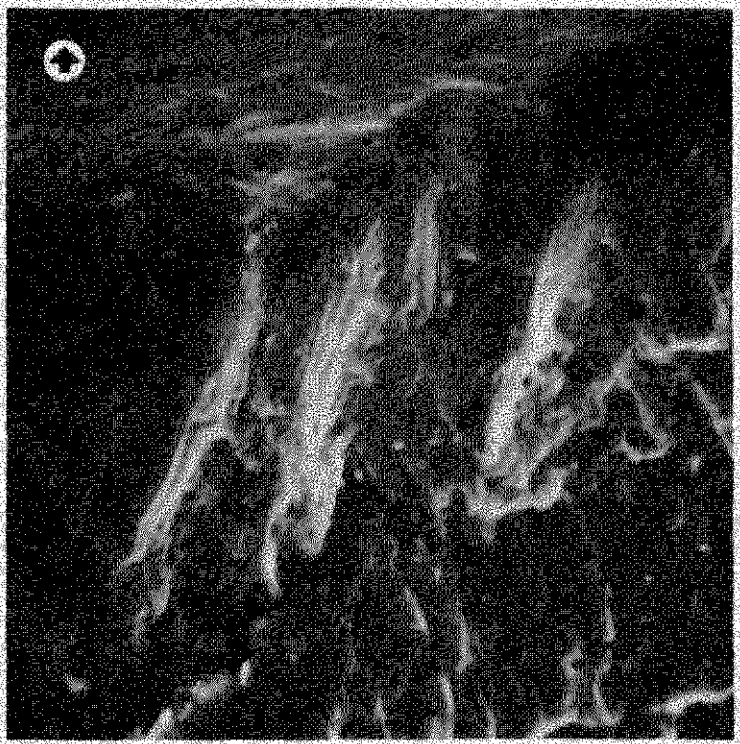

Fig. 51. Radially fractured surface in surface crystal layer. (5,400 ×, s.e.m.)

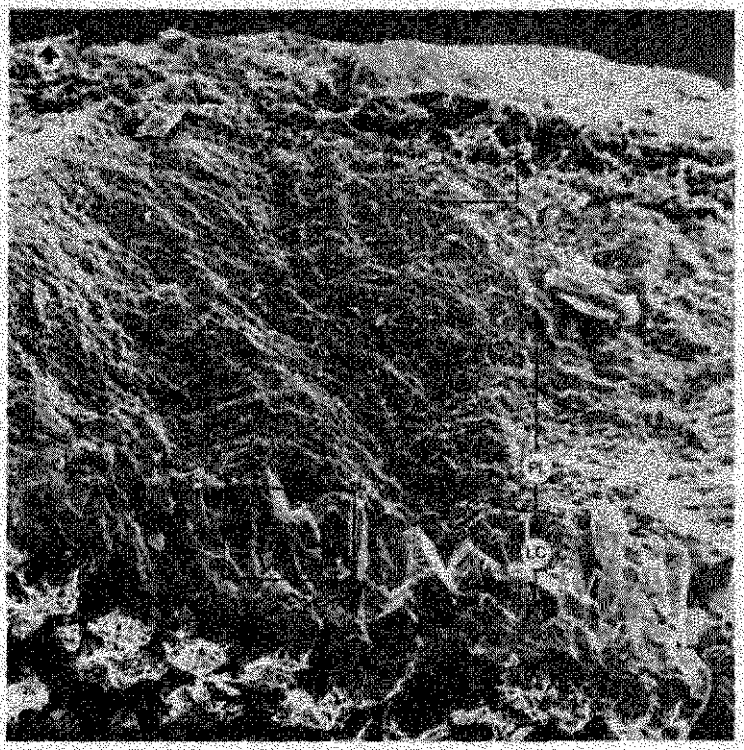

Fig. 48. Inside and radially fractured surface of emu eggshell. (140×, s.e.m.)

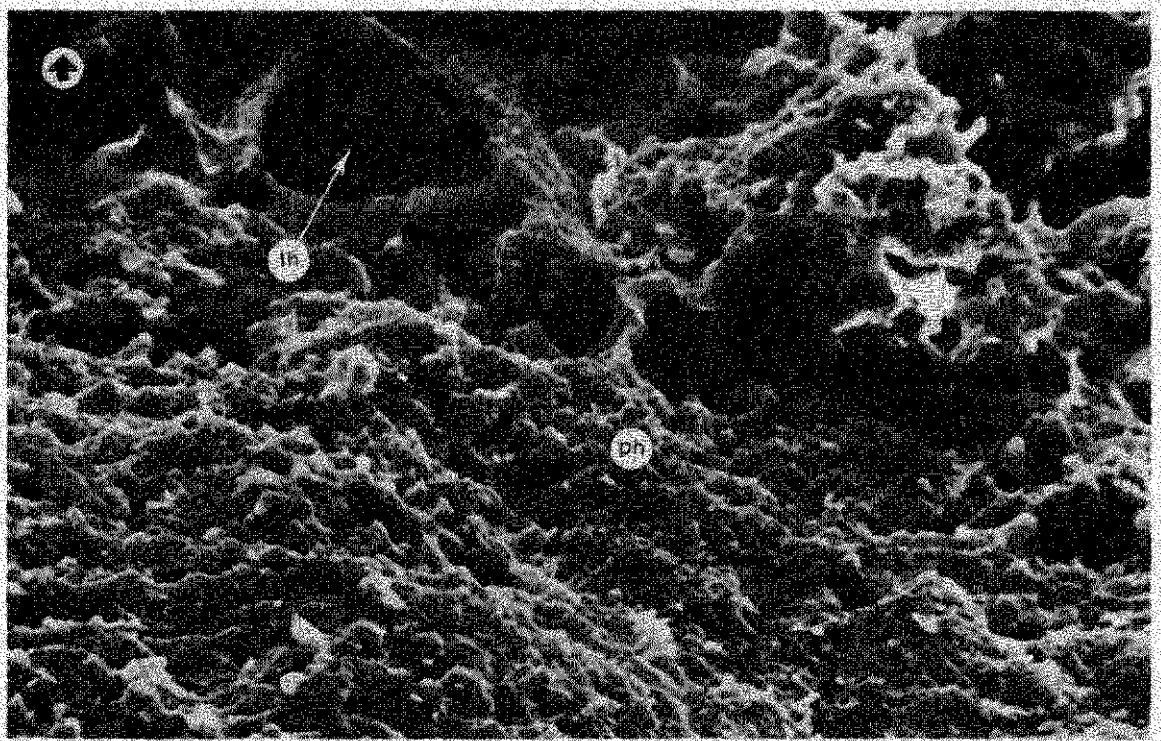

Fig. 49. Radially fractured surface in the outer part of palisade layer of emu eggshell. Detail of Fig. 48. (1,300 ×, s.e.m.)

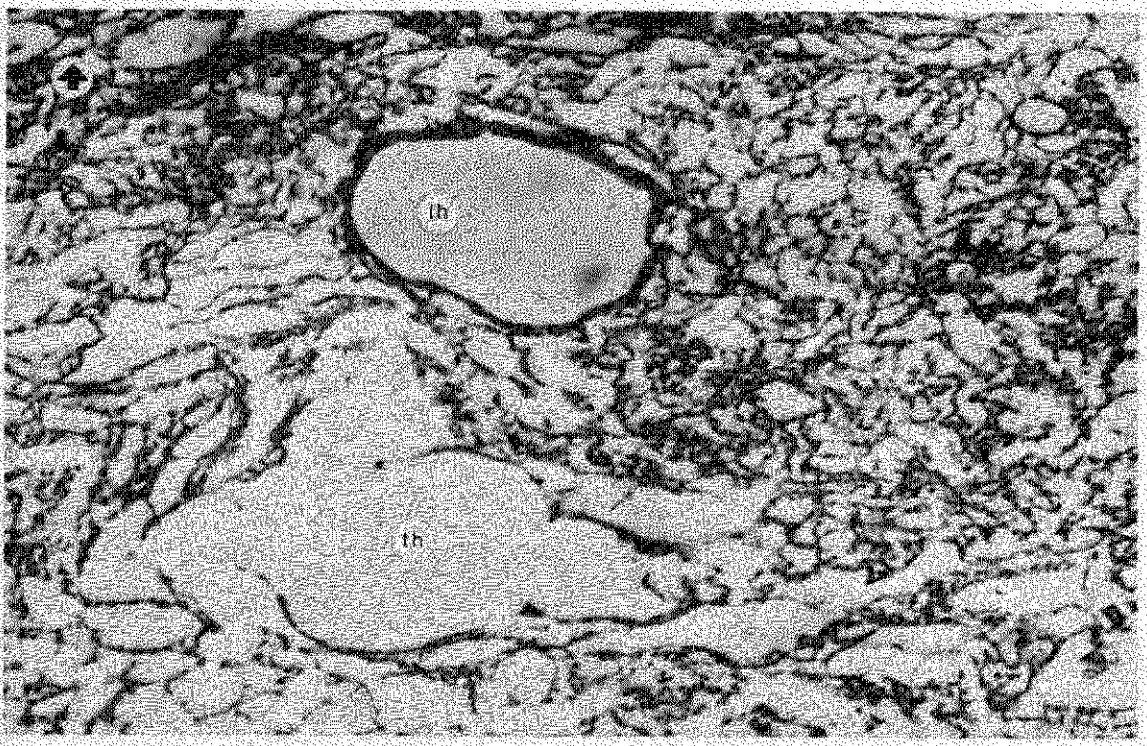

Fig. 50. Decalcified guinea-fowl eggshell. Radial section in palisade layer. (24,300 ×, t.e.m.)

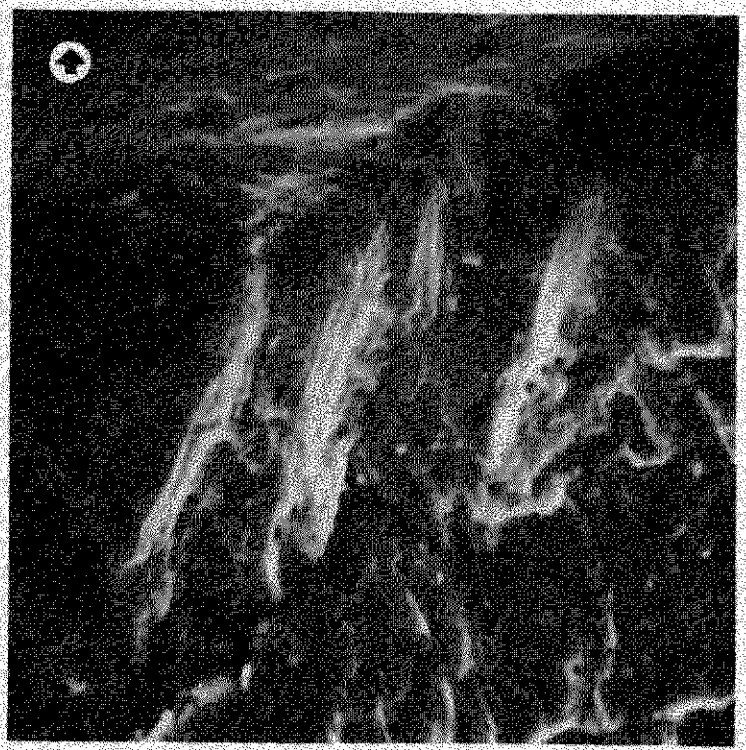

Fig. 51. Radially fractured surface in surface crystal layer. (5,400 ×, s.e.m.)

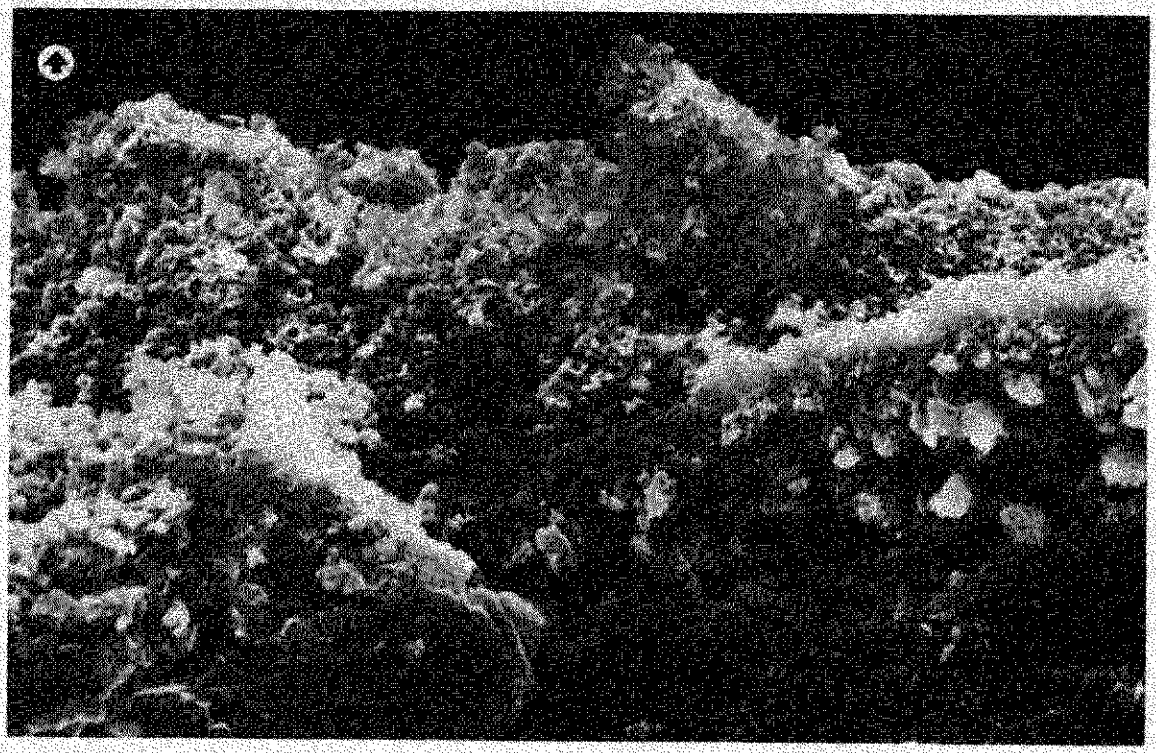

Fig. 52. Radial fracture in guinea-fowl eggshell. Outer part of shell and true cuticle. (2,800 ×, s.e.m.)

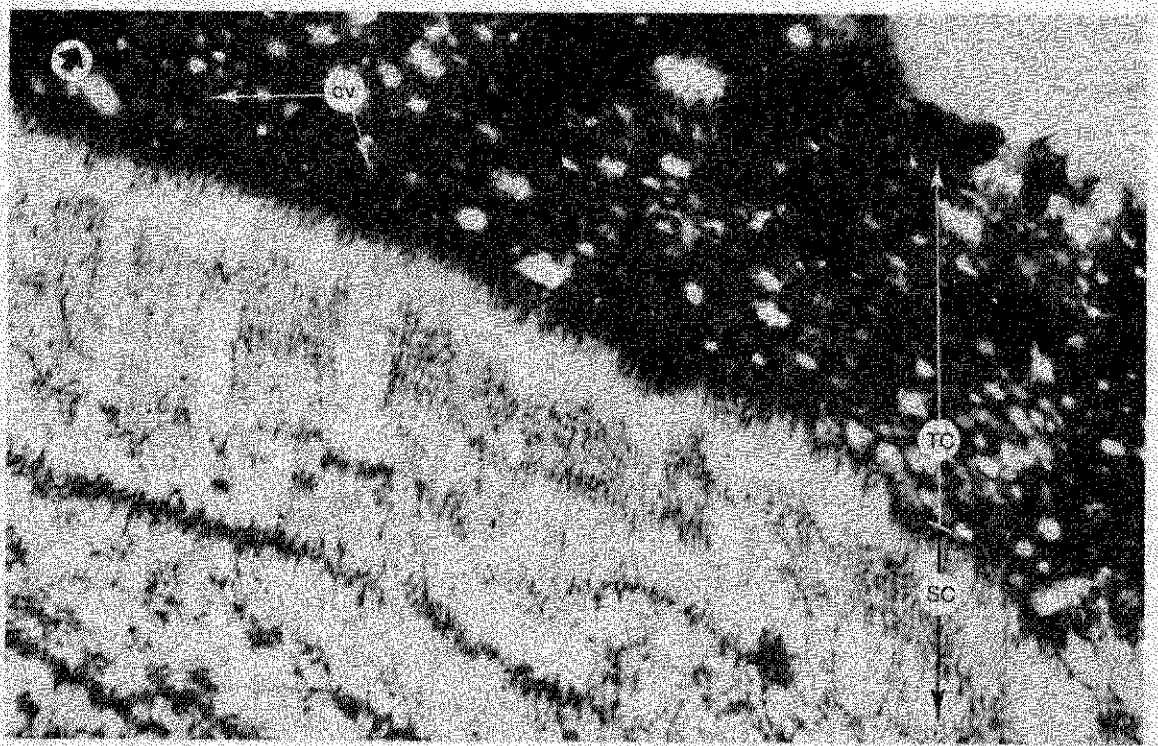

Fig. 53. Decalcified eggshell of a few months old laid egg. Radial section true cuticle and surface crystal layer. $KMnO_4$-stain. (30,000×, t.e.m.)

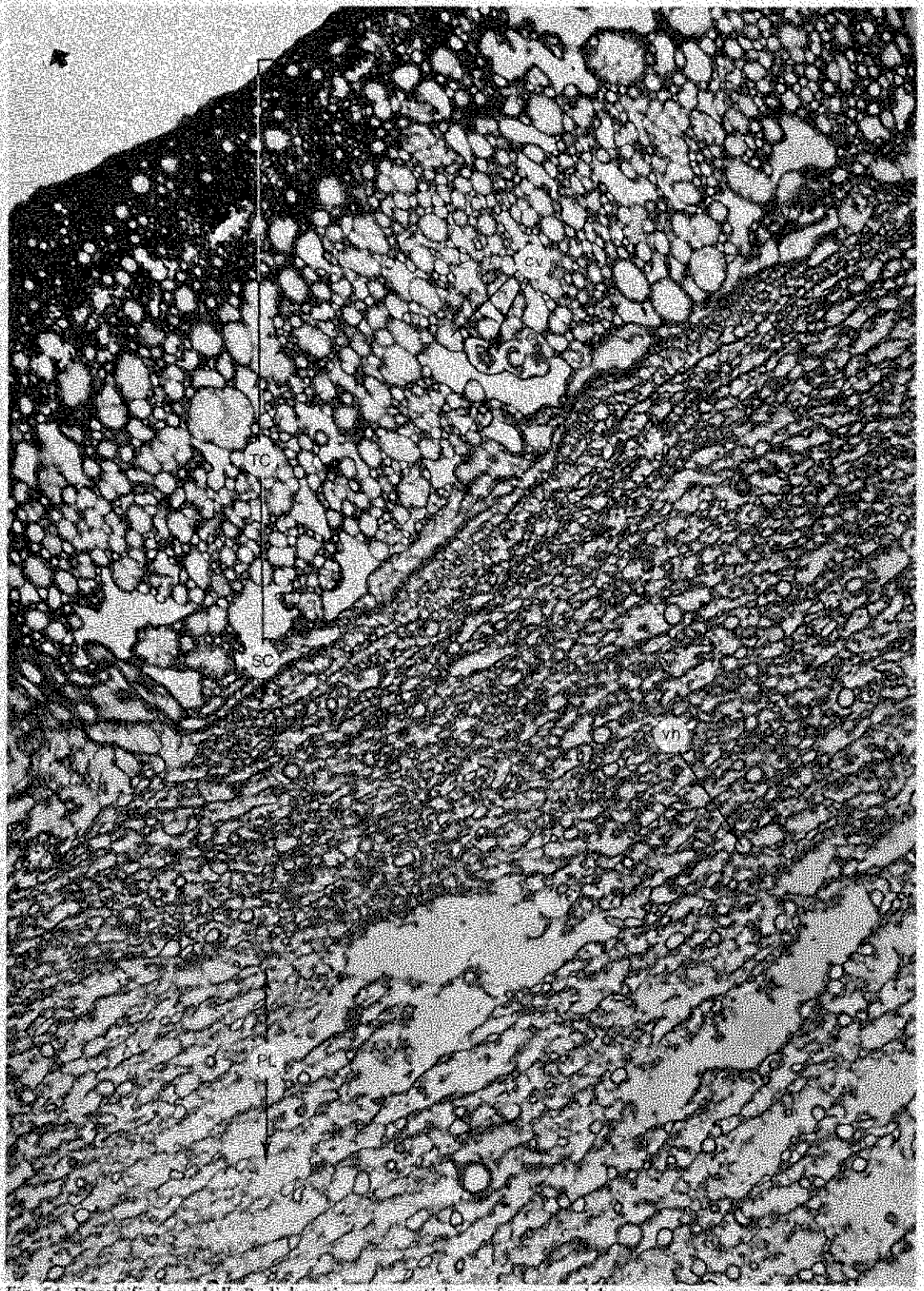

Fig. 54. Decalcified eggshell. Radial section true cuticle, surface crystal layer and outer part of palisade layer. $KMnO_4$-stain. (9,000×, t.e.m.)

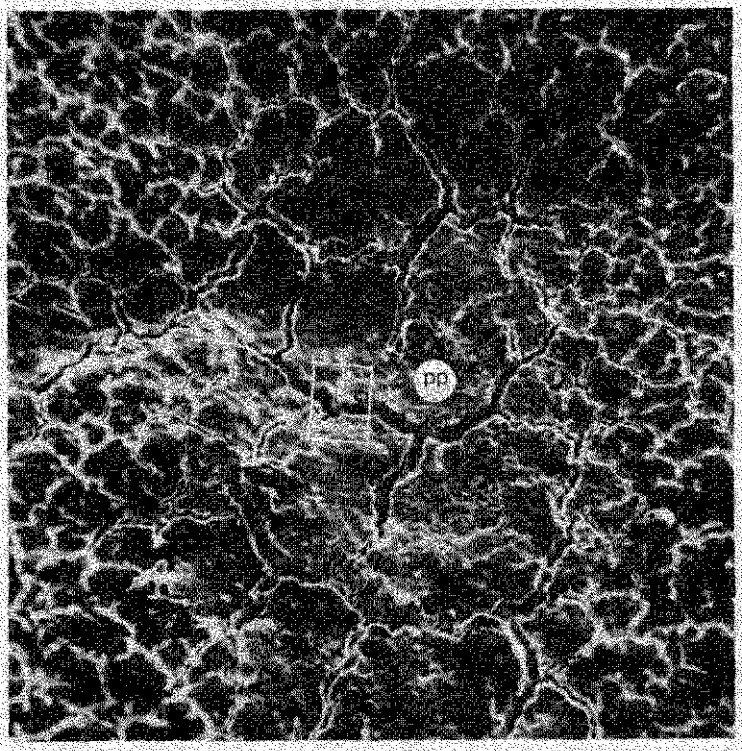

Fig. 55. True cuticle of fresh egg. Pore plaque and surroundings. (540 ×, s.e.m.)

Fig. 56. True cuticle of fresh egg. Fracture in pore plaque. Detail of Fig. 55. (5,400 ×, s.e.m.)

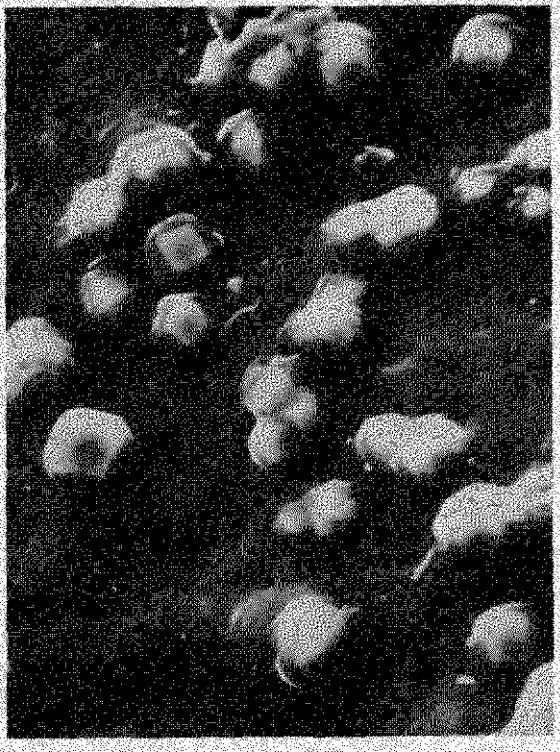

Fig. 57. Boiled egg. Surface true cuticle with covering crystals. (4,600 ×, s.e.m.)

Fig. 58. Shell surface. True cuticle removed with EDTA. Pore. (1,600 ×, s.e.m.)

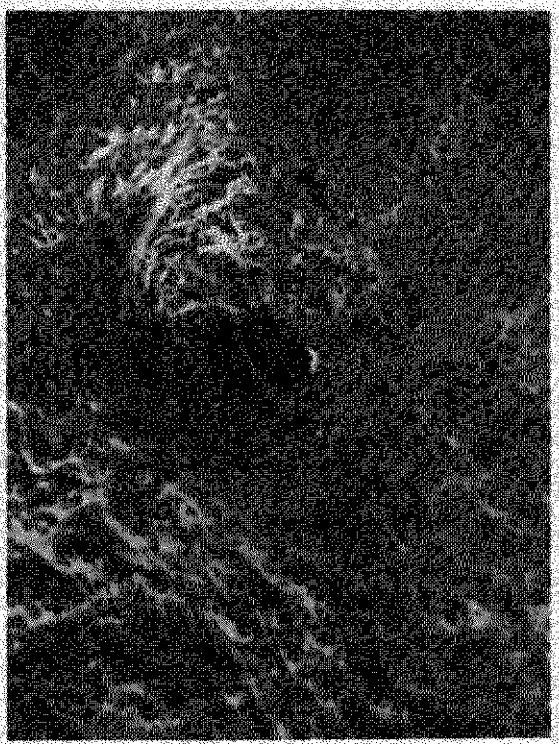

Fig. 59. Shell surface. True cuticle removed with EDTA. Pore. Detail of Fig. 45. (1,600 ×, s.e.m.)

Fig. 60. Shell surface. True cuticle removed with EDTA. Pore wall. Detail of Fig. 58. (3,800 ×, s.e.m.)

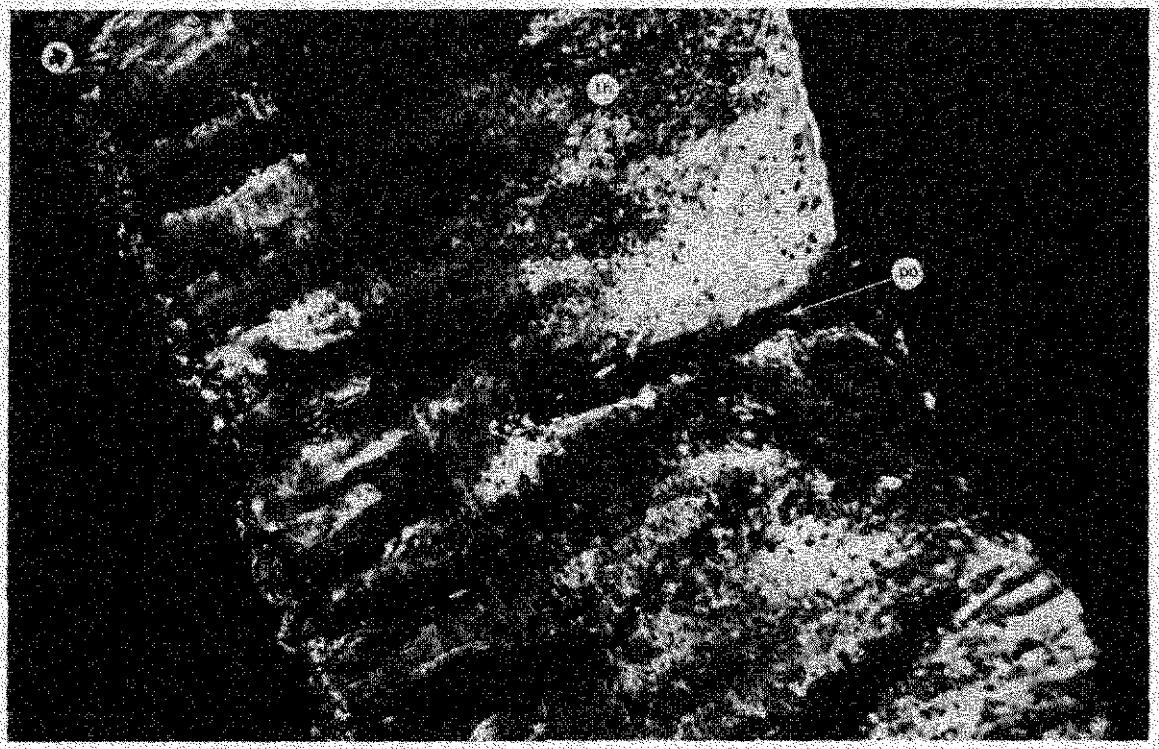

Fig. 61. Guinea-fowl eggshell. Ground section under polarized light. (170 ×, I.m.)

Fig. 62. Ground section of shell under polarized light. (170 ×, I.m.)

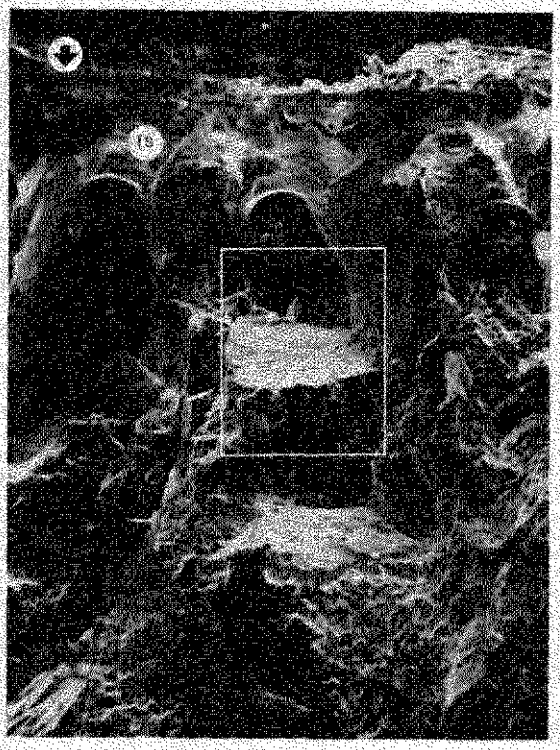

Fig. 63. Radially fractured surface. Inner part of shell with part of membranes. (450 x, s.e.m.)

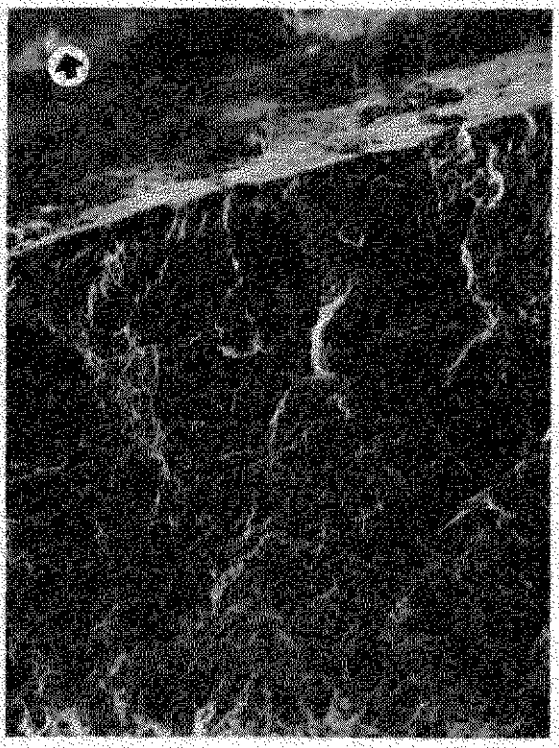

Fig. 64. Radially fractured surface. Outer part of shell. (540 ×, s.e.m.)

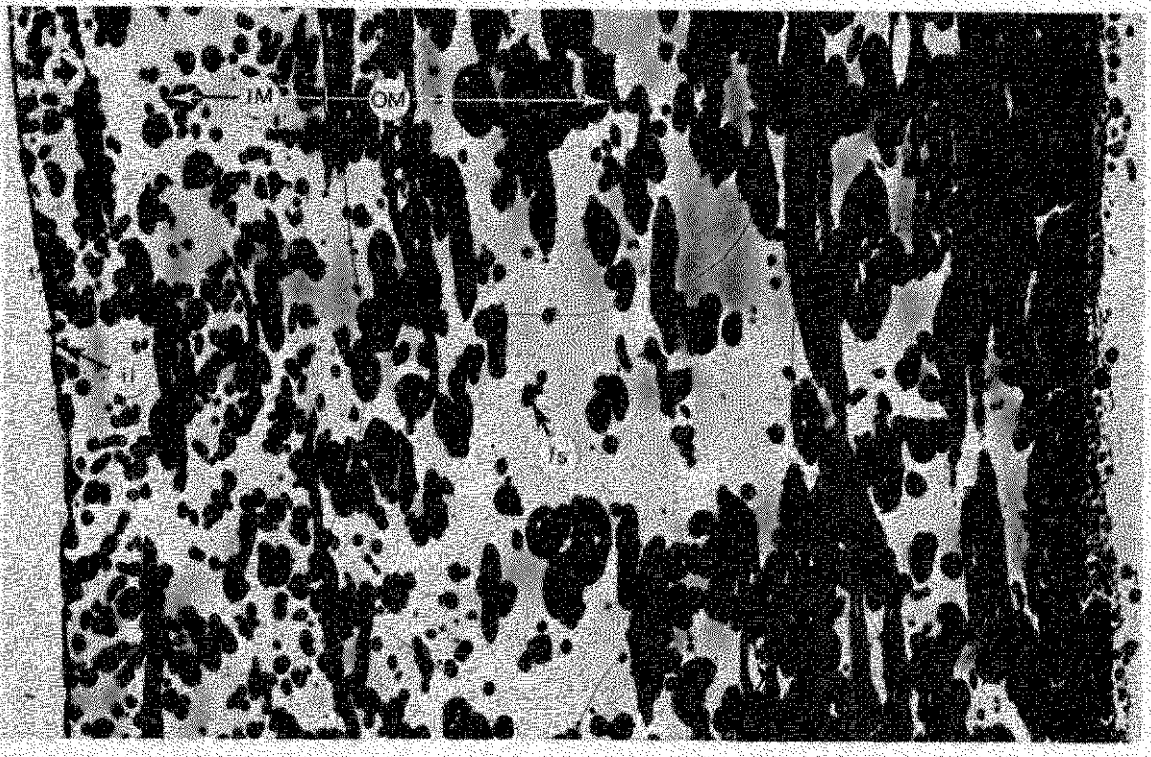

Fig. 65. Radial section of shell membranes of premature isthmus egg. (2,200 ×, t.e.m.)

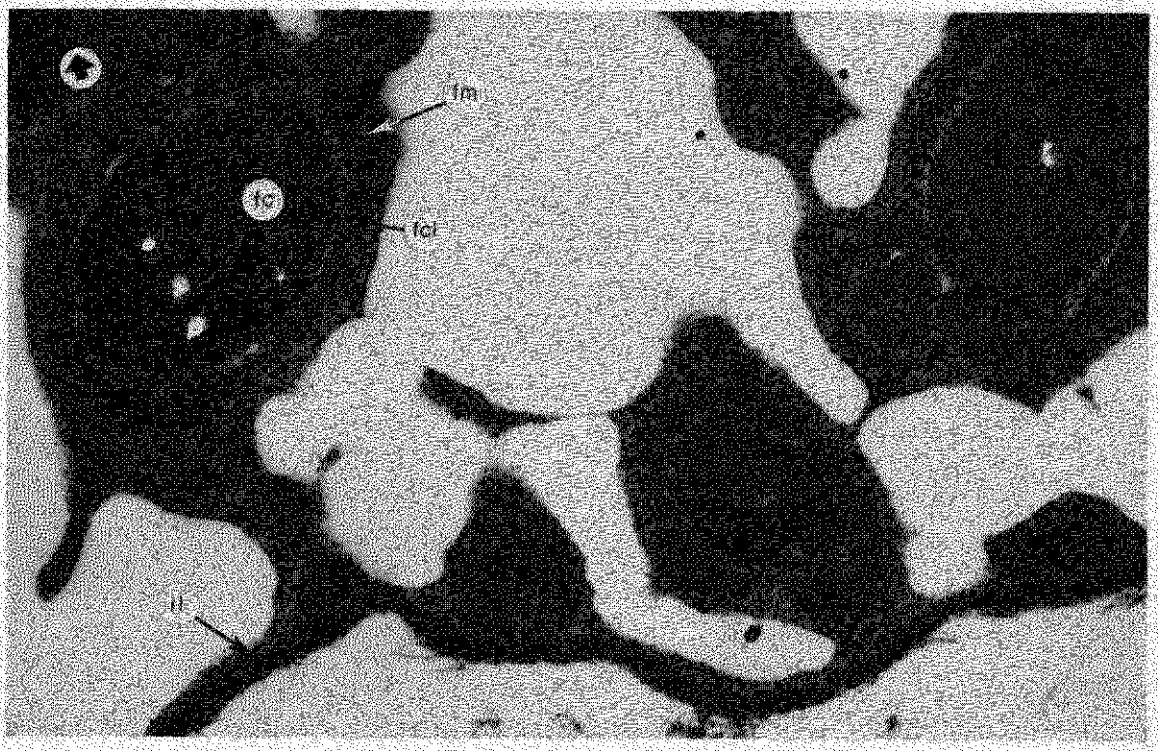

Fig. 66. Premature isthmus egg. Radial section in inner part of shell membranes. Lead citrate stain. (33,300 ×, t.e.m.)

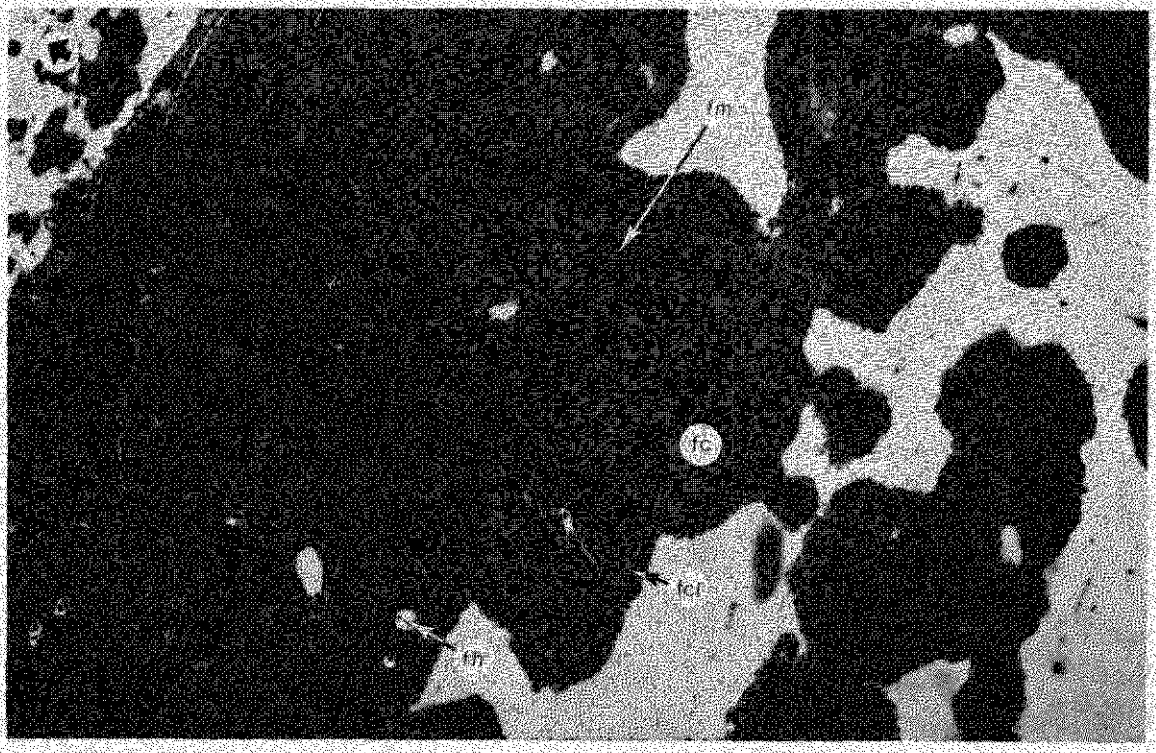

Fig. 67. Premature isthmus egg. Radial section in outer part of shell membranes. (9,000 ×, t.e.m.)

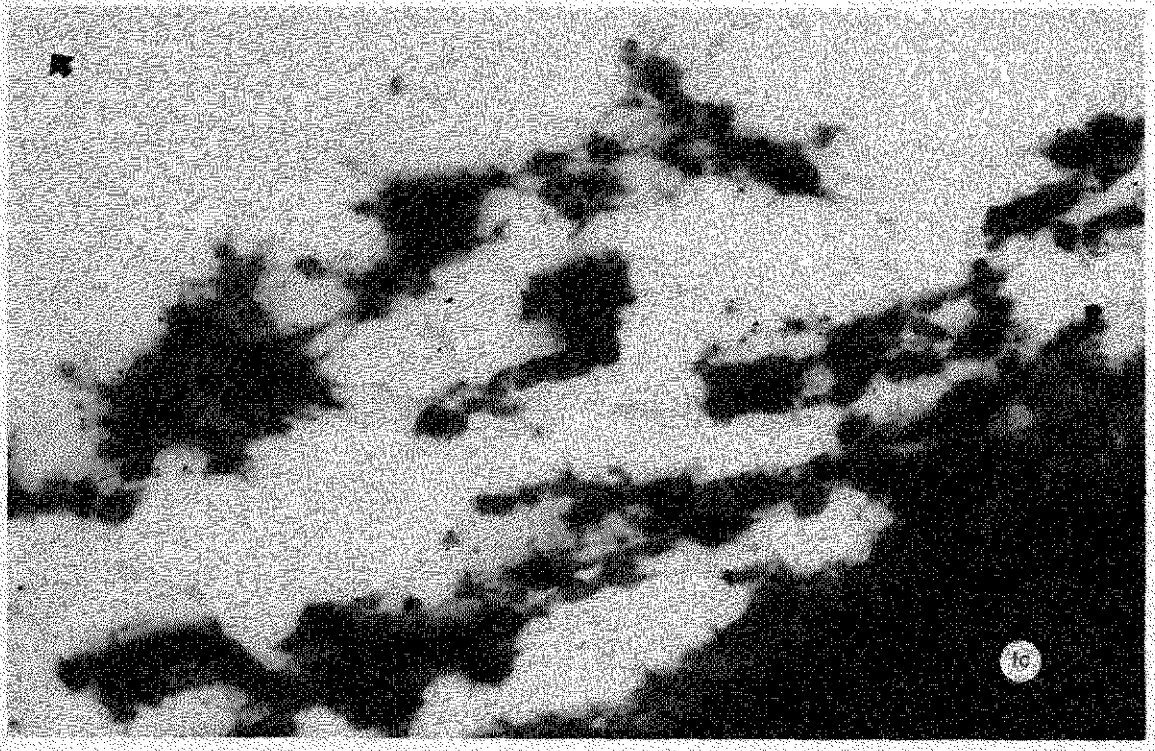

Fig. 68. Premature isthmus egg. Radial section in outer part of outer shell membrane. (66,000 ×, t.e.m.)

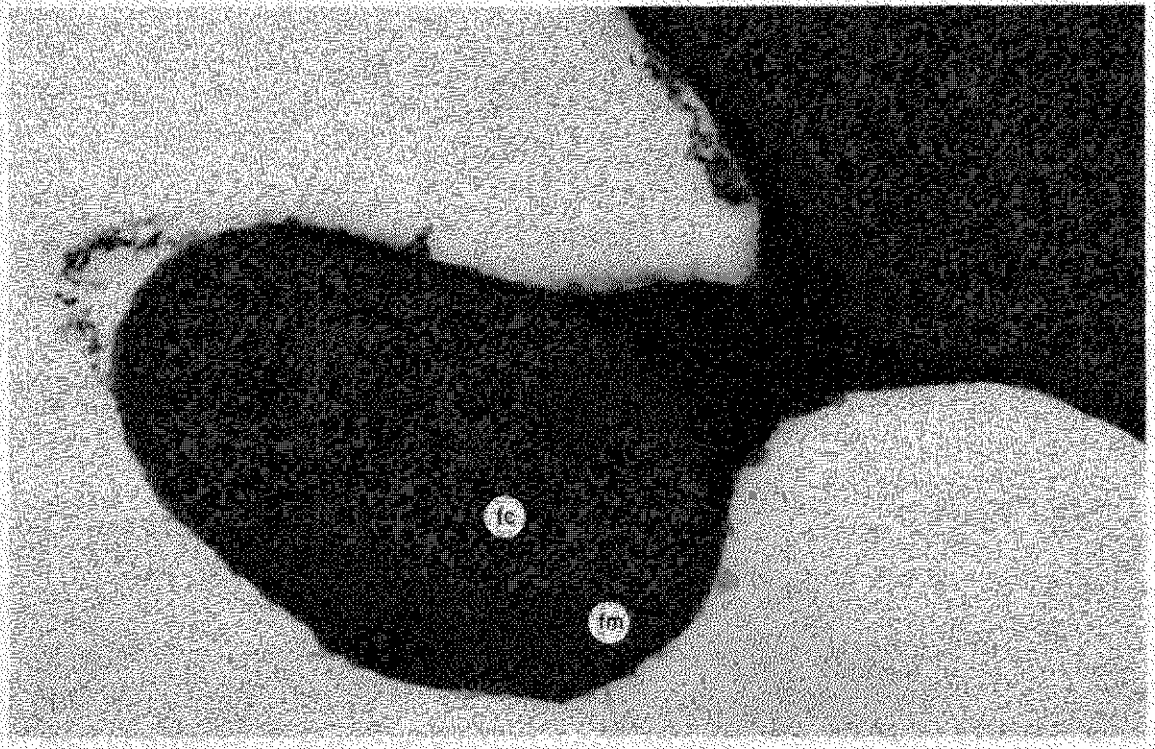

Fig. 69. Radial section membrane fibres. OsO_4-fixation. Ruthenium red stain. (66,400 ×, t.e.m.)

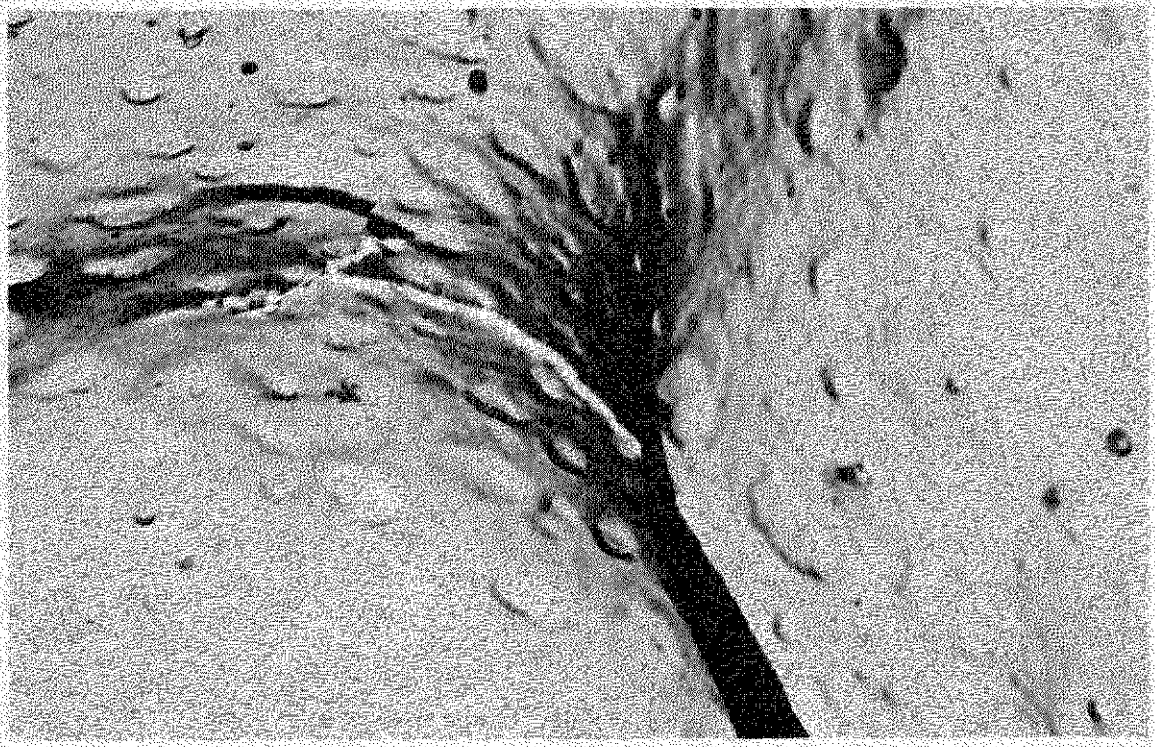

Fig. 70. Surface of an about 16–17 h premature egg. Replica technique used. (66.600 ×, t.e.m.)

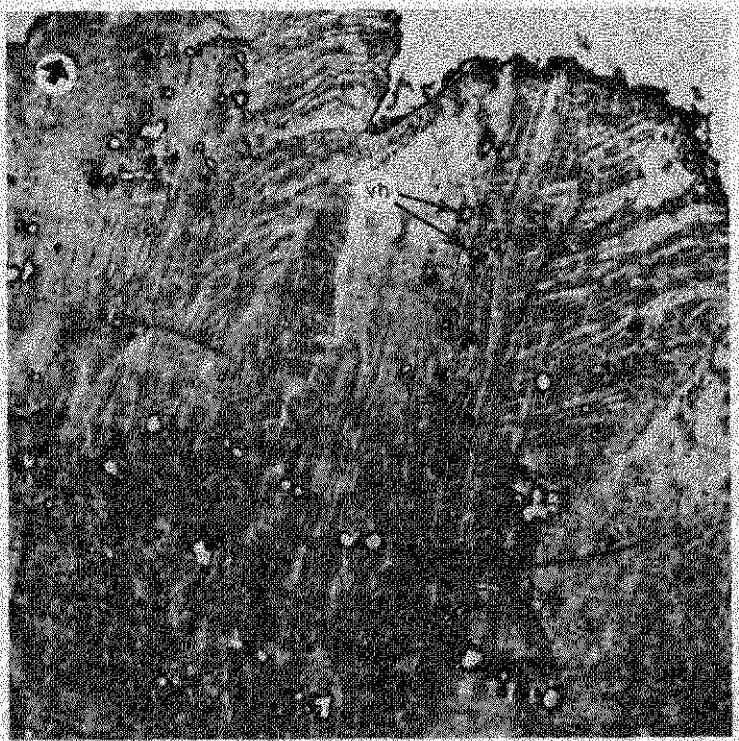

Fig. 71. Decalcified eggshell of an 18 h premature egg. Radial section mammilla. Lead citrate and uranyl acetate stain. (4.500 ×, t.e.m.)

Fig. 72. Surface of an about 16–17 h premature egg. Replica technique used. (10,400×, t.e.m.)

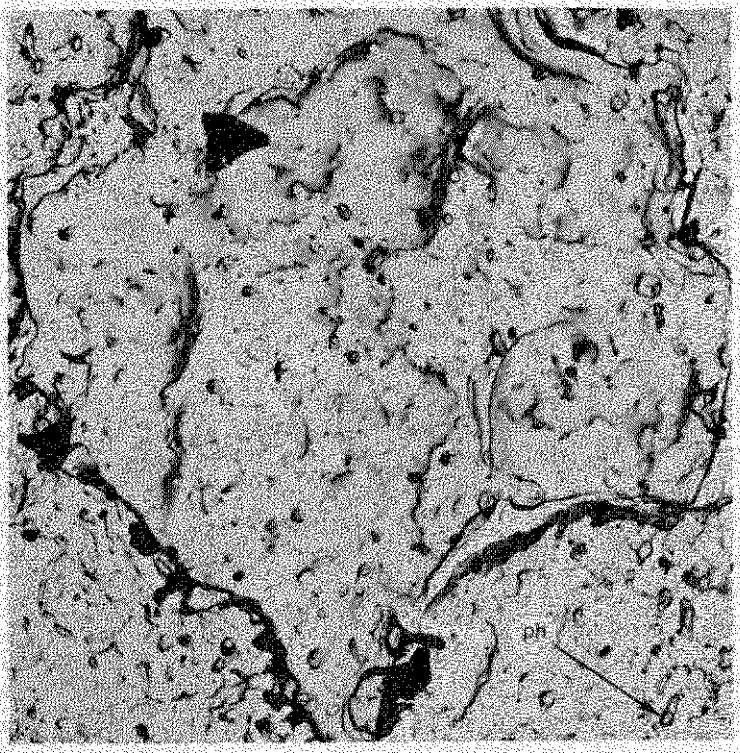

Fig. 73. Surface of a 4 h premature egg. Replica technique used. Column. (6,300 ×, t.e.m.)

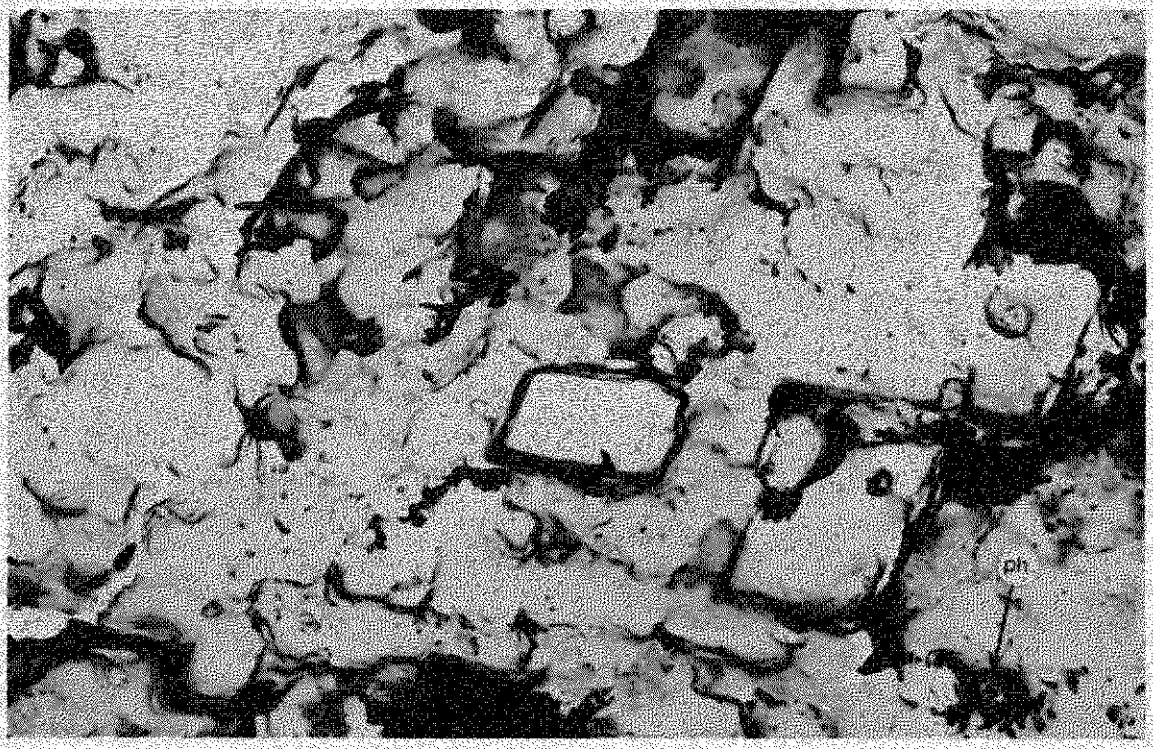

Fig. 74. Surface of an 8 h premature egg. Replica technique used. (18,600 ×, t.e.m.)

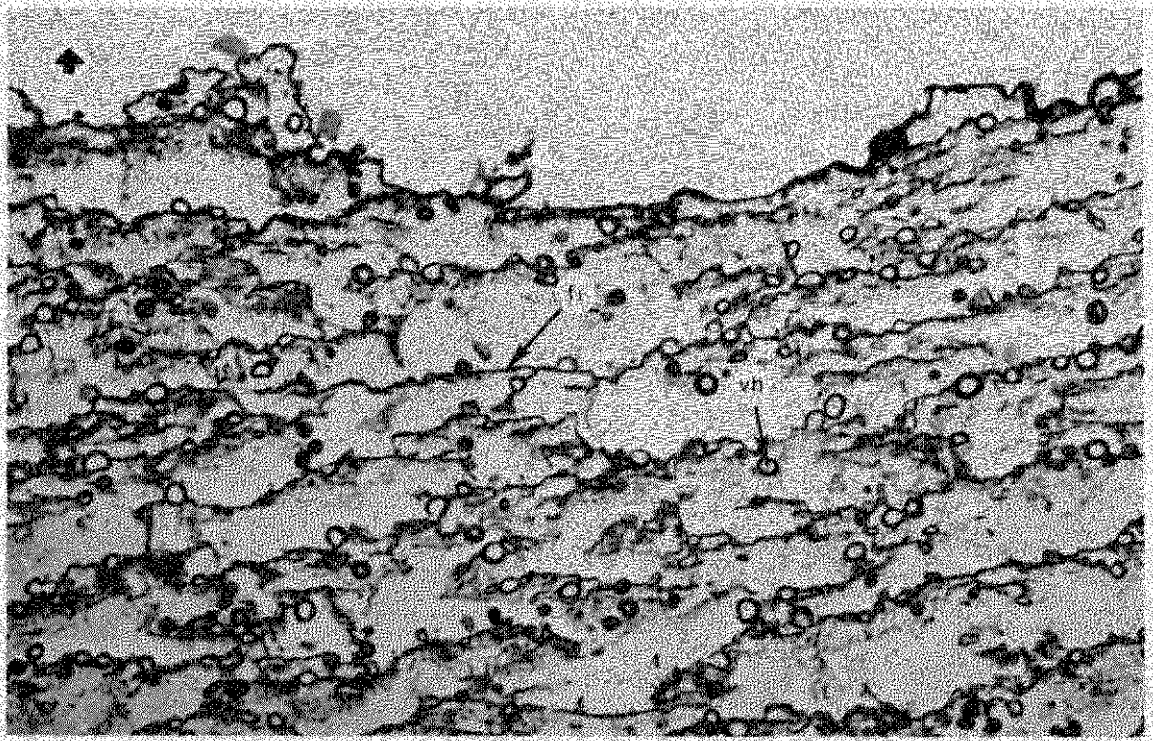

Fig. 75. Decalcified eggshell of a 4 h premature egg. Radial section palisade layer. Lead citrate and uranyl acetate stain. (6,000 ×, t.e.m.)

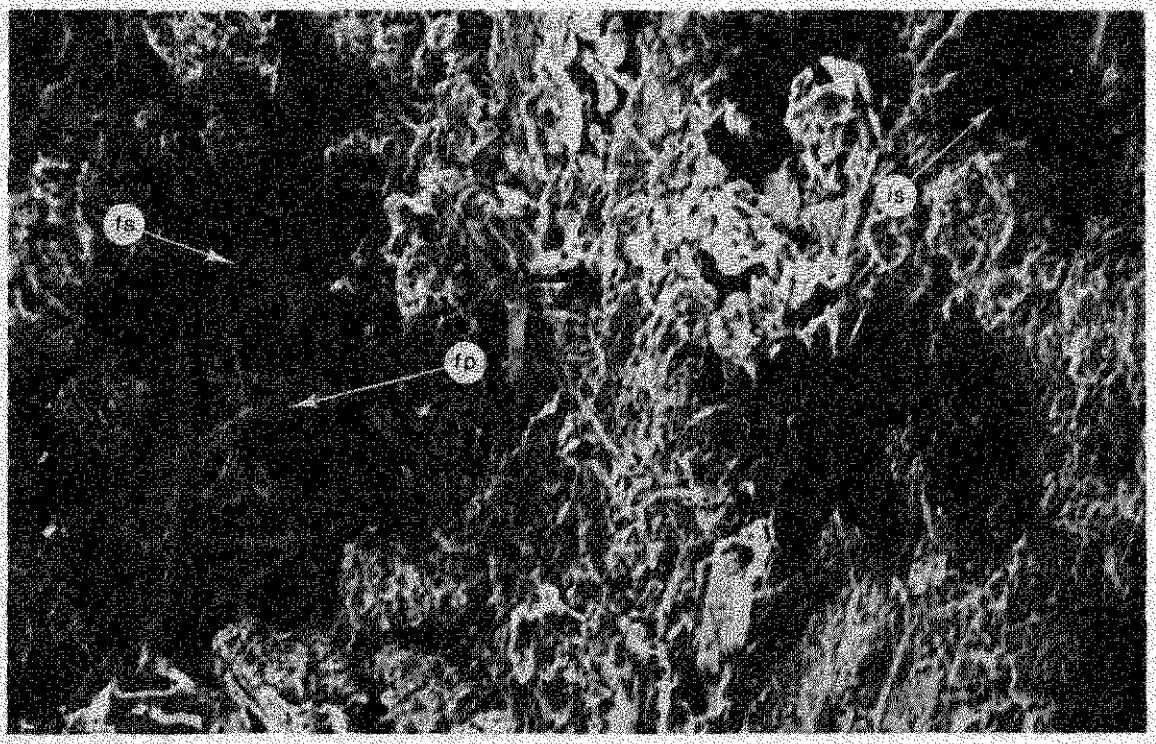

Fig. 76. Outside of outer shell membrane with mammillary fragments after hatching. (2,000 ×, s.e.m.)

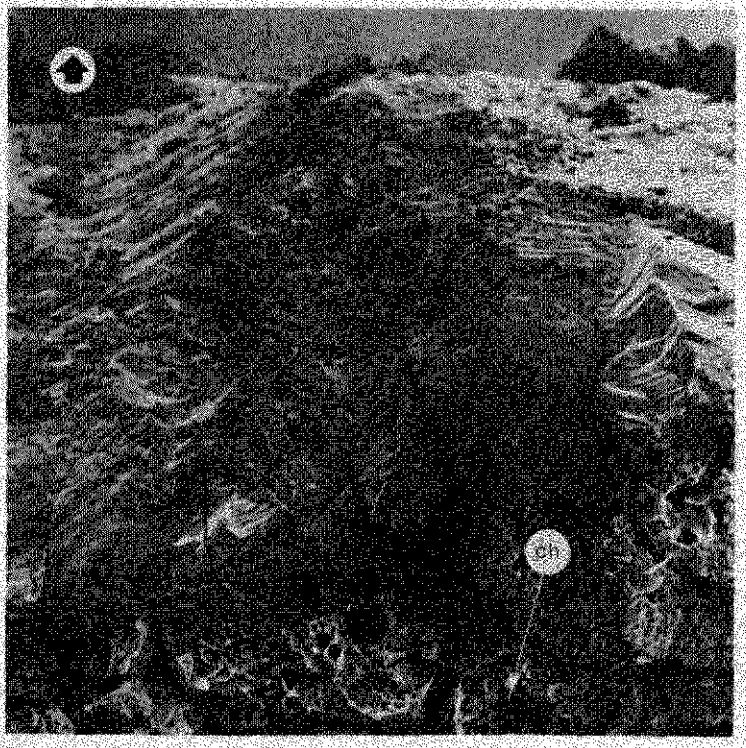

Fig. 77. Inside and radially fractured surface of shell after hatching. (350 ×, s.e.m.)

Fig. 78. Inside of shell after hatching. Appearance of an eroded mammilla. (3,300 ×, s.e.m.)

Fig. 79. Radially fractured surface in mammilla after hatching. Detail of Fig. 77. (3,300 ×, s.e.m.)

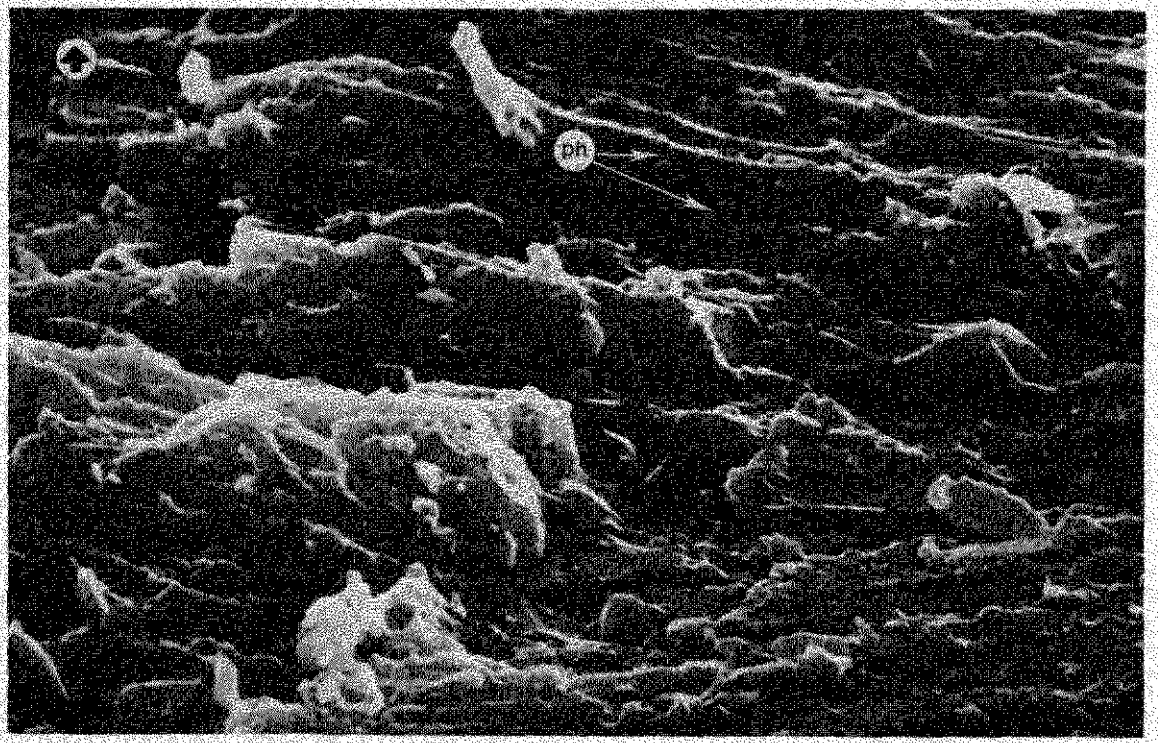

Fig. 80. Radially fractured surface in palisade layer after hatching. (5,900×, s.e.m.)

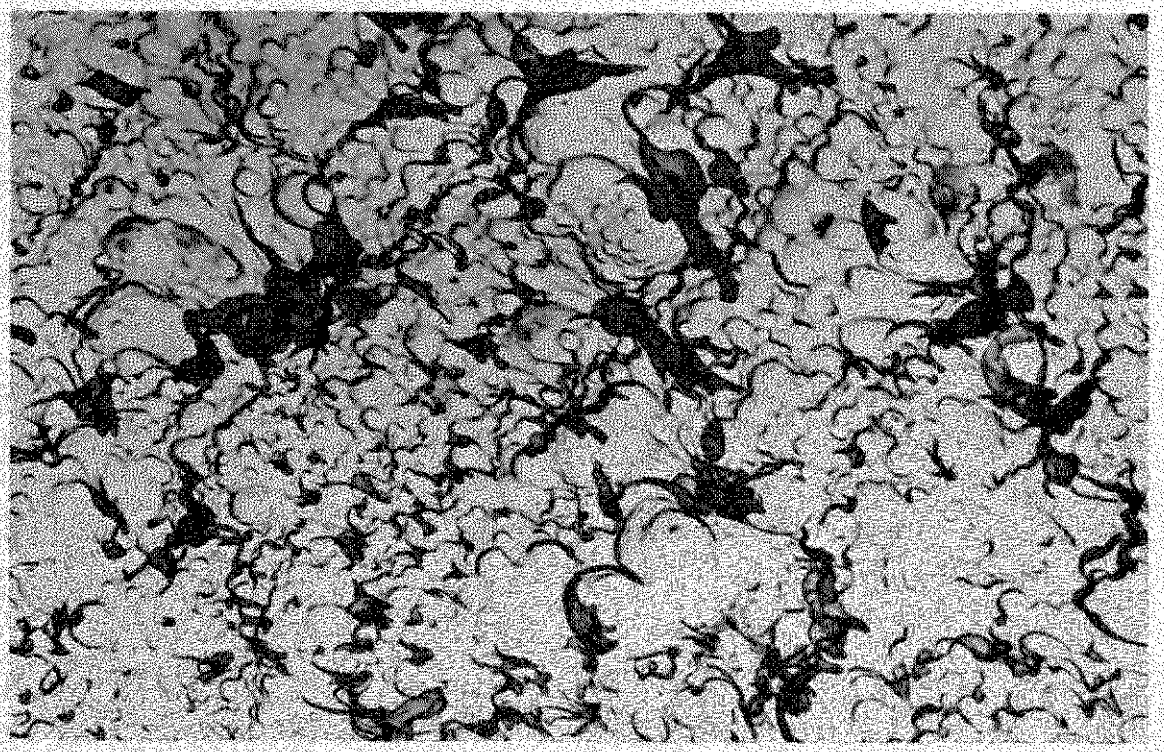

Fig. 81. Normal cuticular surface fresh egg. Replica technique used. (20,000 ×, t.e.m.)

Fig. 82. Pore plaque with star-shaped crack system of a nearly white egg. Replica technique used. (8,000 ×, t.e.m.)

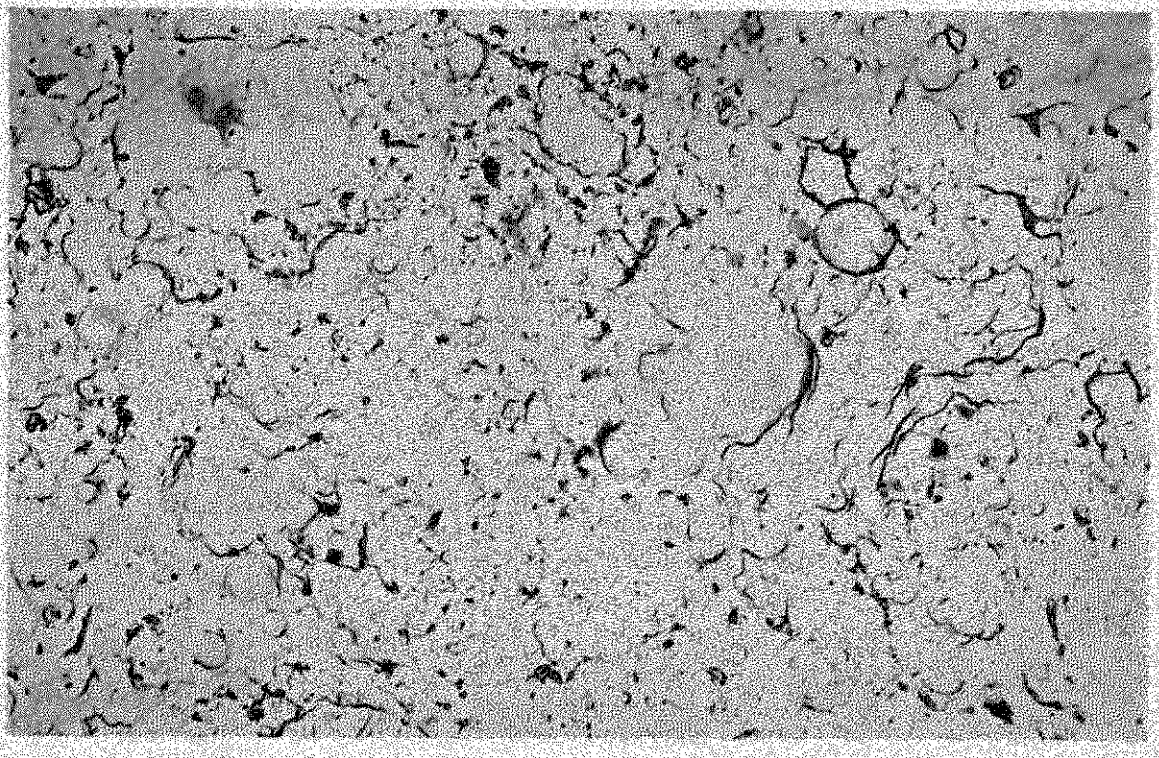

Fig. 83. Cuticular surface structure 11 days after laying. Replica technique used. (20,000 ×, t.e.m.)

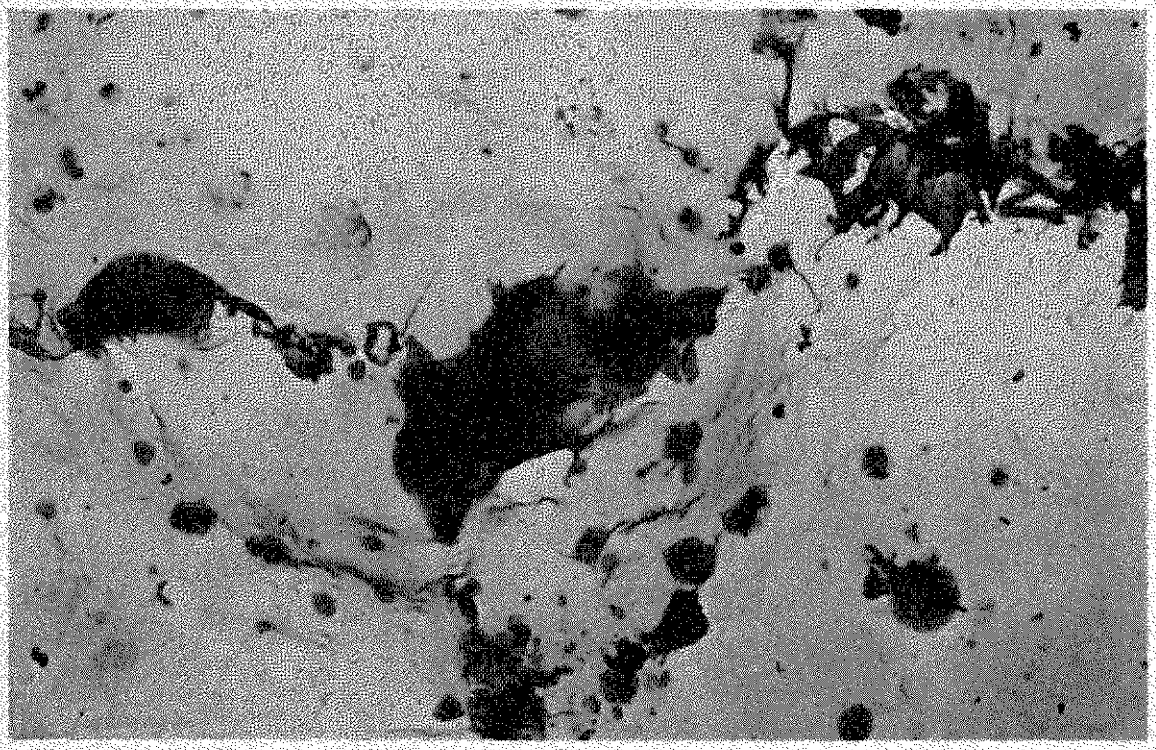

Fig. 84. Cuticular surface structure some months after laying. Replica technique used. (8,000 ×, t.e.m.)

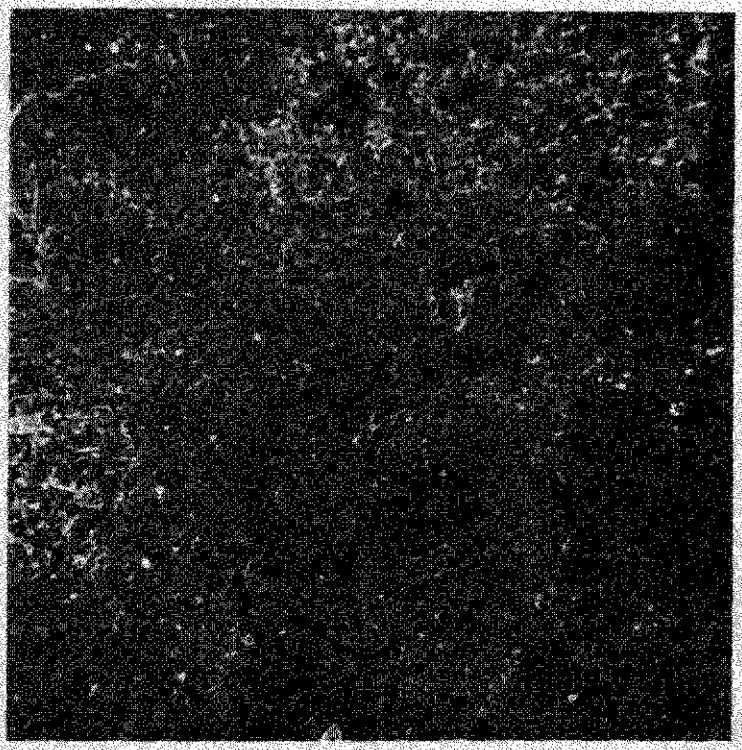

Fig. 85. Surface of old egg. (440 ×, s.e.m.)

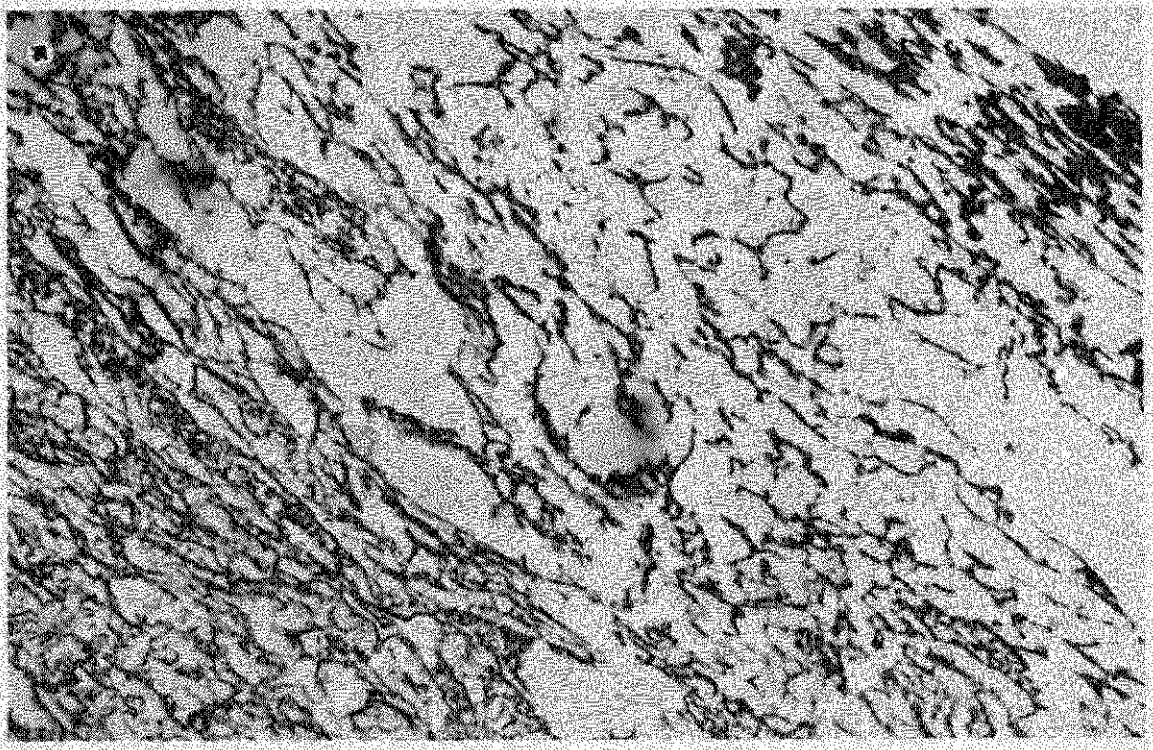

Fig. 86. Decalcified guinea-fowl eggshell. Radial section in surface crystal layer and true cuticle. (16,200×, t.e.m.)

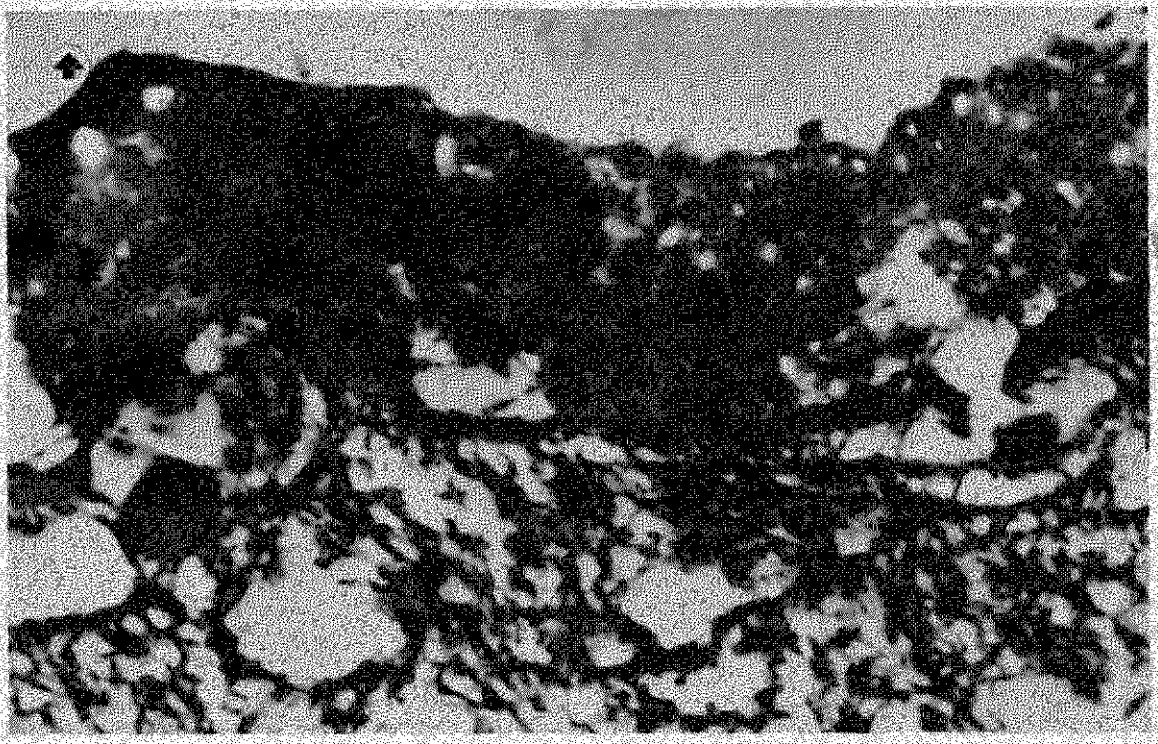

Fig. 87. Decalcified guinea-fowl eggshell. Radial section true cuticle. (37,600 ×, t.e.m.)

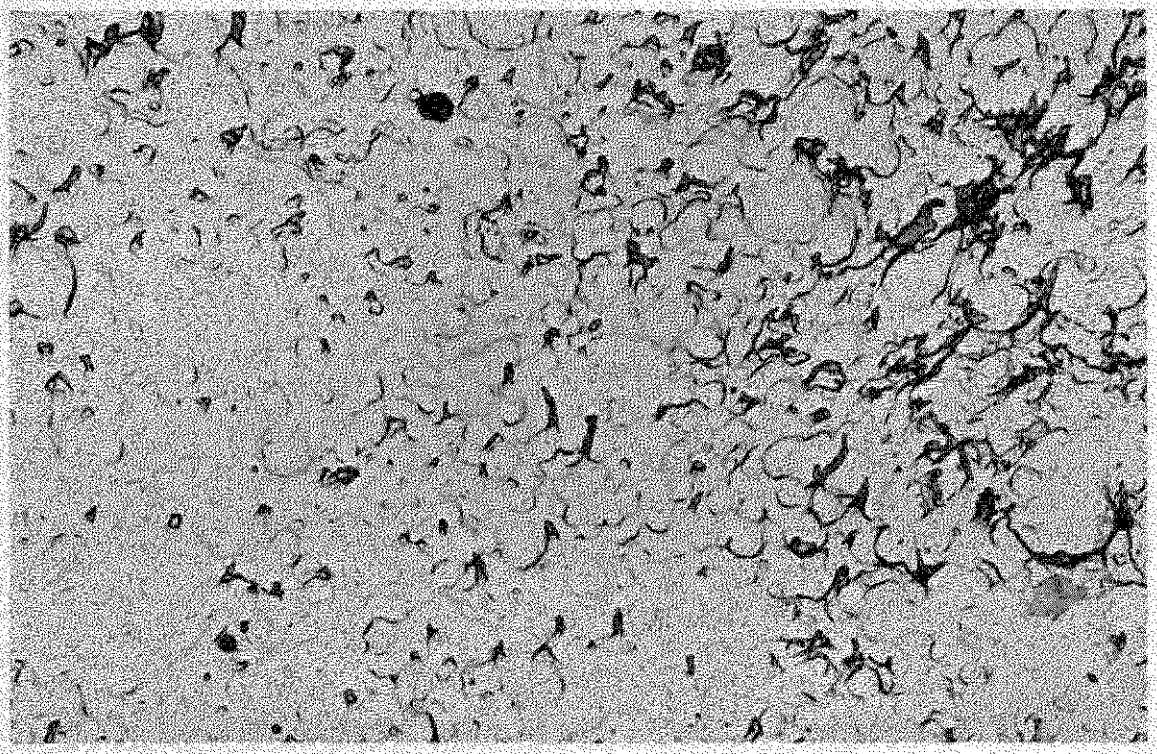

Fig. 88. Cuticular surface structure after washing by a water stream. Replica technique used. (20,000 ×, t.e.m.)

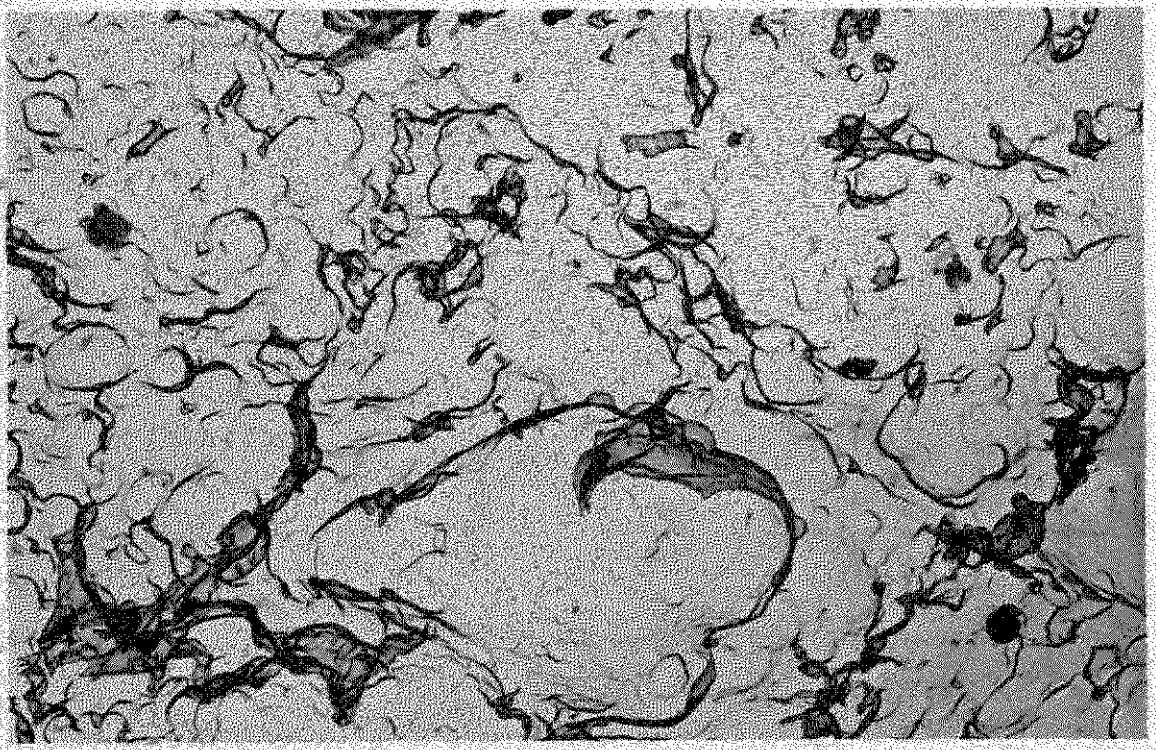

Fig. 89. Cuticular surface structure after washing by hand. Replica technique used. (20,000 ×, t.e.m.)

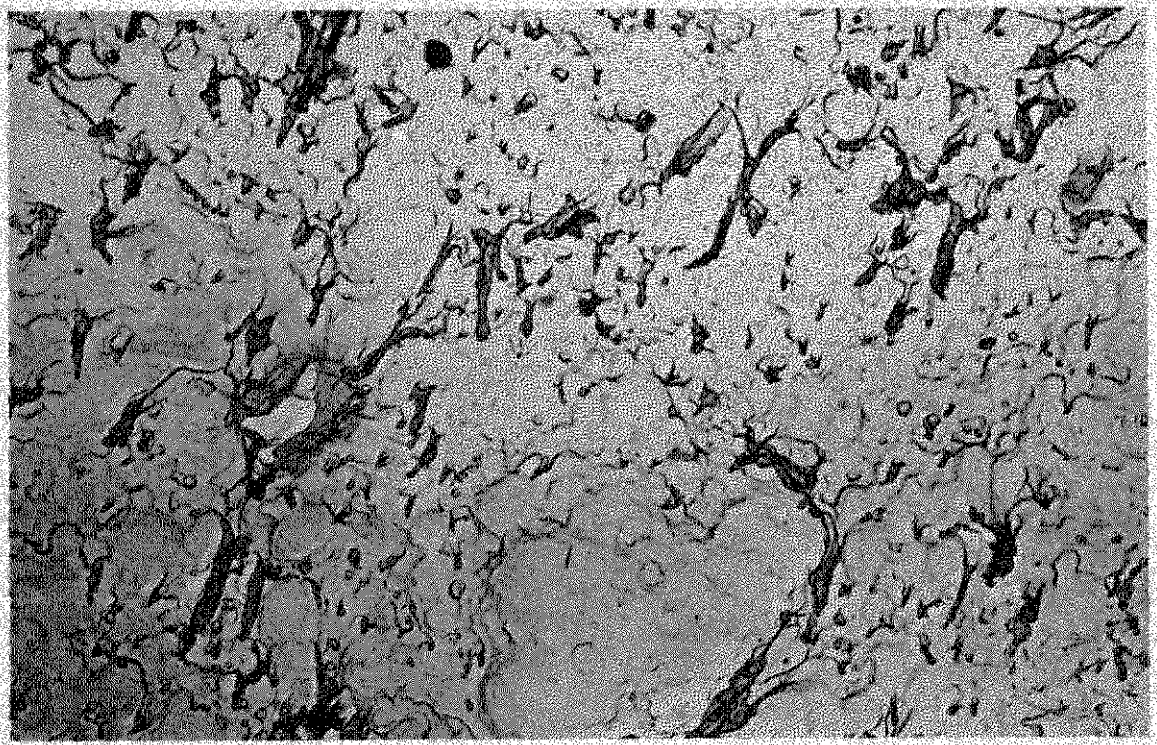

Fig. 90. Cuticular surface structure after washing with a cloth. Replica technique used. (20,000 ×, t.e.m.)

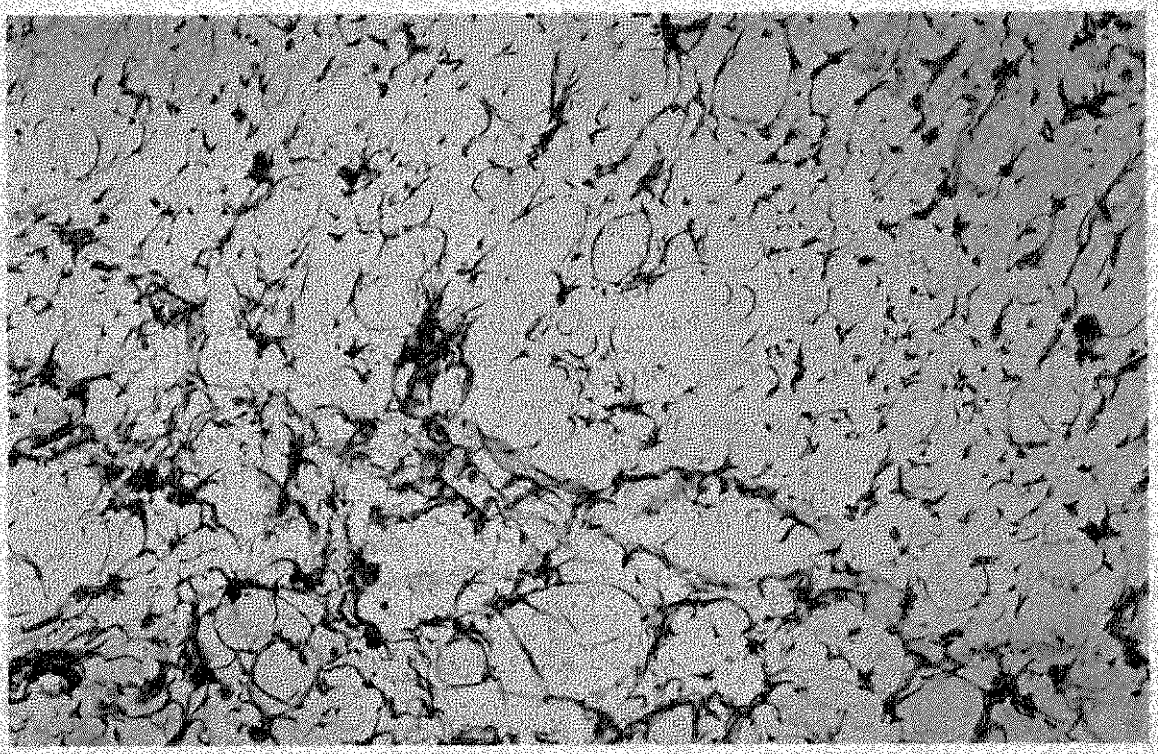

Fig. 91. Cuticular surface structure after a 5 min stay in water of 30° C. Replica technique used. (20,000 × t.e.m.)

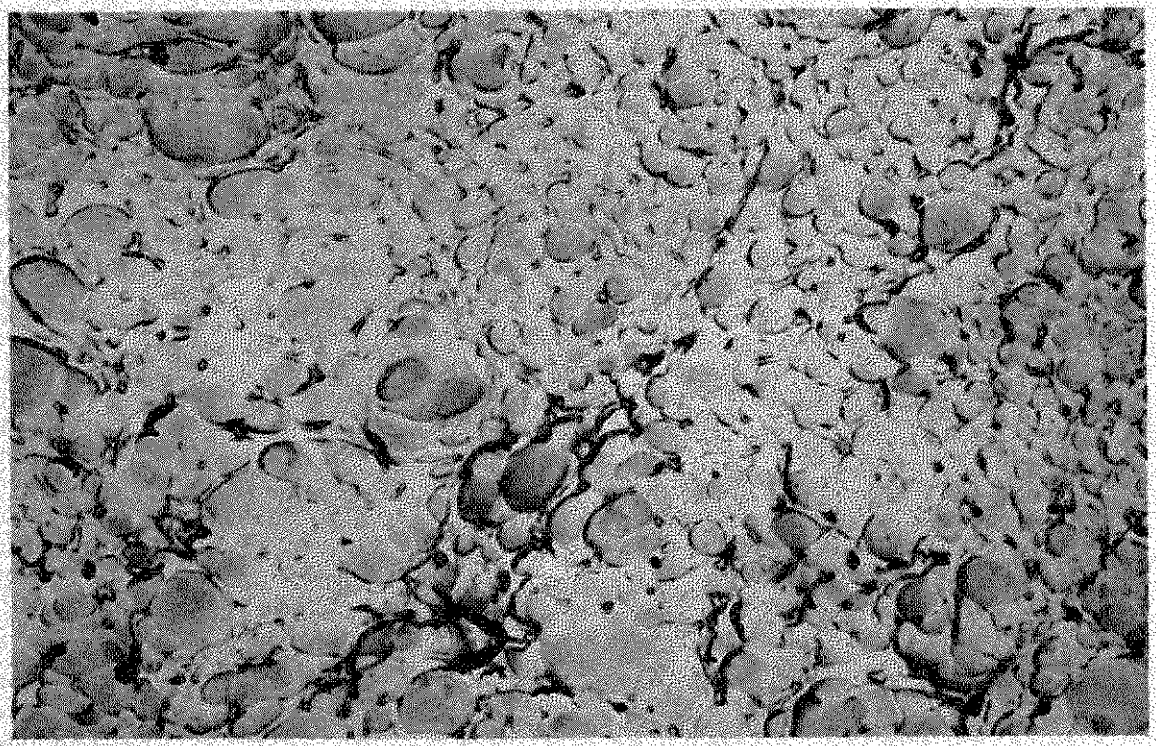

Fig. 92. Cuticular surface structure after a 5 min stay in water of 40° C. Replica technique used. (20,000 ×, t.e.m.)

Fig. 93. Cuticular surface structure after a 5 min stay in water of 70° C. Replica technique used. (20,000 ×, t.e.m.)

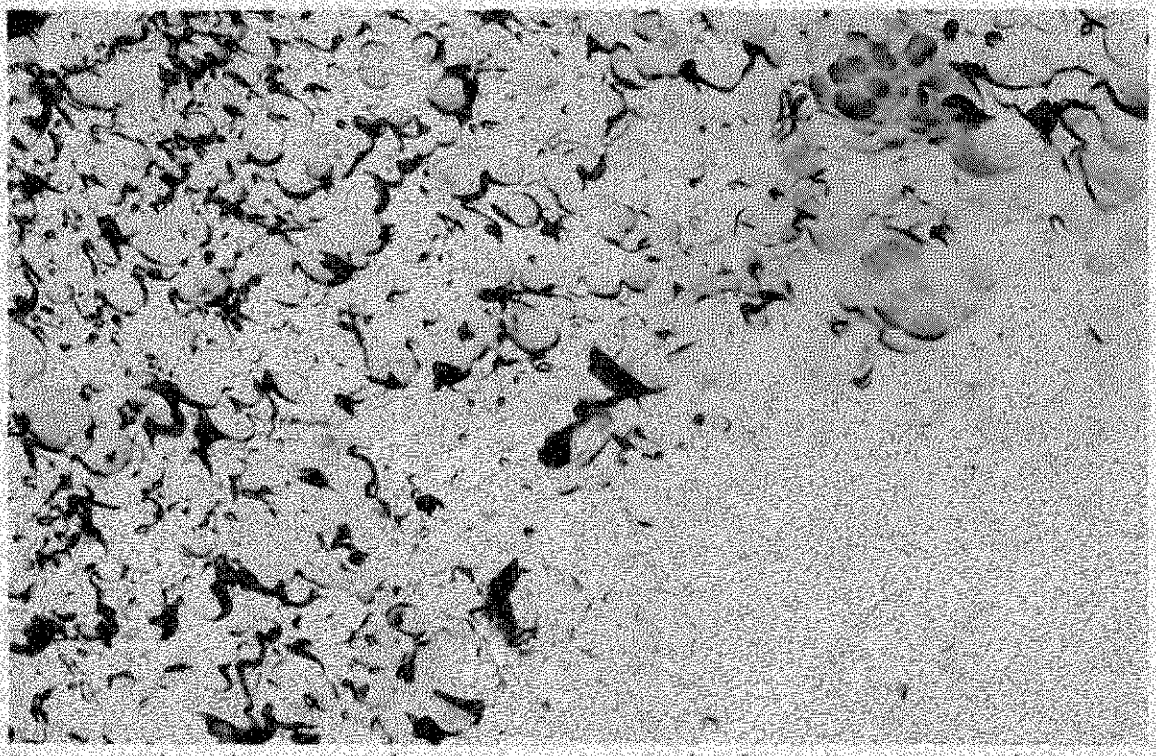

Fig. 94. Cuticular surface structure after a 5 min stay in water of 100° C. Replica technique used. (20,000 ×, t.e.m.)

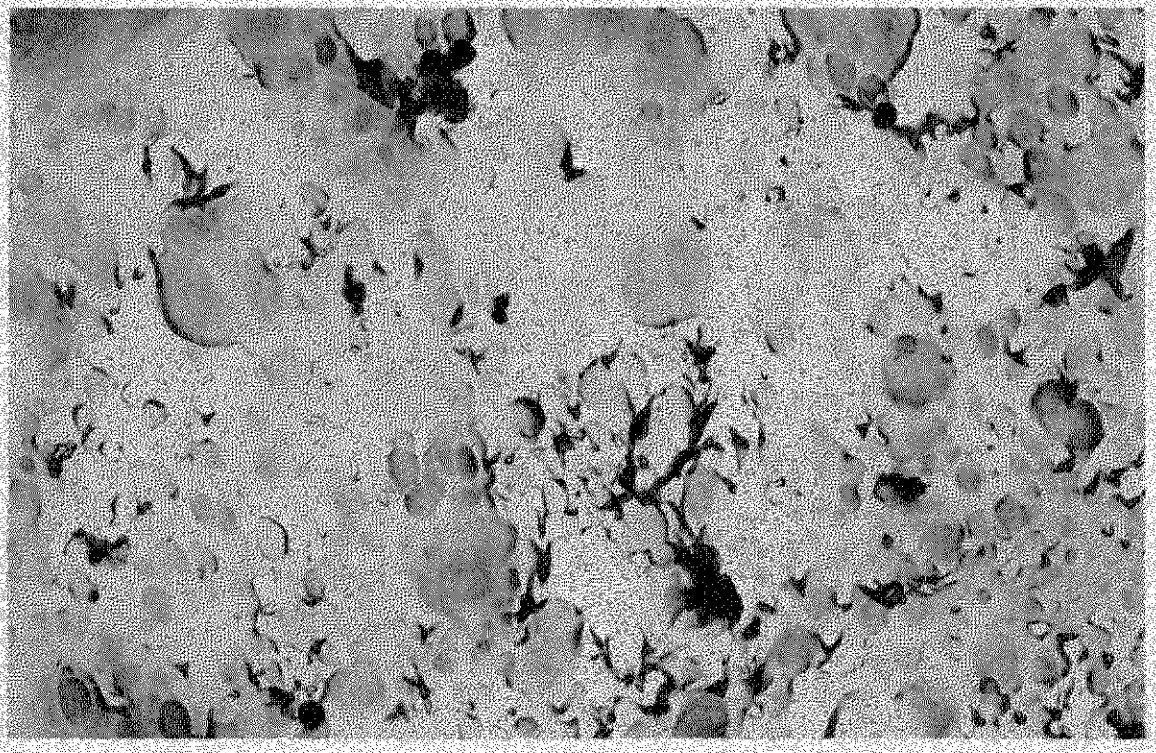

Fig. 95. Cuticular surface structure after washing with detergent. Replica technique used. (20,000 ×, t.e.m.)